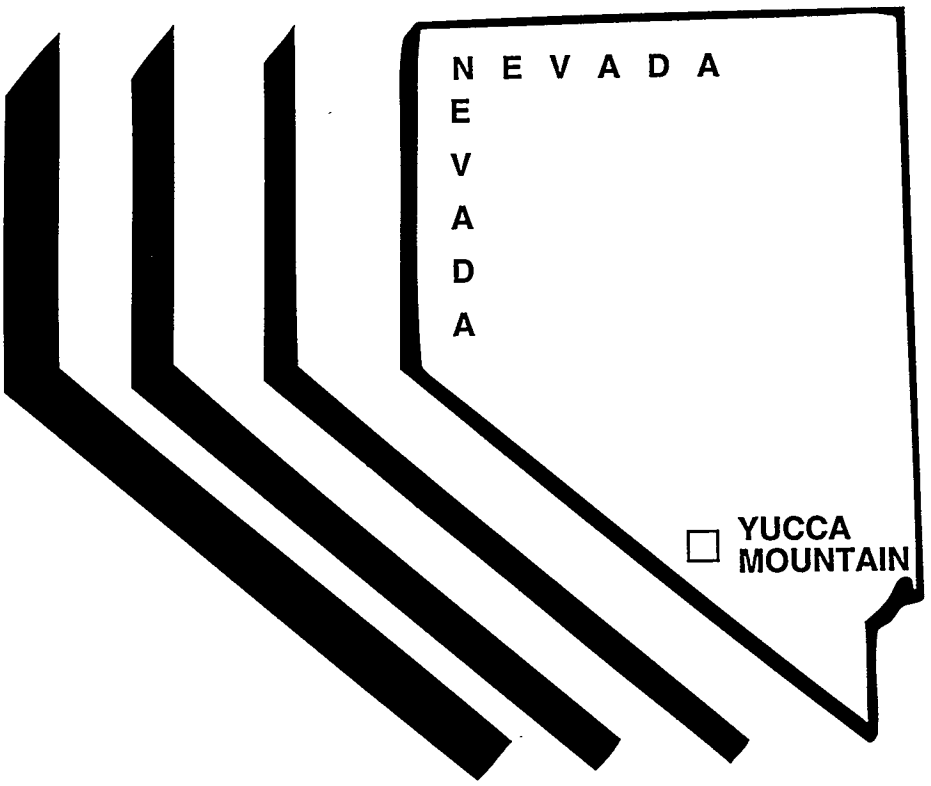
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Yucca Mountain Site Characterization Project Bibliography, 1994–1995

United States Department of Energy



Civilian Radioactive Waste Management Program

Prepared for
Yucca Mountain Site Characterization Office, Las Vegas, Nevada
Office of Civilian Radioactive Waste Management, Washington, D.C.

Prepared by
Office of Scientific and Technical Information
UNITED STATES DEPARTMENT OF ENERGY

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Since 1985 the *Yucca Mountain Site Characterization Project Bibliography* with indexes has been published as biennial supplements, with nonindexed semiannual addenda published in the two-year interim. Beginning with the 1996 data, the bibliography supplements with indexes will be published annually, with no semiannual addenda.

The first annual supplement, which will be Supplement 6, is scheduled to be published in April or May of 1997. That publication will contain information added to the Energy Science and Technology Database between January 1, 1996, and December 31, 1996.

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Following a reorganization of the Office of Civilian Radioactive Waste Management in 1990, the Yucca Mountain Project was renamed Yucca Mountain Site Characterization Project. The title of this bibliography was also changed to Yucca Mountain Site Characterization Project Bibliography. Prior to August 5, 1988, this project was called the Nevada Nuclear Waste Storage Investigations.

This bibliography contains information on this ongoing project which was added to the Department of Energy's Energy Science and Technology Database from January 1, 1994, through December 31, 1995.

The bibliography is categorized by principal project participating organization. Participant-sponsored subcontractor reports, papers, and articles are included in the sponsoring organization's list. Another section contains information about publications on the Energy Science and Technology Database which were not sponsored by the project but have some relevance to it.

Earlier information on this project can be found in the first bibliography DOE/TIC--3406, which covers 1977–1985, its supplements, DOE/OSTI--3406(Suppl.1), DOE/OSTI--3406(Suppl.2), DOE/OSTI--3406(Suppl.3), and DOE/OSTI--3406(Suppl.4), which cover information obtained during 1986–1987, 1988–1989, 1990–1991, and 1992–1993, respectively. All entries in the bibliographies are searchable online on the NNW database file. This file can be accessed through the Integrated Technical Information System (ITIS) of the U.S. Department of Energy (DOE).

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General information and publications on the national program can be obtained through the Office of Civilian Radioactive Waste Management Toll-Free Information System at 1-800-225-NWPA (6972) (or, in Washington, DC, at 488-5513), or by writing to the OCRWM Information Center, P.O. Box 44375, Washington, DC 20026.

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*Civilian Radioactive Waste Management System, Management & Operating Contractor, Las Vegas.

FOREWORD

The Nuclear Waste Policy Act of 1982 (NWPA) established a national policy for the safe storage and permanent disposal of spent nuclear fuel and high-level radioactive waste. Congress assigned primary responsibility for development of a radioactive waste management system to the U.S. Department of Energy (DOE). The concept of a deep geologic repository was selected as the safest and most feasible method for permanent disposal of spent fuel from civilian reactors and high-level waste from national defense programs.

The DOE Office of Civilian Radioactive Waste Management (OCRWM) was formed in 1983 to administer the responsibilities delegated to the DOE by the NWPA. In February 1983, the DOE identified Yucca Mountain, in Nye County, Nevada, as one of nine potentially acceptable repository sites. The sites were evaluated to determine their suitability. In May 1986, the number of sites for further consideration was reduced to three: Yucca Mountain; the Hanford Reservation in Washington State; and a site in Deaf Smith County, Texas. At these sites, the DOE planned to conduct site characterization studies, that is, extensive surface-based and underground investigations. The Nuclear Waste Policy Amendments Act of 1987 suspended site studies in Washington and Texas and directed the DOE to characterize only the Yucca Mountain site.

The Yucca Mountain Site Characterization Project Office in Las Vegas, Nevada, formerly the Yucca Mountain Project Office, has local responsibility for the scientific investigations to determine if Yucca Mountain is a suitable repository site. The Yucca Mountain Site Characterization Project (YMP) work force includes scientists from diverse disciplines as well as engineers and support personnel employed by the DOE, other government agencies, national laboratories, and private contractors. The major participants include the U.S. Geological Survey; Lawrence Livermore National Laboratory; Los Alamos National Laboratory; Sandia National Laboratories; Raytheon Services Nevada; Reynolds Electrical & Engineering Company, Inc.; Science Applications International Corporation; and TRW, Inc.

Yucca Mountain is located about 100 miles northwest of Las Vegas on the Nevada Test Site's southwestern border. The property is administered by the Bureau of Land Management, the U.S. Air Force, and the DOE. The parcels of land designated for the potential repository have been withdrawn from public use to prevent intrusions that might affect the quality of scientific data or future repository performance.

Yucca Mountain is a long, narrow ridge running north and south, with a steep western slope and a more gradual eastern slope. The ridge rises 1,000 to 1,200 feet above the surrounding alluvial flats. The mountain appears to possess several attributes that are desirable for a repository site: an arid environment, a deep static water table, slow hydrologic transport within the water table, and a volcanic tuff formation that would help retard radionuclide movement.

Preliminary data indicate Yucca Mountain is a favorable site, but adverse conditions may exist. Concerns have been raised about potential volcanic activity, faulting, earthquakes, and possible fluctuations in the water table.

Additional site characterization studies are necessary to analyze all factors that could affect the performance of a repository.

The Yucca Mountain Site Characterization Plan (SCP), a 6,000-page document, outlines numerous surface, underground, and climatological studies that must be performed to evaluate the site's suitability. The SCP contains a description of planned activities, information on their priority, and a general schedule for the site characterization program. Individual areas of study are presented in greater detail in separate SCP Study Plans. During site characterization, the DOE must also evaluate environmental and socioeconomic conditions.

Site characterization studies are divided into surface-based investigations and in situ testing. The surface-based program is a series of investigations designed to characterize the surface and subsurface environment throughout the repository study area. For in situ testing, an underground laboratory will be established at the depth of the potential repository horizon to study the processes and phenomena contributing to waste isolation performance and to evaluate how an engineered facility would affect the hydrogeologic environment.

All data gathered during the site characterization process must meet strict quality assurance (QA) requirements to be accepted for NRC licensing. While some of the site characterization activities will rely on advanced state-of-the-art technology and some of the country's top scientists to gather and analyze data, exemplary scientific work alone is not enough. Project staff and their contractors must follow stringent QA procedures to ensure that all data are verifiable. The NRC will require traceability of all scientific samples; therefore, measures have been implemented to ensure that site characterization activities will produce verifiable data.

A new Program Plan adopted in 1995 defines additional measures of progress in site characterization. It also accelerates key evaluations compared with those scheduled in the 1988 SCP. The revised strategy phases the program to provide for a management assessment of the site in 1998. This assessment, relying more directly on the process-level models being developed for the site and the engineered system, will indicate the type and capacity of repository that can be built at Yucca Mountain and how it will perform. It will also include a plan and cost estimate for work remaining to complete a license application to the NRC and an estimate of how much a repository system will cost to build and operate.

MANAGEMENT OVERVIEW

FY 1994

The U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM), to ensure compliance with applicable regulations and other requirements imposed upon it, systematically reviewed and revised the System Requirements Documents. These documents were developed on the basis of a systematic review of regulatory documentation and the functions the system must perform. The entire set of requirements documents was completed and implemented.

In site geologic characterization, surface-based and laboratory studies continued. All boreholes for the neutron access program were completed, and trenching of faults continued. A map of the near-surface potential moisture flux at Yucca Mountain was prepared. This map identifies potential areas of relatively high net-infiltration rates and serves as important input to site-scale unsaturated flow models. The geochemistry program addressed concerns about the validity of experimental data from previous testing. These new studies showed that the methodology used over the past decade for empirical batch sorption data collection and sample size selection has been valid.

Excavation of the Exploratory Studies Facility (ESF) North Ramp Starter Tunnel was completed, and delivery of the tunnel boring machine (TBM) began. Design packages for the TBM launch chamber were completed. The first test alcove in the ESF was excavated for the purposes of conducting radial borehole and hydrochemistry tests. These tests are designed to detect vertical movement of water in the liquid or vapor phase and the effects of excavation on hydrologic properties.

Advanced conceptual design of the repository and waste package proceeded. Approval was given by the Director of OCRWM to incorporate the multipurpose canister into the Program Baseline. The multipurpose canister, combined with appropriate outer containers, provides a standard package for storage, transportation, and disposal of spent nuclear fuel, reducing the number of spent-fuel-handling operations and associated occupational exposures. Standardizing storage technologies in this way will reduce total program costs and simplify repository operations.

The change to the multipurpose canister impacts potential repository design. Horizontal, in-drift emplacement will be required to accommodate the multipurpose canisters. Work continued on establishing thermal loading limits and on determining the effect of fuel age and waste package spacing on the timing of the spent fuel peak temperature. Studies showed that areal mass loading and fuel aging have a significant impact on peak temperature but little effect on long-term temperature.

Another major iteration of the Total System Performance Assessment was completed. Improvements over previous assessments included a more realistic source term, enhanced site stratigraphy, and a more realistic representation of hydrologic flow processes. Also, calculations were completed for longer time periods. Performance assessment results were incorporated into the License Application Annotated Outline for submission to the U.S. Nuclear Regulatory Commission.

Public outreach activities continued, with Yucca Mountain tours, workshops on the programmatic and technical aspects of the project, and exhibits. Interactions continued between the Department of Energy and the State of Nevada, affected counties, and a number of external agencies and groups. The OCRWM international program continued cooperative activities with several countries and international organizations to share advances in technology, science, and public education in nuclear waste disposal.

FY 1995

A new Program Plan was developed by OCRWM with two main objectives. One of these objectives was to bring the site characterization program into conformity with financial resources that can be reasonably expected. The other was to enable OCRWM to make significant and measurable progress toward key objectives in accordance with a five-year plan. The plan includes milestones developed with input from the public and oversight groups. A new performance-based quality assurance audit program was also developed and implemented.

Rock characteristics data and the results of laboratory geotechnical analyses were provided for ESF design. Data from studies of infiltration in the unsaturated zone to define the upper boundary condition for infiltration were made available for model development. Continued data collection from boreholes supported the characterization of the gaseous phase movement in the unsaturated zone. Surface-based air-permeability testing was completed in three boreholes drilled using three different drilling methods, and the results were incorporated into numerical flow models. Climatology investigations continued, and the results were used to increase confidence in the regional climate modeling code. Seismic profiles and slip rates were determined for faults within the site area. Unsaturated-zone modeling efforts

installed at USW UZ-6s. Divergent tracer tests were conducted at USW UZ-6s and at the small-diameter, shallow boreholes near the crest of Yucca Mountain.

In hydrochemical characterization, tests were conducted to determine sorption equilibrium constants and retention equations for sulfur hexafluoride in contact with volcanic tuffs, gypsum cement, and clinoptilolite. Pore-water extraction was accomplished on selected core samples from several boreholes by one-dimensional compression and distillation.

Rock hydrologic properties were estimated from correlations previously derived between unsaturated zone hydrologic parameters and porosity. One-dimensional numerical simulations of water movements based on the stratigraphy observed in boreholes UE-25 UZ-4 and 5 were prepared. The simulations indicated that capillary barrier effects at the contact between nonwelded, unfractured tuffs and underlying fractured, welded tuffs will prevent increased infiltration until water potentials at the contact become large enough to initiate fracture flow. This is estimated to require several hundreds of years and perhaps longer. Similar capillary barrier effects will prevent drainage of water from the nonwelded and bedded tuffs overlying the vitric caprock of the Topopah Spring Member for tens of thousands of years.

Development of the three-dimensional site-scale model of Yucca Mountain continued. Various nonuniform infiltration distribution simulations showed large amounts of lateral flow and concentrated vertical percolation even when uniform infiltration rates are assumed. Gas flow and the geothermal gradient were incorporated into the site-scale model. Monitoring of water levels in the saturated zone at Yucca Mountain continued. Four zones in two wells were monitored continuously to detect water-level fluctuations caused by earthquakes. Data collection was completed on batch sorption experiments for lithium bromide, and column transport experiments with lithium bromide were conducted.

Regional hydrochemical data were collected, compiled, and analyzed. These data will be used in determining regional flow paths and the site hydrologic boundaries. The preliminary groundwater flow model was also analyzed for its possible contribution to defining boundary conditions for the site-scale model.

Data collection was completed for the chemical and petrographic study of 12 calcite samples from boreholes USW G-2 and USW GU-3/G-3. The fracture calcites included samples from above and below the water table. Petrographic, chemical, and stable-isotope data compilation was completed for calcite from surface calcretes and calcite from fractures. Data collection was completed on instrumental neutron activation analyses of calcites from several boreholes. Dust samples collected from natural dust traps and from the drilling rig at UE-25 UZ-16 were characterized using x-ray diffraction and scanning electron microscopy. Quantitative mineralogic analysis for UE-25 UZ-16 core samples, including reduction of x-ray diffraction data, was completed. X-ray diffraction was used to quantitatively analyze the mineralogy of 105 samples ranging in depth from 12.0 to 513.3 meters.

The clay mineralogy of tuffs from Yucca Mountain was studied to contribute to understanding the alteration history of the rocks and to predict potential future alterations. Potassium/argon dates obtained on illite/smectite separated from the tuff suggest that the rocks at depth in the northern portion of Yucca Mountain were altered soon after the creation of the Timber Mountain caldera to the north, about 10 to 11 million years ago. Data collection was completed on altered rock at Busted Butte and Yucca Mountain. Preliminary plans were completed for natural self-analog studies of alteration in the Topopah Spring Tuff, in conjunction with numerical modeling, as a means of understanding hydrothermal effects in the potential repository.

Studies were completed that will help determine the role of iron oxides in radionuclide sorption and whether actinides can be significantly retarded by iron oxides in the near- and far-field environments. A study to determine the effect of naturally occurring organic materials on the sorption of cadmium and neptunium onto oxide minerals and tuff surfaces was completed. Sorption model development included studies of reactions of water and goethite surfaces. It was found that altered goethite surfaces exhibited a comparatively slow reaction with water to produce a decrease in surface area.

Data collection was completed on the solubility of the actinides neptunium, plutonium, and americium in water characteristic of carbonate-rich water found in well UE-25 P-1. The water composition studied represented the probable upper limit of potential mobilizing ligands, especially carbonate, expected to contact the waste. The application of pulsed photoacoustic spectroscopy to determine equilibrium constants in dilute radionuclide solutions continued. Studies investigated the speciation and oxidation state of plutonium (IV) carbonate solutions as a function of pH, carbonate concentration, and temperature. Additional studies focused on the speciation of neptunium (V) hydrolysis and carbonate-formation reactions that are significant in interpreting any neptunium experiment.

In geophysical integration activities, development continued on the three-dimensional computer-based model yielding a stratigraphic and structural synthesis. Detailed site-scale modeling of the area near the North Ramp of the Exploratory Studies Facility was completed. An isopach map for the nonwelded to partially welded top of the crystal-rich caprock of the Topopah Spring Tuff was completed. Logs from selected North Ramp boreholes were examined for characterization of geophysical properties of microstratigraphic units and contacts in boreholes with noncored intervals. Geologic mapping, lithologic studies of core from boreholes, and surface and borehole geophysical studies were integrated to produce a preliminary geologic cross section along the North Ramp alignment of the Exploratory Studies Facility. Water content and porosities

within the unsaturated zone were computed from density and epithermal neutron logs obtained in 15 water table boreholes. The separation between the water content and porosity logs clearly demarcated the lithophysal zones within the Topopah Spring Tuff.

Mapping of the structural features within the potential repository continues. Work continued on petrographic and geochemical examination to define the internal stratigraphy of the Tiva Canyon Tuff. A stratigraphic section was measured and sampled at the northwest end of Isolation Ridge traversing the nonwelded tuffs between the Pah Canyon and Tiva Canyon tuffs. Measurement began of a section along Solitario Canyon cliff, measuring units from the crystal-rich nonlithophysal zone of the Topopah Spring Tuff to the columnar subzone of the crystal-poor lower nonlithophysal zone of the Tiva Canyon Tuff.

Field mapping of the Exploratory Studies Facility (ESF) North Ramp Starter Tunnel was completed. Fracture fingerprint drawings were produced from data collected in the starter tunnel, portal cut, and drainage channel of the ESF North Ramp. Processing began on vertical seismic profiling data acquired from boreholes USW NRG-6 and USW WT-2. Design specifications for underground testing in the ESF were finalized.

In three-dimensional rock characteristics model development, welded/nonwelded stratigraphic models were developed for the Total System Performance Assessment (TSPA). A preliminary LYNX model of several stratigraphic units at Yucca Mountain was constructed. Several Geostatistical Software Library software routines were modified to provide better checking of simulations.

Initial interpretations of late Pleistocene climate were made based on aquatic microfossil data collected from sedimentary deposits in the Las Vegas Valley. From microfossil data, it is estimated that mean annual precipitation may have been three to four times higher than modern precipitation rates. Studies were begun of fossil ostracodes and aquatic gastropods from a core taken in late Holocene sediments from the Pahranagat Mountains. Isotope values obtained from terrestrial snails suggest a polar isotope signature for late summer rain, implying that summers were characterized by a winter-like atmospheric circulation that would greatly reduce evaporation because of increased precipitation and reduced average summer temperatures.

Preliminary interpretations of late Pleistocene plant microfossils from packrat middens suggest that precipitation varied from two to five times modern precipitation rates and mean annual temperatures were 7 to 9 degrees Celsius colder than modern. Pollen data from late Holocene Pahranagat core suggest that the lower treeline moved up and down the local slopes many times in response to variation in Holocene effective moisture. A 9,000 year record from tree rings from sites in southern Nevada shows Holocene episodes from 10 to 100 years in length that were both wetter and drier than more modern periods of dryness (900 to 1400 A.D.) and wetness (1400 to 1900 A.D.).

A lithologically distinctive older gravel was recognized and mapped along Fortymile Wash. Evidence suggests that this gravel is of late Miocene age, indicating a late Miocene establishment of Fortymile Canyon. Sandy eolian deposits and buried soils within the deposits were sampled for U-series disequilibrium and thermoluminescence analyses. X-ray fluorescence analyses of sediment samples from playas between Beatty and Tonopah were completed.

Hydrogenic discharge deposits at the southern end of Crater Flat were investigated using U-series disequilibrium and thermoluminescence geochronological techniques. Strontium and U-isotopic compositions of water from the perched-water zone in USW UZ-14 were obtained. Compilation, synthesis, and interpretation of geochemical and isotopic data from spring and well waters in the Ash Meadows flow system continued. Sample spring and well waters were analyzed for major ions and strontium isotopes.

Assessment of geophysical data needs for the project volcanism study was begun. Several structural models for the Yucca Mountain region were identified and divided into subsets for assessment of the structural controls of basaltic volcanic activity. New sets of spatial prediction models were developed. Revised simulation modeling was completed for the recurrence rate of volcanic events, the disruption probability, and the probability of magmatic disruption of the repository. Field work was conducted at Scarp Canyon to study dike geometry and the effects of dikes on wall rocks. Basaltic volcanism was evaluated with regard to its potential for rupturing the repository.

New information on radiometric age data from altered rocks and known mineral occurrences in the Yucca Mountain vicinity was obtained. Evaluation of hydrocarbons in the Yucca Mountain region continues. Topographic base maps of Bare Mountain and the Striped Hills were produced using Digital Elevation Model data, and limestone sample localities were plotted on these maps. Strontium isotopic data for Paleozoic limestones from several locations were compiled and evaluated.

A section map of the North Ramp Bow Ridge fault area was prepared to incorporate information from boreholes UE-25 NRG#1, UE-25 NRG#2, UE-25 NRG#2A, UE-25 NRG#25B, UE-25 NRG#3, and UE-25 RF#8. Drilling was completed on boreholes UE-25 NRG#44 and UE-25 NRG#5. High-resolution seismic surveys were completed on the west side of Exile Hill. Locations were identified for additional North Ramp boreholes, to be designated USW NRG-8a, USW NRG-8b, and USW NRG-8c.

Mechanical properties tests were completed on core samples from the North Ramp boreholes. Laboratory tests on soil samples from UE-25 NRG-2A were also completed. Thermal expansion testing of air-dry samples from various depths was completed from ambient to 110 degrees Celsius. Polished thin sections were made on samples from several depths, and mesoscopic descriptions of these samples were completed.

Samples from USW NRG-6 were analyzed for mineralogical, petrologic, chemical, and thermal properties. Studies showed that thermal conductivity of samples from USW NRG-6 is less than that of samples from the Tiva Canyon and Topopah Spring members, regardless of saturation level. The studies also showed that thermal conductivity values are greater for fully saturated samples than for oven-dried and air-dried samples, especially for samples from the nonwelded bedded tuff unit.

Thermal expansion tests were completed on samples from USW G-1 and USW NRG-6. Representative thermal strain curves were generated from the test data and were incorporated into the far-field thermal strain calculations for the Exploratory Studies Facility Design Package 2C. Samples were collected from core taken in the NRG drillholes for intact mechanical properties testing. Natural fracture samples were collected from core taken from drillhole USW NRG-6 for mechanical properties testing. Several studies produced data relating to the time-dependent mechanical properties of fractures and to the effect of roughness on the mechanical properties.

Geotechnical activities were conducted in the North Ramp Starter Tunnel to confirm the adequacy of design, construction, and long-term performance. Blasting in the Starter Tunnel alcove was monitored seismically. Load cells installed on 15 of the rock bolts forming part of the Starter Tunnel support were monitored. Closure pins were installed at the same locations as the load cells, and convergence measurements were made.

Field trips were conducted to identify possible earthquake sources and to update interpretations concerning Quaternary faulting, earthquake magnitudes, and potential earthquake recurrence rates. Information was compiled from available geologic maps and other sources pertaining to source parameters for known and suspected Quaternary faults within 100 km of Yucca Mountain. Proposed probabilistic and deterministic seismic hazard methodologies were evaluated in relation to repository design and performance parameters.

Field testing of the forces required to topple precariously balanced rocks continued. Seismic data from the Yucca Mountain region were continuously recorded. All sources for Little Skull Mountain earthquake motions were merged, and analysis of the Little Skull Mountain earthquake sequence was completed.

Field work was done to characterize fault disruption and displacement history among faults in Rock Valley. Principal structural parameters were noted, described, and located on field maps for further analysis. Air photo analysis led to the making of preliminary choices of fault traces that were candidates for trenches.

Field data compilation and Quaternary fault mapping at Yucca Mountain were completed. Preliminary photogrammetric logs of Wall 4 at Busted Butte and of Trench 14 on the Paintbrush Canyon fault were prepared. The collection, analysis, and interpretation of all geophysical data for Windy Wash were completed. Field work was conducted in north Windy Wash to evaluate scarp evolution and to determine potential sites for cosmogenic isotopic dating. Stratigraphic contacts and structures in Trenches CF-1 and DF-1A on Fatigue Wash fault were cleaned, mapped, and flagged. New trenches were excavated on the Solitario Canyon fault. A new trench, MWV-T3, was excavated, and Trench A1 was deepened and extended.

Geologic, tectonic, magnetic, and gravity data were integrated and synthesized. Enhanced remote sensor image data for Yucca Mountain and its larger geologic setting were received from the Jet Propulsion Laboratory. Work continued on development of a preliminary tectonic model that is congruent with plausible tectonic scenarios.

In geomechanical analysis studies, a series of laboratory tests was conducted to provide data for mechanical computer code validation. Another series of experiments studied the effects of a nonstandard loading condition on the mechanical properties of joints. The surface characteristics of natural fractures were studied in order to relate these to the frictional data gathered on replicas on the surfaces. A number of thermal-mechanical analyses were conducted to support experiments planned for the Exploratory Studies Facility. The development of joint constitutive models was completed. Improvements to the continuum joint model continued, and a single joint set, three-dimensional version of the successful two-dimensional model was implemented.

In repository design studies, advanced conceptual design work continued with a view toward determining the emplacement mode, which is closely related to thermal load and waste package size and type. Advanced conceptual design studies of subsurface repository operations and maintenance were initiated. Information was compiled for seven types of waste package. Studies were initiated to help quantify the effective thermal properties of a crushed tuff backfill. Materials to be left by Exploratory Studies Facility construction activities which could potentially impact waste packages were identified.

The Thermal Loading Systems Study was performed. Its objective was to identify a range of thermal loading options believed to meet licensing requirements and to determine needs for further study, code development, and steps to reduce thermal loading issue uncertainties. Heat conduction calculations were performed to evaluate near-field, preclosure performance. Hydrothermal calculations were also done to evaluate postclosure performance due to changes in temperature and water movement on a mountain scale. Laboratory-scale experiments were performed to determine the effects of saturation variations on nonisothermal flow in sand. Four thermal loading scenarios were investigated in connection with TSPA studies. Thermomechanical analyses in support to North Ramp Design Package 2C were completed, with evaluations of cross sections along the North Ramp subjected to in situ, seismic, and thermal loads.

Evaluations of sealing concepts were started, with specific attention given to their application to the current Exploratory Studies Facility/potential repository layouts and concepts. A study plan for testing sealing was initiated. Plans were developed for conducting laboratory tests and limited field demonstrations of seals.

Parametric evaluations of waste package designs were conducted. These included thermal and criticality evaluations with respect to a number of variables. Several engineering calculations and bases were developed, and a matrix of waste package design options was developed. Studies were performed to determine the size and weight of a rock that could cause permanent plastic deformation of a waste package.

In support of the thermal loading systems study, a preprocessor that calculates the heat generation tables for the V-TOUGH code was developed. This preprocessor calculates kilowatts per metric ton of uranium for a given fuel type, age, burnup, and enrichment. A new set of mountain-scale repository models was developed. The impact of drift-scale, buoyant, gas-phase convection on hydrothermal performance near emplacement drifts was studied. Also studied was the use of variations in areal mass loading to provide a nearly uniform duration of boiling throughout the entire repository.

Work was completed on the study to determine electrical resistivity as a function of water saturation using samples from USW G-4 core at room temperature. Work began on a similar study at 40 degrees Celsius. Results will allow electrical resistance measurements to be used as an indicator of saturation in field and laboratory tests. Work continued on the experiment to determine the moisture retention curve and one-dimensional imbibition using USW G-4 core. The data from this experiment will be used to calculate relative permeability as a function of water saturation. Work continued on the analysis of thermohydrological behavior for a wide range of thermal loading conditions and hydrological properties.

Leveling and surface fracture mapping of the Large Block Test site were completed. Preliminary analysis indicated that the block is suitable for planned tests of several thermohydrological hypotheses. A geomechanical numerical simulation of the Large Block Test was begun, and hydrothermal modeling analysis continued.

Uranium dioxide dissolution experiments were completed. Work continued on long-term, room-temperature dissolution experiments. Flow-through dissolution tests on ATM-106 fuel in both oxidized and unoxidized forms continued. Oxidation drybath testing of spent fuel at temperatures less than 200 degrees Celsius continued. Spent fuel oxidation tests with a thermogravimetric apparatus were conducted to address the phase stability of the uranium oxide plateau.

Version 7 of the EQ3/6 software for use in near-field environment characterization and site characterization was maintained and Version 7.2a was released to all project-related users. Version 8 was in development. Data restructuring for Version 8 was completed.

Work continued on the scoping study of cladding temperature history for various drift emplacement heat loadings and of cladding creep endurance. Information on the source term was provided for inclusion in the TSPA. Work continued on the study of cladding temperature history for various drift emplacement heat loadings, and input was provided for the performance assessment. Documentation began on the stochastic model for condensate drainage. Data was provided for detailed temperature, saturation, and liquid flux histories through the repository using V-TOUGH. A model was developed to perform thermal calculations in the vicinity of waste packages placed horizontally in drifts.

Work continued on compiling information on the corrosion and oxidation behavior of ferrous materials—carbon steels, cast irons, and low-alloy steels. The degradation mode survey on ferrous materials being considered in multiple-barrier concepts continued. Detailed tables were prepared for the atmospheric and aqueous corrosion data for these materials. Studies were done on stress corrosion crack growth rate. Work began on setting up a slow crack growth rate measuring system. A draft of the degradation mode survey on ferrous materials was completed.

Performance assessment in support of ESF design included studies in three major areas. First was an evaluation of (ESF) and surface-based testing tracers, fluids, and materials used in the ESF to determine their potential impacts on waste isolation. Second was an evaluation of ranges of ESF ramp and drift sizes under consideration to determine their respective impacts on preclosure radiological safety and postclosure waste isolation. Third was a comparison of drill-and-blast ESF excavation with mechanical excavation techniques including tunnel boring machines, again with respect to preclosure radiological safety and postclosure waste isolation. An initial preclosure probabilistic risk assessment was conducted on items important to worker radiological safety. Rock-fall likelihoods and consequences were estimated. Numerical calculations were performed to assess tunnel stability under the expected range of thermal loads.

The TSPA included verification and validation studies using the TOUGH2 code. The studies investigated the effect of fracture permeability on the dryout of a potential nuclear waste repository and the perching of water above a repository as a function of time after waste emplacement. The TOUGH2 and FEHM codes were used to solve a series of test problems relating to multiphase, nonisothermal flows in porous media. Studies were begun to compare the performances of TOUGH2 and FEHM for modeling coupled heat and fluid flow at the near-field scale and to consider waste package vicinity conditions related to parameters such as waste package spacing, infiltration rates, and vapor diffusivity.

In caisson studies, the final design of the caisson was completed. Procedures were developed for water sampling and pH measurement for the caisson experiment. Integrated transport experiments developed sorption models and batch sorption experiments in support of the caisson test. Batch nickel sorption experiments were completed.

Data for TSPA analyses were extracted from site and analog data for statistical reduction. These were depicted as probability distributions, and an expanded reference to support the TSPA was prepared. Development continued on the east-west INTRAVAL cross section, and debugging of INTRAVAL test cases was completed. Configuration continued of the INGRES system for the Performance Assessment Data Base to facilitate data retrieval and presentation in the required format.

Extensions of TSPA analyses to evaluate the performance of the subsystems imbedded in the total system representation of Yucca Mountain were planned. Work was done on a methodology for multilevel performance assessments of unsaturated flow, unsaturated transport, and saturated flow/transport process level foundation studies. Definition of nominal case scenarios progressed. Several models were developed, including models for gas-phase releases, releases through basaltic volcanism, and releases through human intrusion. The ESF design and construction activities progressed. Technical assessment of ESF seismic design inputs continued. A probabilistic assessment of vibratory ground motion hazard was completed. The excavation of Test Alcove 1 was completed. The tunnel boring machine design, fabrication, and check out as well as the infrastructure installation on the North Portal pad, were closely monitored. Water and electricity were made available at the North Portal, and the assembly pad for the tunnel boring machine was completed. Delivery of the tunnel boring machine began.

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Quality Assurance (QA) audits were conducted in participant organizations. Determination of Importance Evaluations were produced for areas relating to the Exploratory Studies Facility (ESF) and surface-based testing. The QA Classification and Implementation Plan and the Item Classification and Maintenance of the Q-List were approved; these documents complete the transition to the classification and grading process. Revision 3 to the Q-List was approved.

Collection of precipitation and meteorological data continued. Storm events at Yucca Mountain from 1991 to 1993 were analyzed geostatistically. Satellite data, lightning data, synoptic weather charts, and video logs continued to be collected and archived. Streamflow and precipitation data were collected at and near Yucca Mountain for use as input to flood frequency analyses, infiltration modeling studies, and performance assessment.

Various hydrologic test data from drillhole USW G-2, including tracejector and spinner surveys, geophysical logs, and hydrochemical sampling were reviewed and processed. In addition, temperature logs were analyzed and processed to obtain estimates of vertical groundwater flux. The temperature logs revealed a complex thermal regime significantly influenced by vertical fluid movement. Historical water-level data from USW G-2 were also analyzed. In upper Fortymile Wash, soil-moisture and depth-to-water measurements were conducted regularly. Precipitation, streamflow, unsaturated-zone, and saturated-zone data in Fortymile Wash for water year 1993–94 were compiled.

Basic hydrologic analysis of the regional flow system was completed. In hydrologic system modeling, a method was developed to allow quicker and more complete evaluation of how well groundwater modeling output from the MODular Finite Element (MODFE) model reproduces the actual groundwater system conditions. Updating continued on the three-dimensional hydrogeologic framework model of the Death Valley regional groundwater flow system.

The effects of annular washout zones around boreholes on measurements from neutron geophysical tools and neutron moisture meters was investigated. The effects of rock fragments of greater than 2 millimeter diameter on the saturated hydraulic conductivity and the water retention properties of the skeletal soils at Yucca Mountain were measured. Consequently, the infiltration study was reconfigured and accelerated. Characterization continued of the hydraulic and physical properties of the unconsolidated surficial material. Surface infiltration rates and sorptivity values were determined at selected locations.

Water content profiles from 97 unsaturated zone neutron-access boreholes were measured monthly. A conceptual model of shallow infiltration was defined. Development, calibration, and verification continued of one-dimensional numerical models of shallow infiltration and evapotranspiration. Development began on a net infiltration flux map and a potential fast-pathways flux map.

Estimates of average groundwater residence time were obtained by leaching rock cuttings to extract chloride for analysis of chlorine-36 as a naturally occurring radionuclide that is carried into the subsurface by percolating water. Several vertical profiles were collected from the soil and fractured rock face exposed at the UE-25 NRG#5 drill site. These profiles were studied to evaluate the role of the soil cover and fractures in transmitting infiltrating water into the Tiva Canyon welded unit. Evaluation continued of the elevated chlorine-36 results throughout the profile for borehole USW UZ-N55. The chlorine-36 signal in a perched water sample from USW NRG-7/7a was measured and found to have no indication of an elevated component. Analysis of alluvial samples from USW UZ-N14, from depths of 2 to 9 meters, indicated that chlorine-36 from global atmospheric weapons testing fallout had penetrated to 4 meters at this location. Two pore-water samples extracted from the

USW UZ-N14 drill core were analyzed for chloride and bromide, with the bromide-to-chloride ratios used to correct water residence time estimates for deep rock samples.

Analyses of physical and hydrologic properties of rock outcrop samples from eight Yucca Mountain surface outcrop transects showed several lithologic transitions throughout the unsaturated zone which have rapid property changes with depth. Boreholes UE-25 UZ#16, USW NRG-7A, and USW NRG-6 were instrumented. Data collected indicated a difference in the pneumatic-pressure responses between instrument stations above and below the Topopah Spring vitric caprock.

Gas permeability testing of rocks from G-Tunnel materials similar to the Calico Hills unit was completed. Preparations for axial-fracture testing continued. The ponding test continued on a large fractured welded tuff block from the Tiva Canyon columnar unit. Single-hole, air-permeability testing was completed in the Tiva Canyon Alcove 1 anisotropy radial boreholes. Monitoring for perched water in the ESF and in the first alcove continued, with no perched water being detected. Perched water was encountered during drilling of surface borehole USW SD-7. Analysis of all available data on perched water encountered in boreholes at Yucca Mountain revealed that perched water generally occurs where highly fractured rock units are underlain by less-fractured rock units that have more-permeable matrix properties.

Studies were conducted to determine the air circulation in open boreholes USW UZ-6 and USW UZ-6s to develop a database suitable for calibrating gas-phase circulation models for the unsaturated zone. Shut-in pressure testing continued at UE-25 NRG#4 and was begun at UE-25 NRG#2B, UE-25 NRG#3, and UE-25 NRG#18. Progress was made in understanding the capabilities and limitations of the LIDAR instrument system for locating and characterizing preferred pneumatic pathways. Gas samplings from open boreholes in the unsaturated zone were conducted in UZ and NRG boreholes. A laboratory batch-type testing procedure was developed to investigate the sorptive characteristics of crushed materials for gas tracers, and adsorption experiments were conducted.

Development and validation of test methods for one-dimensional compression and high-pressure one-dimensional compression of pore-water extraction were documented. Two conceptual flow models were used for fitting the tritium data from UE-25-UZ#16 to estimate the residence time of unsaturated-zone water. Chemical and isotopic compositions of perched water from boreholes USW UZ-14, USW NRG-7A, and USW SD-9 were studied.

Numerical simulations were made to match measured flow through a block of partly welded fractured tuff. A simulated fracture network was developed for the ESF Starter Tunnel area, an area of about 10,000 square meters. A procedure was developed for predicting the gridblock-scale hydraulic conductivity of a fracture under saturated or unsaturated conditions. Simulations were run of transient infiltration, under ponded conditions at the surface, into a one-dimensional vertical column of gridblocks from the three-dimensional site scale model.

Topographic and stratigraphic data were compiled from the Yucca Crest area around boreholes USW UZ-6 and USW UZ-6s. These data were used to create a computational mesh compatible with TOUGH2 input requirements for a three-dimensional numerical model of gas circulation. Fractal and geostatistical methods were investigated as a means for describing the spatial structure of the bulk permeability values calculated from borehole air-injection testing.

Development of the three-dimensional site-scale model of the natural site hydrogeologic system of Yucca Mountain continued. A two-dimensional model was generated for gas flow near borehole USW UZ-6s to extend the capacity to simulate gas flow to the site scale three-dimensional model. The North Ramp of the ESF was incorporated into the site-scale model.

Monitoring of water levels in the saturated zone at Yucca Mountain continued. Four zones in two wells were monitored continuously to detect water-level fluctuations caused by earthquakes. The Modular Ground Water Flow (MODFLOW) program was used to develop a three-dimensional equivalent-porous-medium model of the C-hole complex. Laboratory-scale data were collected for C-hole sites for validity testing of a matrix-diffusion model for transport of a dissolved species, with a view to determining the effectiveness of the saturated zone as a significant barrier to radionuclide migration. Background pressure data were collected from packed-off zones in wells UE-25 c#1, c#2, and c#3.

The FEHMN code was chosen for simulation of the site saturated-zone flow system. Testing of the FEHMN groundwater flow, heat, and solute transport code was completed using test problems supplied by the developers of the code. Work began on constructing the saturated-zone hydrogeologic framework model that will be used as a basis for the flow model. The solution algorithm for the TRINET fracture-network model was extended to include two-dimensional elements for calculation of flow and transport in rock matrix. The conceptual model was prepared for groundwater flow at the C-hole complex.

Progress was made in understanding the water–rock interactions in silicic volcanic rocks, and work was done on developing conceptual models of water–rock interactions. Experiments were begun to quantify the various reactions that can impact the chemistry of unsaturated zone waters. A chloride-balance method for calculating average infiltration rates was tested using groundwater chemistry data from the unsaturated zone at Yucca Mountain. Field and laboratory data on the impact of variations in groundwater compositional parameters on the sorption behavior of radionuclides were evaluated.

Studies indicated that past silica mobilization in the potential host rock at Yucca Mountain has led to a significant increase in the porosity of the rock along fractures in the Topopah Spring Member. Additional data on fracture–mineral and matrix–mineral distributions were collected. Core samples were examined for the occurrence of the zeolite erionite. Sample analysis was completed for materials from the UE-25 UZ#16 and USW SD-9 drill sites and for background eolian dusts, with an emphasis on the potential occurrence of erionite. Optical and x-ray diffraction methods were used to define fracture mineralogy in UE-25 UZ#16 samples extending from the surface down to the saturated zone.

Studies of calcite-silica deposits showed mineralogic and chemical affinities among the fault deposits, adjacent bedrock, overlying soils, and a possible eolian contribution. Studies of hydrothermal deposits indicated that groundwater upwelling is not expected at Yucca Mountain. Results from potassium-argon studies of Yucca Mountain clinoptilolites showed a consistent pattern of older apparent ages, approaching the ages of the host tuffs, in samples from below the static water level, whereas younger ages were indicated in samples from the unsaturated zone. Within the unsaturated zone, apparent ages become younger with decreasing depth.

Studies of zeolites and other secondary minerals from tuffs deposited in saline lakes in the region around Yucca Mountain were undertaken to gain a better idea of the variability of the apparent ages of zeolite potassium-argon compared to the ages determined for other minerals. Paleohydrology studies were undertaken to better understand chemical transport during zeolitization.

Data collection continued on mineralogic alteration in ESF samples. Studies continued on the repository effects on the radionuclide retardation properties of existing mineral assemblages and the contribution of hydrous minerals to the total pore water and to the modulation of temperature in a repository environment. Solubility studies of clinoptilolite and analcime showed that analcime yielded a dissolution rate significantly faster than that for clinoptilolite.

A neptunium-sorption database including neptunium-sorption data as a function of stratigraphic unit and groundwater composition at Yucca Mountain was compiled. Data collection was completed on the study of neptunium sorption onto calcite as a function of concentration in drillhole UE-25 J#13 and UE-25 p#1 waters. Crushed-tuff column studies were begun to calculate the potential effect of siderophores on the transport of radioactive wastes. Studies continued of the surface characteristics of natural mineral assemblages and their relation to the sorption of neptunium onto tuff.

Data collection was completed on a comparison of solubilities and redox characterizations from oversaturation and undersaturation experiments on neptunium, plutonium, and americium in UE-25 p#1 well water. To define solubility parameters and bridge gaps in the data acquired in previous bulk solubility experiments, experiments were begun to thermodynamically characterize radionuclide speciation and produce thermodynamic constants required for reliable solubility modeling. Neptunium and plutonium solubility were modeled using information from the GEMBOCHS database.

The role of sorption in the retardation of radionuclides was interpreted using sorption distribution coefficients in performance assessment calculations. Validation began of the batch sorption distribution coefficients for neptunium (V) in UE-25 J#13 and UE-25 p#1 waters using solid-tuff columns made of zeolitic tuffs. Data collection was completed on the transport of neptunium through Yucca Mountain solid tuff under saturated conditions as a function of flow velocity. A study of selenium transport through unsaturated tuff columns was completed. Autoradiography was used to characterize the radionuclide retardation that can be expected from radionuclide sorption onto minerals coating the fractures in fractured-tuff column experiments. Microautoradiography was used to study plutonium exposure on five bulk-rock tuff types and one fracture sample. Water from UE-25 J#13 was analyzed for colloid concentration using light-scattering particle-counting techniques.

A coupled silica-deposition geochemistry model was developed. The model integrates the change in precipitation and the associated porosity decrease with changes in porosity and permeability, thus coupling the effects of repository heating, geochemistry, and flow. Four diffusion cells were fabricated for studying the diffusion of technetium, neptunium (V), uranium (VI), and plutonium (V) through devitrified Topopah Spring Tuff and zeolitic Calico Hills Tuff using waters from wells UE-25 J#13 and UE-25 p#1. Verification of the coupled reaction/transport simulator LEHGC1.0 was completed. Numerical simulation efforts focused on chlorine-36 simulations. Studies began on the movement of carbon-14 in both the liquid and vapor phases.

Borehole location and stratigraphic data from 41 boreholes were compiled and reviewed. Lithologic logging was conducted and graphical lithologic logs were prepared. Analyses of core samples of the Tiva Canyon Tuff from drillhole UE-25 NRG#3 indicate that concentrations of certain trace elements vary with stratigraphic position. These analyses further indicate that sharp changes in concentration mark the boundary between the high-silica rhyolite of the upper lithophysal zone and the quartz latite of the upper cliff zone. A geochemical database of major and trace element data obtained from whole-rock analyses of samples from boreholes USW G-1 and USW G-3/GU-3 was compiled.

Stratigraphic relations within selected tuff units were characterized by examining, sampling, and describing these intervals in Yucca Mountain boreholes. A draft digital location map for all measured sections was compiled, and a draft digital topographic location map was prepared for measured sections on and near Yucca Mountain. The database

and existing surfaces for the three-dimensional geologic framework model were updated.

Gravity and ground magnetic measurements obtained across the Ghost Dance fault were processed for initial modeling efforts. Gravity and magnetic anomalies data obtained near the North Ramp alignment were prepared for modeling. Seismic reflection data were acquired in Crater Flat and at Yucca Mountain. Magnetic data along the seismic reflection line were also acquired. These data will be used as input for the three-dimensional geologic model.

Samples of Tiva Canyon Tuff acquired in a faulted area at the eastern end of Antler Ridge were prepared for x-ray fluorescence analyses. Data from the opaque mineral phases characterizing each zone within the Tiva Canyon Tuff in Antler Ridge and in borehole USW GU-3 were summarized and tabulated. A preliminary study of linear features on low-angle photos was completed and results were plotted on topographic maps. Trace-element distribution in boreholes and outcrop was used to identify and confirm the contact between the quartz latite and the rhyolite in the Tiva Canyon Tuff and the Topopah Spring Tuff.

In work characterizing the structural features within the site area, survey information on the Fran Ridge pavement was obtained and field maps were completed. Three fracture study areas in the nonwelded unit of the Paintbrush Tuff were identified for surveying. Fracture mapping of the Antler Ridge exposure was completed. Geologic mapping of the North Ramp of the ESF began, and mapping of the Starter Tunnel, Test Alcove #1, and the drainage channel was completed. Vertical seismic profile and surface reflection data were refined and made available for integration into the LYNX database for surface and subsurface stratigraphic studies.

Laboratory measurement of framework hydrologic bulk properties from drillhole USW SD-9 and the USW SD-12 was completed. Additional stratigraphic data were obtained for drillholes USW SD-9 and SD-12 and for seven NRG holes. Compilation of rock properties data began. Geologic logging of core from the USW SD-9 drillhole was completed. Geometric and geostatistical modeling of rock-quality data for cross-sectional profiles along the ESF North Ramp and main test level drifts continued. A prototype three-dimensional geometric model for the Yucca Mountain site area extending away from the main repository block and from the topographic surface to the Paleozoic basement was created. Development began of an extended three-dimensional site geologic model.

In paleoclimate studies, paleontological and pollen analyses focused on evaluating the late Holocene climate variability of the ostracode and pollen stratigraphic records from southern Pahranagat Lake. Radiocarbon chronological studies were used to evaluate the accuracy of radiocarbon ages obtained from various mollusks found in the marsh deposits surrounding Yucca Mountain. Climate indicator plant species from ancient woodrat middens were dated. Faunal and water samples were collected from springs between Alamo and Caliente, Nevada. Studies of ostracodes extracted from core taken from the southern Pahranagat Lake indicate that the size of the lake has varied considerably over the last 2000 to 3000 years. Stable isotope studies of biogenic carbonate from the upper part of the Pahranagat core were completed. Studies of packrat middens provided better understanding of the timing of vegetation migrations onto the valley floors of southern Nevada during the Pleistocene and of migration of plants up and down slope during the Holocene. Results from stable carbon isotope analyses of plant material from middens can provide indication of available water for infiltration and recharge.

Uranium and thorium isotopic compositions were obtained on carbonate nodules and calcified plant material from the Horse Tooth Deposit. Samples from the Crater Flat and Horse Tooth deposits were analyzed for uranium and thorium isotopes by mass spectrometry. Uranium and thorium isotopic analysis from three aliquots of a nodular carbonate from Crater Flat were completed. Deposits from near the southern end of Crater Flat were also sampled and analyzed for stable and radiogenic isotopes. Carbonate deposits from Pahroc Spring were analyzed for stable carbon and oxygen isotopes.

In postclosure tectonics studies, multiple structural models of the probability of magmatic disruption of the repository, controlled area, and the Yucca Mountain region were assessed. Structural models for the distribution of basaltic volcanic activity were reviewed. Paleomagnetic data were collected for the older basalt of Crater Flat and the basalt dike of Solitario Canyon to test the detectability of basalt intrusions using magmatic methods. The probabilistic volcanic hazard assessment was revised to incorporate newly acquired data on the age, location, and volume of volcanic centers in the region.

The first set of natural analog studies of xenolith abundances was completed at the Lucero volcanic field in New Mexico. Initial geochemistry and mineralogy sampling and analyses were carried out at the Paiute Ridge intrusive complex. Factors that determine the geometry of intrusions at shallow depths were described.

In geochronology studies, a final chronostratigraphic model was completed for the Lathrop Wells volcanic center using revised data from trenching and from field, geochemistry, and geochronology studies. Microprobe analyses were completed of mineral phases from representative eruptive units at Lathrop Wells. Data collection continued on the geochronology of all post-Miocene eruptive centers in the Yucca Mountain region, and strontium, neodymium, and lead isotopic analyses were continued.

In natural resource assessment studies, procedures for assessing the potential for mineralization of the Miocene volcanic rock mass and its basement of Paleozoic limestones at Yucca Mountain were developed and implemented. Two studies implementing these procedures found no evidence

of past involvement of volcanic rocks with mineralizing fluids. In another study, samples collected from the upper cliff and caprock zones of the Tiva Canyon Tuff were analyzed for major and trace elements including precious metals and elements considered to be pathfinders for epithermal mineralization. Strontium, lead, and oxygen isotope analyses and x-ray fluorescence analyses for selected major and trace elements were conducted on brecciated and altered samples with fault zones at Trench 14 and Busted Butte. The data do not indicate any introduction of radiogenic isotopes or oxygen isotope exchange by hydrothermal fluids, leading to the conclusion that the fault zones have not been pathways for epithermal mineralizing solutions.

The geotechnical investigation for the North Ramp was completed. The North Ramp cross section was revised to include additional borehole data, and the Exile Hill cross section was revised to include additional data based on refined lithostratigraphic interpretation and surface mapping. Field tests were conducted in Trench NRT-1. The geology and rock structure log for drillhole NRG-7A was completed.

In thermal and mechanical rock properties studies, samples from Fran Ridge unit TSw2 were examined for bulk properties and grain densities, and for mineralogical, petrologic, and bulk chemical characterization. Testing for the effects of saturation on thermal conductivity was completed. Potential correlations between thermal properties and sample characteristics were examined for samples from USW NRG-6. Measurements of thermal conductivity and thermal expansion were made on samples of the TSw2 and TSw1 thermomechanical units from drillholes UE-25 NRG#4, UE-25 NRG#5, and USW NRG-7a.

Samples were collected from the NRG drillholes for intact mechanical properties testing. A study was conducted of time-dependent deformation involving high-temperature experiments under creep and low strain rate conditions. Natural fractures from UE-25 NRG#4, USW NRG-6, and USW NRG-7A were characterized using a laser profilometer to obtain topographic information. Samples of systematic drilling hole core were collected for fracture mechanical properties testing. Development continued on a computer program to model the dilation, normal stiffness, and shear stiffness of single fractures in rock. Analyses were conducted to determine the temperature, displacement, and stress fields that will result from the in situ thermomechanical experiments in the ESF.

In the North Ramp Starter Tunnel and its alcove, peak particle velocities resulting from construction blasting were measured, and load cells were installed on selected rock bolts and monitored. Cross-drift convergence pins and multipoint extensometers were installed at selected locations. Geotechnical design verification activities and rock mass quality evaluations were conducted. Installed geotechnical instruments were monitored, and new instruments were installed closely following the excavation of the ESF. Plans were finalized and procurements were begun for measurement of diesel exhaust in the ESF ventilation system.

Geologic, geophysical, and seismic data continued to be compiled to support seismic source evaluation and characterization for the Probabilistic Seismic Hazard Analysis. Literature searches were conducted to compile information about historical surface-rupturing earthquakes in the Basin and Range Province and normal-faulting earthquakes in analogous regions. Faults in the Yucca Mountain region were examined to assess their paleoseismic data and uncertainties. The Preliminary Table of Quaternary Fault and Seismic Source Parameters (Version IV) was updated and expanded. Seismograms from available databases were assembled, and analyses of the variation of ground-motion amplitudes as a function of earthquake magnitude, source-site distance, and frequency spectra were begun. Work began on assessment of existing ground-motion models for applicability to Yucca Flat underground nuclear explosion data. Work also began on one-dimensional uphole/downhole modeling of underground nuclear explosion data.

The methodology for using the distribution of precariously balanced rocks as an indicator of past ground-motion levels was documented. Seismic monitoring of the southern Great Basin continued. Calibration of analog seismic stations continued. The catalog of evens and waveform data for calendar year 1994 was completed. Portable seismic instruments were deployed in Rock Valley and at locations along the Crater Flat seismic reflection line. First arrival times from the Non-Proliferation Experiment (a conventional explosion) on the northern Nevada Test Site and a shot at Ryan, California, were used to model the velocity structure of the upper crust near Yucca Mountain. Results from these tests gave no indication of anomalously low-velocity material, which would suggest molten or near-molten magma at shallow depth below Yucca Mountain or in southern Crater Flat.

Analysis of previously collected data on the Bare Mountain fault indicated that the Quaternary rate of faulting along this feature is very low and that the age of the most-recent faulting event may be no younger than late Pleistocene. Two trenches were excavated on the south and north strands of the Rock Valley fault zone. Data from investigations in the Camp Desert Rock area and the Specter range was evaluated with information on the Rock Valley fault zone. Data were collected on the Cane Spring fault zone. Studies of Paleozoic rocks in the Calico Hills area indicate that these rocks are not structurally detached from the overlying Miocene rocks, thus eliminating the possibility that a detachment fault at that horizon constitutes a source of seismicity for consideration in repository design.

Geologic mapping of key areas within the Beatty Mountain quadrangle continued. The geologic map of the Big Dune quadrangle was compiled. Preparation began on a map report compiling geologic, geomorphic, and stratigraphic age information on all major faults in the Yucca Mountain area and categorizing them as known Quaternary, suspected Quaternary, or bedrock fault segments. Studies continued on the history of movement on known or suspected Quaternary

faults. Uranium-series data were compiled and ages were estimated for samples from fault-associated trenches on the east side of Yucca Mountain. Scarp ages in Solitario Canyon and northern Windy Wash were determined using cosmogenic dating of rock samples collected from near the top and base of the scarp face.

Four trenches were excavated across Crater Flat fault. Field data collection from Trench 14D on the Bow Ridge fault was completed. Preliminary logs from Trenches CF2 and CF3 on the Windy Wash fault were examined and revised. Logs were completed for walls #1, #2, and #4 at the exposures of the Paintbrush Canyon fault on Busted Butte. Logging began at Trench SCF-T2 on the Solitario Canyon fault, and preliminary logs of the south and north walls and inner slot of Trench A1 on the Paintbrush Canyon fault were completed. Stratigraphic logs of boreholes SR-1, SR-2, and SR-3 near Trench SCR-T1 on the Stagecoach Road fault were completed.

In altered zone characterization studies, experiments were begun to evaluate the effect on water composition and secondary mineral development of water–rock interactions in vitric and vitrophyric rocks that occur in the near-vicinity of the repository. Development began of experiments to measure the impact of water–rock interaction effects on porosity and permeability. Initial reconnaissance computations to bound the effects of coupled hydro-geochemical processes were completed.

Development of repository layout concepts continued, and drawings showing interfaces with the ESF were baselined. Needed data from the repository surface and subsurface design activities were identified. Data to be used in the repository conceptual design process were developed. An analysis was performed to further define zones acceptable for waste emplacement within the Topopah Spring densely welded devitrified lithophysal-poor tuff unit, which was identified as the primary repository area. The analysis considered geotechnical, thermal, and hydrologic characteristics of the rock and their application to repository construction, and it established vertical and horizontal limitations on repository development. Waste emplacement management studies continued with the goal of determining the maximum amount of waste that can be emplaced in the primary repository area for a given thermal load. A system study evaluating several waste emplacement modes was concluded and an evaluation was in process.

Evaluations were made of the potential for impacts to the waste isolation capabilities of the site from both surface and subsurface materials expected to remain at the site after closure. The muck storage pad was evaluated for its impact to the geochemical properties of the site. The effect of the sanitary sewage leach field to be located one kilometer southeast of the North Portal pad was evaluated. Also evaluated were potential impacts from grouted in-place borehole instrumentation, retained constituents of diesel exhaust, and the dry chemical used in the planned fire protection system. Several analyses were developed for the potential impacts of water use, such as dust control water, during construction and operation of the ESF. The potential impact of water discharged in the North Ramp on repository performance was evaluated in terms of effects on aqueous radionuclide transport through the backfill portion of the engineered barrier system and unsaturated zone. Septic tank discharge in the sanitary sewage leach field was analyzed to identify a suitable location for the effluent discharge.

Measurements and associated instruments required to conduct a thermal loading performance confirmation program were identified. A number of sensitivity analyses were initiated. Calculations were begun to determine the amount of local boiling with large waste packages at low thermal loads and the amount of dryout on a drift-scale. Numerical simulations were performed in conjunction with nonisothermal flow experiments to better understand the mechanisms associated with nonisothermal flow. Thermal property heterogeneity impact was investigated by examining the effects of thermal property representations on predicted temperature profiles. Results from near-field thermal analyses were documented.

In waste package studies, both low and high thermal loads were considered. A set of three-dimensional finite element models of the repository was constructed to determine near-field thermal behavior for a high and three low thermal loading scenarios. Preliminary analyses were conducted to determine the robustness of outer barrier and basket designs. A methodology was developed for estimating the probability of waste package criticality from hazards from the post-emplacement environment. A three-dimensional finite-element model was developed to study the resistance of a multibarrier waste package for uncanistered fuel to rock falls. Additional models were developed to analyze dropping of the waste package. A model was developed to evaluate the contribution of corrosion-allowance material to containment life. Several studies addressed container oxidation and corrosion, degradation by mechanical stress, and thermal degradation of fuel cladding.

A repository-scale thermohydrological model was used to investigate the sensitivity of the relative humidity and temperature at various locations in the repository to the gas-phase diffusion efficiency. Repository-scale thermohydrological calculations were conducted for six sets of matrix properties. Five backfill strategies were evaluated.

In studies of the hydrologic properties of the waste package environment, the experiment to determine the effect of confining pressure on fracture healing was completed. A detailed analysis was conducted of the thermohydrological effects of repository heat near the ground surface. Thermohydrological sensitivity studies were conducted to determine the impact of small bulk permeability on temperature and relative humidity conditions at the repository. Thermohydrological models were used to analyze the impact of an optimized areal mass loading distribution and

enhanced gas-phase diffusion on temperature and relative humidity conditions in the potential repository. X-ray imaging to determine water saturation continued.

Small block laboratory testing was conducted to investigate the coupled thermomechanical, thermohydrological, and thermochemical response of the rock to conditions similar to the near-field environment of the potential repository. Uniaxial compression tests were conducted. Samples were prepared for testing to determine the effect of radiation on irradiated and non-irradiated core samples to determine if radiation affects mechanical properties. The large block test was replanned to improve understanding of the coupled thermohydrological processes required to develop models that can be used to predict the hydrologic responses of the near-field environment.

Studies of the effects of man-made materials in the postemplacement environment continued. Scoping experiments on diesel fuel hydrous pyrolysis were completed. Analyses of microbiota that may be affected by diesel fuel and diesel exhaust were conducted. Other tests were planned to consider the effects of construction of the ESF, including exposure of the local rock to air and impact of isotopes on elements such as chlorine. Preliminary computer chemical simulations were conducted using the EQ3/6 geochemical modeling code.

Flow-through testing of oxidized fresh fuel continued, and a series of EQ3/6 computer calculations was completed. Unsaturated dissolution tests also continued to evaluate long-term dissolution/release performance of spent fuel. Long-term oxidation tests continued with several light-water reactor spent fuels in dry baths. Thermogravimetric analysis tests were completed. Tests were conducted to determine the types and quantities of radionuclide elements released from waste glasses when subjected to intermittent dripping water. Work began to interface the glass waste form dissolution model to the Yucca Mountain Integrating Model (YMIM) performance assessment model.

Waste package performance studies continued with considerations of various metallic materials, including nickel-rich stainless alloys, nickel-base alloys, and titanium. A survey of nonmetallic barrier material capabilities indicated that nuclear waste containers could be fabricated from ceramic materials, although their brittle nature may make preferable their use in conjunction with metals. Studies were planned to determine the long-term corrosion properties of metallic alloys being considered for waste package structural materials. Experiments to evaluate other degradation modes were developed.

Methods were developed for the upscaling and averaging of hydraulic parameters in the unsaturated-zone model domain for use in the groundwater flow simulation. The 1994 groundwater travel time calculations were completed and documented. A near-field thermohydrologic model was developed to evaluate the heat transport and flow occurring in the vicinity of heat-generating waste packages placed within a backfilled drift. Final batch adsorption and column experiments to provide data needed to model the caisson experiments were performed. Final material characterization experiments associated with the caisson were completed. Experiments were conducted to evaluate the predictive ability of alternate models that could be used in performance assessment to describe retardation due to sorption.

Efforts continued to define frameworks for effective and efficient integration of experimental and process-level modeling work into performance assessment work. Several analyses were completed to update and enhance the performance assessments. Alternative formulations of retardation factors that could be used to bound the significance of transport of radionuclides by colloids on the results of Total System Performance Assessment calculations were examined.

Modifications were made to the design packages for various aspects of the ESF. The ESF seismic design inputs were evaluated, and recommendations were made for additional design inputs. Tests were completed to support the design of the water storage tanks and the muck conveyor system for the ESF. Several key surface facilities were under construction. Excavation of the ESF continued.

Bibliography With Abstracts

YUCCA MOUNTAIN SITE CHARACTERIZATION OFFICE

1 **Multiple event considerations for postclosure seismic hazard evaluations at Yucca Mountain, Nevada.** Lee, R.C. (Science Applications International Corp., Las Vegas, NV (United States)); King, J.L.; Grant, T.A. pp. 76-82 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Postclosure waste canister design requirements suggest the values used for seismic design have less than a 10% chance of being exceeded in a 1,000 year postclosure period. Considerably longer periods (10,000 years) for waste canister design are being considered to take into account potentially longer engineered canister lifetimes and the corresponding potential for a radionuclide barrier with increased performance. Such lengthy design periods may entail engineering design of waste systems that would be exposed to multiple episodes of seismic strong shaking without any benefit of retrofit or repair following each event. Reconnaissance seismic hazard studied conducted for the waste handling facility suggest that repository block waste canister design include consideration for the occurrence of multiple episodes of strong motion if postclosure periods greater than 1,000 years are considered.

2 **Design control overview for the Yucca Mountain Site Characterization Project Exploratory Shaft Facility.** Cikanek, E.M. (Hazard Engineering Co., Las Vegas, NV (United States)); Petrie, E.H. pp. 202-209 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

This paper presents an overview of the design control process used for the Exploratory Shaft Facility (ESF) at Yucca Mountain. Design and design control is a complex, often iterative, and a well documented process. Design control is defined as the process of assuring that applicable regulatory requirements and the design basis for applicable structures, systems, and components are correctly translated into specifications, drawings, procedures, and instructions. Elements of the design control process described are: External design input, Quality Assurance (QA) grading, Engineering Plan, internal design input, interface control, design analysis, output documents, progress reviews, design verification, acceptance by the Project Office, field changes, and QA records.

3 **Design considerations for the Yucca Mountain Project Site Characterization.** Bullock, R.L. (Raytheon Services Nevada, Las Vegas, NV (United States)); Grenia, J.D. pp. 216-220 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Site Characterization Facilities (SCF) to be located in volcanic tuff at Yucca Mountain is a challenge to manage, design, and construct. This challenge is a result of a number of factors: This is a first of a kind facility to be planned, characterized, designed and built under the purview of a US nuclear regulatory agency; Stringent regulations inherited from the nuclear power agencies have been adapted and modified to allow design and construction of a surface/underground laboratory for the qualification of a repository site for the possible future storage of nuclear waste; Detailed interface is required between a number of participants to assure licensability of the SCF integration into a future repository; Stringent design and construction procedures; Stringent Quality Assurance and quality control. The regulations and requirements that flow down to the A/E for development of the SCF design are voluminous and unique to this project. The volume of regulations, constraints, and amount of oversite found on this project has no parallel in private sector engineering.

4 **Application of QA grading to Yucca Mountain Site Characterization Project items and activities.** Murthy, R.B. (Dept. of Energy, Las Vegas, NV (United States)); Smith, S.C. pp. 221-228 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Grading is the act of selecting the quality assurance (QA) measures necessary to develop and maintain confidence in the quality of an item or activity. The list of QA measures from which this selection is made are the 20 criteria of the Yucca Mountain Site Characterization Project Quality Assurance Requirements Document.

5 **Design reviews from a regulatory perspective.** Foster, B.D. (Science Applications International Corp., Las Vegas, NV (United States)). pp. 229-234 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

This paper presents views on the role of the licensing engineer in the design process with specific emphasis on design reviews and the automated information management tools that support design reviews. The licensing engineer is seen as an important member of a design review team. The initial focus of the licensing engineer during design reviews is shown to be on ensuring that applicable regulatory requirements are addressed by the design. The utility of an automated tool, such as a commitments management system, to support regulatory requirements identification is discussed. The next responsibility of the licensing engineer is seen as verifying that regulatory requirements are transformed into measurable performance requirements. Performance requirements are shown to provide the basis for developing detailed design review criteria. Licensing engineer input during design reviews is discussed. This input is shown to be especially critical in cases where review findings may impact application of regulatory requirements. The use of automated tools in supporting design reviews is discussed. An information structure is proposed to support design reviews in a regulated environment. This information structure is shown to be useful to activities beyond design reviews. Incorporation of the proposed information structure into the Licensing Support System is proposed.

6 **Controlling the description of a high-level radioactive waste isolation system.** Zumba, C.F. (Science Applications International Corp., San Diego, CA (United States)); Shipler, D.B. pp. 235-239 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Control of large, complex, regulation-driven programs using traditional management methods has not been wholly effective. What is needed is a rigorous yet flexible method that is amenable to controlling the design of engineered and natural subsystems while an understanding of the natural subsystem is under investigation. The key to developing such a methodology is controlling the known and predicted model of the system. Regulatory, engineering, and scientific needs can be successfully met and controlled by maintaining a current model of the system as new information is obtained, as new investigative plans are developed, and as physical changes are made to the system.

7 **Yucca Mountain Site Characterization Project waste package plan.** Harrison-Giesler, D.J. (Dept. of Energy, Las Vegas, NV (United States)); Morissette, R.P.; Jardine, L.J. pp. 296-300 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The goal of the US DOE's Yucca Mountain Site Characterization Project (YMP) waste project program is to develop, confirm the effectiveness of, and document a design for a waste package and associated engineered barrier system (EBS) for spent nuclear fuel and solidified high-level nuclear waste (HLW) that meets the applicable regulatory requirements for a geologic repository. The Waste Package Plan describes the waste package program and establishes the technical approach against which overall progress can be measured. It provides guidance for execution and describes the essential elements of the program, including the objectives, technical plan, and management approach. The plan covers the time period up to the submission of a repository license application to the US Nuclear Regulatory Commission (NRC).

8 **Dry drilling and coring development for unsaturated zone studies.** Long, R. (Dept. of Energy, Las Vegas, NV (United States)); Wonderly, D.; Wright, E. pp. 810-815 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Two areas of major difficulty associated with characterization of any unsaturated zone are the conventional drilling and coring processes used to acquire the samples. These processes are inherently contaminating processes if the circulation fluid used and the cuttings generated are not controlled. The Site Characterization Program at Yucca Mountain requires both uncontaminated core for analysis and a "near borehole environment" as close to in-situ conditions as possible for hydrologic testing. As a result, a prototype development program has been initiated to develop drilling and coring processes which allow for acquisition of uncontaminated core and which cause minimal disturbance of in-situ conditions within the formation exposed at the borehole wall.

9 **Geologic sample handling and logging at Apache Leap, Arizona.** Davis, J.H.; Hartley, J.A.; Moyer, J.L.; Sinks, D.J. pp. 816-821 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Early in 1990, the Yucca Mountain Project Office (Project Office; presently the Yucca Mountain Site Characterization Project Office) of the US DOE completed two prototype boreholes at Apache Leap, Arizona, to test dry drilling and coring techniques that will be used during site characterization activities at Yucca Mountain, Nevada. Staff of the Sample Management Facility (SMF), Technical and Management Support Services contractor, used the boreholes to test sample handling and geologic logging procedures. Results of this testing indicate that modifications to approved Project Office procedures will be necessary before site characterization commences. These modifications include reduction of paperwork, verification of drill depths, upgrade of equipment, and enhanced training of SMF field staff.

10 **Monitoring compliance with requirements during site characterization.** Herrington, C.C. (SAIC, Las Vegas, NV (United States)); Jennetta, A.R.; Dobson, D.C. pp. 917-920 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive

waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The question of when a program of Regulatory Compliance should be applied and what it should be applied to, when the subject of compliance is a High Level Radioactive Waste Repository, defies resolution by merely relating to past practices of licensees of the US Nuclear Regulatory Commission (NRC). NRC regulations governing the disposal of High Level Waste include interactions with the potential applicant (US DOE) during the pre-license application phase of the program when the basis for regulatory compliance is not well defined. To offset this shortcoming, the DOE will establish an expanded basis for regulatory compliance, keeping the NRC apprised of the basis as it develops. As a result, the preapplication activities of DOE will assume the added benefit of qualification to a suitable Regulatory Compliance monitoring and maintenance plan.

11 **Test and evaluation of natural barriers at Yucca Mountain, Nevada: Management of the site characterization program.** Blanchard, M.B. (DOE, Las Vegas, NV (United States)); Jones, S.B.; Voegele, M.D.; Younker, J.L. pp. 927-931 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The US DOE is responsible for managing a characterization program for the Yucca Mountain site to collect data needed to determine if the site is suitable for recommendation for development as a repository. If found to be suitable, the site will then begin the licensing process with the US NRC. Given the long time period over which this process occurs, it is essential that the data base for the site is systematically documented and updated. Likewise, the records for preliminary performance evaluations are an essential part of that documentation package. A cornerstone of DOE's management approach to site characterization and evaluation are documented and available for scrutiny by oversight groups and the NRC, especially during the licensing process.

12 **Application of QA program for Yucca Mountain Site Characterization Project geologic investigations.** Murthy, R.B. (DOE, Las Vegas, NV (United States)); Smith, S.C. pp. 1214-1219 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The High Level Waste Program requires safe disposal of nuclear waste in a geologic medium for thousands of years. Traditionally, the nuclear industry relies heavily on engineered items. The Mined Geologic Disposal System (MGDS) Program relies equally, if not more, on the natural barriers for containment of radionuclides. As a consequence, a stringent quality assurance (QA) program must be applied to geologic and scientific site suitability investigations.

13 **The last twelve months at Yucca Mountain.** Gertz, C.P. (DOE, Las Vegas, NV (United States)); Robison, A.C. pp. 1314-1318 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The US DOE is evaluating Yucca Mountain in Nevada to determine if the site would be a safe location for a high-level radioactive waste repository. As mandated by Congress, the DOE must study the geology, hydrology, environment and other factors to predict whether a geologic repository about 305 meters (1,000 feet) below Yucca Mountain's surface could isolate high-level waste for 10,000 years. Yucca Mountain lies on the western edge of the Nevada Test Site, 177 kilometers (110 miles) northwest of Las Vegas. The Yucca Mountain Site Characterization Project (YMP) has embarked on a broad-based testing program designed to examine all factors that could impact the performance of a repository. While there are several site studies under way, major site investigations have not progressed as planned. The DOE is presently involved in litigation with the state of Nevada, which has refused to issue environmental permits that are required before new site characterization studies can begin. This paper will examine progress made on the YMP during the past year, discuss studies that are planned in the near-term, and will describe the Project's interactions with oversight groups, government entities, and the public.

14 **Perils of project development on public land open to mining.** Jacobs, W.R. (SAIC, Las Vegas, NV (United States)). pp. 1319-1323 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Conducting a government project on public land open to the general mining laws can result in added costs, legal entanglements, schedule uncertainties, and the potential for unanticipated safety issues and concerns due to interactions with mining claimants. Planning for such projects must include a careful assessment of not only land access needs and restrictions, but also possible scenarios for conflict with activities authorized under the general mining laws throughout the life of the project. It is essential to have a thorough knowledge of the applicable mining laws and how they are currently being interpreted and applied by the responsible regulatory authorities and land managers. The Yucca Mountain Project approach to land access, problems encountered with mining claims filed under the Mining Law of 1872, and the lessons learned from these experiences are discussed in this paper.

15 **Being responsive and getting the job done right.** Seidler, P.E. (SAIC, Las Vegas, NV (United States)); Andrews, W.B.; Grassmeier, K.F.; Standish, P.N. pp. 1324-1328 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The US DOE, Yucca Mountain Site Characterization Project Office (YMSCPO) has been given the responsibility for characterization of the potential and repository site at Yucca Mountain, Nevada, and the responsibility of informing and working with the Project. In support of these responsibilities, the Project Office has begun a preliminary review of

potential railroad routes to Yucca Mountain for the transportation of high-level radioactive waste. An extensive effort has been undertaken to integrate the route review evaluation with public and local government concerns.

16 **Management of comments on DOE's Site Characterization Plan (SCP) and integration with the planned geotechnical program.** Bjerstedt, T.W. (DOE, Las Vegas, NV (United States)); Gil, A.V.; Baird, F.A. pp. 1336-1342 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The US DOE has committed to respond to comments on the SCP throughout the site characterization process. As of January 1990 DOE has received 4,574 comments on both the SCP/Consultation Draft and the statutory SCP. Of these, 2,662 responses have been completed and returned to the originators. Many comments are programmatic in nature and express diverse concerns beyond the scope of the SCP. DOE uses a three-tiered process in responding to comments that integrated technical and management responsibilities. The process defines specific roles in developing, reviewing, and concurring on responses. Commitments or open-items can be generated in DOE responses to comments, which are tracked on a relational database. Major changes reflected in the Secretary of Energy's 1989 reassessment of the high-level waste program were advocated in comments on the SCP. Most DOE commitments, however, deal with consideration of recommendations contained in SCP comments relevant to low-levels of technical planning detail (SCP Study Plans). Commitments are discharged when referred to the appropriate quality-affecting or management process whereupon their merits can be evaluated.

17 **Archaeological program for the Yucca Mountain Site.** Pippin, L.C. (Desert Research Institute, Reno, NV (United States)); Rhode, D. pp. 1444-1448 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Archaeological surveys, limited surface collections and selected test excavations in the Yucca Mountain Project Area have revealed four distinct aboriginal hunting and gathering adaptive strategies and a separate historic Euroamerican occupation. The four aboriginal adaptations are marked by gradual shifts in settlement locations that reflect changing resource procurement strategies. Whereas the earliest hunters and gatherers focused their activities around the exploitation of toolstone along ephemeral drainages and the hunting of game animals in the uplands, the latest aboriginal settlements reflect intensive procurement of early spring plant resources in specific upland environments. The final Euroamerican occupation in the area is marked by limited prospecting activities and travel through the area by early immigrants.

18 **Management and research of desert tortoises for the Yucca Mountain Project.** Rautenstrauch, K.R. (EG&G Energy Measurements, Las Vegas, NV (United States)); Cox, M.K.; Doerr, T.B.; Green, R.A.; Mueller, J.M.; O'Farrell, T.P.; Rakestraw, D.L. pp. 1449-1455 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

A program has been developed for the Yucca Mountain Project (YMP) to manage and study the desert tortoise (Gopherus agassizi), a threatened species that occurs at low densities at Yucca Mountain. The goals of this program are to better understand the biology and status of the desert tortoise population at Yucca Mountain, assess impacts on tortoises of site characterization (SC) activities, and minimize those impacts. The first steps we took to develop this program were to compile the available information on the biology of tortoises at Yucca Mountain, ascertain what information was lacking, and identify the potential impacts on tortoises of SC. We then developed a technical design that can be used to identify and mitigate direct and cumulative impacts and provide information on tortoise biology. Interrelated studies were developed to achieve these objectives. The primary sampling unit for the impact monitoring studies is radiomarked tortoises. Three populations of tortoises will be sampled: Individuals isolated from disturbances (control), individuals near major SC activities (direct effects treatment and worst-case cumulative effects treatment), and individuals from throughout Yucca Mountain (cumulative effects treatment). Impacts will be studied by measuring and comparing survival, reproduction, movements, habitat use, health, and diet of these tortoises. A habitat quality model also will be developed and the efficacy of mitigation techniques, such as relocating tortoises, will be evaluated.

19 **Assessing impacts on biological resources from Site Characterization Activities of the Yucca Mountain Project.** Green, R.A. (EG&G Energy Measurements, Las Vegas, NV (United States)); Cox, M.K.; Doerr, T.B.; O'Farrell, T.P.; Ostler, W.K.; Rautenstrauch, K.R.; Wills, C.A. pp. 1456-1460 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

An integrated impact assessment program was developed to monitor the possible effects of Site Characterization Activities (SCA) on the biological resources of the Yucca Mountain area. The program uses control and treatment sites incorporating both spatial and temporal controls. The selection of biotic variables for monitoring was based on their relative importance in the ecosystem and their ability to provide information on potential impacts. All measures of biotic and abiotic variables will be made on the same sample plots to permit linking changes in variables to each other.

20 **The reclamation program for the Yucca Mountain Project.** Ostler, W.K. (EG&G Energy Measurements, Las Vegas, NV (United States)); O'Farrell, T.P.; Winkel, V.K.; Schultz, B.W. pp. 1461-1468 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The US DOE is required by law and other regulatory requirements to reclaim disturbances created by site characterization activities at Yucca Mountain. Because of the difficulty of reclaiming arid areas and the lack of site specific information on successful reclamation techniques and procedures, the DOE has developed a comprehensive reclamation program. The program consists of three phase: Planning, operational and research. The planning phase is a continuing process that ensures that program policy, goals, tasks and responsibilities are clearly identified and linked. Three inter-related planning documents have been released by the DOE that establish the program objectives and outline the steps needed to successfully meet those objectives. The operational phase uses best available knowledge to develop and implement reclamation plans that are site-specific for each disturbance. Reclamation activities start prior to any surface disturbance with a survey of each disturbance by trained scientists. The scientists survey the area for the presence of protected species or critical wildlife habitat. They also gather vegetation, landscape, soils and other environmental data that is used to assess the impact of the proposed disturbance. Recommendations can be made to either avoid areas or mitigate impacts. The operational phase includes interim reclamation to protect valuable resources and control erosion prior to final reclamation. Monitoring of reclaimed sites is conducted to correct problem areas and insure that reclamation objectives are achieved. The third phase of the reclamation program is designed to provide site-specific information on effective reclamation techniques through research and field demonstrations. Information on potentially successful techniques will be used to update to improve the effectiveness of the reclamation activities at Yucca Mountain.

21 **Toward linking demographic and economic models for impact assessment.** Williams, C.A. (SAIC, Las Vegas, NV (United States)); Meenan, C.D. pp. 1534-1539 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

One of the objectives of the Yucca Mountain Project, in Southern Nevada, is to evaluate the effects of the development of a high-level nuclear waste repository. As described in the Section 175 Report to the Congress of the US, the temporal scope of this repository project encompasses approximately 70 years and includes four phases: Site characterization and licensing, construction, operation, and closure and decommissioning. If retrieval of the waste were to be required, the temporal scope of the repository project could be extended to approximately 100 years. The study of the potential socioeconomic effects of this project is the foundation for this paper. This paper focuses on the economic and demographic aspects and a possible method to interface the two. First, the authors briefly discuss general socioeconomic modeling theory from a county level view point, as well as methods for the apportionment of county level data to sub-county areas. Next, the authors describe the unique economic and demographic conditions which exist in Nevada at both the state and county levels. Finally, the authors evaluate a possible procedure for analyzing repository effects at a sub-county level; this involves discussion of an interface linking the economic and demographic aspects, which is based on the reconciliation of supply and demand for labor. The authors conclude that the basis for further model development may rely on the interaction of supply and demand to produce change in wage rates. These changes in expected wages should be a justification for allocating economic migrants (who may respond to Yucca Mountain Project development) into various communities.

22 **A decision support system for performance-based site characterization.** Barbour, T.G. (SAIC, Golden, CO (United States)); Lockerd, M.J. pp. 1704-1709 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The complex and dynamic requirements of site characterization present a major management challenge. ParaTrac, a regulatory and technical information system, is described as a valuable tool in assisting managers of such programs. ParaTrac is currently being used on the Yucca Mountain Site Characterization Project to help prioritize site testing based on high-priority regulatory requirements. It has also been used in field activities tracking, MGDS systems analysis, project technical database input, and study plan preparation. The process of planning and implementing a performance-based site characterization program is discussed in general. The questions of "What data are needed?," "How much is enough?," and "How much will it cost?" are addressed. A detailed illustration of how the ParaTrac system can be used to answer these questions is also given. ParaTrac captures the regulatory basis for site characterization and provides a data management system to allow rapid retrieval of related information. These regulatory requirements can be tracked through the entire site characterization process, from parameter information needs to field testing and data collection, and ultimate to various analyses. An example of this process is given for a regulation dealing with ground-water travel time.

23 (CONF-9107280–1) **Thermal and metallurgical considerations of a novel design for the nuclear waste container.** Skaggs, R.; Moujaes, S.; Lei, Y.; Gopal, V.V. Nevada Univ., Las Vegas, NV (United States). [1994]. 15p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. From Nuclear waste packaging focus '91; No City Given, NY (United States); Jul 1991. Order Number DE95000598. Source: OSTI; NTIS; INIS; GPO Dep.

The Departments of Civil and Mechanical Engineering at University of Nevada, Las Vegas are involved in the high level nuclear waste project. Designing containers for long term disposal of spent nuclear fuel and high level radioactive waste, is one of the project tasks. A multi-barrier robust waste containment scheme is being, actively researched, as preliminary work, has shown that, this scheme would better resist the degradation mechanisms set up by phenomena such as geological activity, water immersion, occurrence of mechanical loading, dry oxidizing conditions and wet reducing conditions. The physical configuration of the waste cannister, has an inner shell of copper base alloy, to resist a wet reducing environment, an outer shell of nickel base alloy, to resist dry and oxidizing conditions and a nonconducting oxide barrier to separate the two metallic barriers. Cement concrete is being considered for this role. With 10cm of concrete between the metal alloy shells and the

maximum allowable thermal loads reaching 4740W, the possibility of reaching temperatures, that could be detrimental to concrete is real (i.e., 300C and above). The temperature of the inner shell, to a great degree is a function of the thickness of the oxidic concrete layer. Another possible option being studied is the use of alumina as a sandwich, between the two metal shells. With the 10cm alumina the maximum inner shell temperature will be 230C. To maintain the inner shell at a relatively lower temperature, only a single copper base container will be used at the time of emplacement. After a period of 50 years, the waste is either retrieved for processing or the system is upgraded to a permanent multibarrier system.

24 (CONF-930205–82) **Carbon-14 releases from an unsaturated repository: A senseless but expensive dilemma.** Pflum, C.G. Science Applications International Corp., Las Vegas, NV (United States). [1993]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-87NV10576. From Waste management '93; Tucson, AZ (United States); 28 Feb - 4 mar 1993. Order Number DE94000976. Source: OSTI; NTIS; INIS; GPO Dep.

The purpose of the US Environmental Protection Agency (EPA) Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (40 CFR Part 191 or standards) is to protect public health and safety. The 1985 rule was developed on the basis of the assumption that the repository would be located in a geologic formation that lies below the water table. It is appropriate to examine gaseous releases and transport of pollutants in order to determine site adequacy. When the provisions of the 1985 standard are applied to Yucca Mountain, specifically the limits for carbon-14, we can release in 10,000 years no more than 7,000 curies of carbon-14 in the form of carbon dioxide. Meanwhile, the US Department of Energy (DOE) and others indicate that the repository may release about 8,000 curies of carbon-14 dioxide, an amount that exceeds the standard by 10 to 20 percent. The original basis of the 1985 standards was that, in a site below the water table, the limit for carbon-14 was technically achievable. It was not a standard based on a release level that would prevent a danger to public health. If we examine the danger to public health of the release of 8,000 curies of carbon-14 dioxide during and 8,000-year period, this release would not a pose a significant threat to the average individual. Industry and natural sources release many times this amount of carbon-14 dioxide each year. The question therefore becomes: is it appropriate to spend an additional $3.2 billion on waste packages when the expenditure does not measurably improve the public health?

25 (CONF-9303214–1) **Rural migration in southern Nevada.** Mosser, D.; Soden, D.L. Nevada Univ., Las Vegas, NV (United States). [1993]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. From National Social Science Association meeting; San Francisco, CA (United States); 31 Mar - 3 apr 1993. Order Number DE93018976. Source: OSTI; NTIS; INIS; GPO Dep.

This study reviews the history of migration in two rural counties in Southern Nevada. It is part of a larger study about the impact of a proposed high-level nuclear waste repository on in- and out-migration patterns in the state. The historical record suggests a boom and bust economic cycle has predominated in the region for the past century creating conditions that should be taken into account by decision makers when ascertaining the long-term impacts of the proposed repository.

26 **Photogeologic reconnaissance of X-tunnel at Little Skull Mountain.** Voegele, M.D. (SAIC, Las Vegas, NV (United States)). pp. 182-187 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

On June 29, 1992, a magnitude 5.6 earthquake occurred immediately to the south of Little Skull Mountain; the depth of the shock was about 9 kilometers (6 miles). It is the location of an underground structure known as X-tunnel, that once supported deep basing studies for the Air Force in the 1980s. The Nevada Operations Office of US DOE authorized access to the facility on several occasions to allow technical specialists from the Yucca Mountain Site Characterization Project, including geoscientists and engineers, to gather information about possible damage related to the earthquake. Examination of the underground facility in the vicinity of Yucca Mountain indicated little or no damage to the facility. Photogeologic reconnaissance affirmed that the potential for damage to underground facilities is moderated and attenuated by depth below the ground surface.

27 **Science education beyond the classroom.** Harle, E.J. (SAIC, Las Vegas, NV (United States)); Van Natta, D.; Powell, M.L. pp. 217-220 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Yucca Mountain Site Characterization Project (YMP) sponsors a variety of classroom-oriented projects and activities for teachers who request them. Also available, though, are extra-curricular programs. One notably successful program is a workshop designed to award girl and boy scouts with geology and atomic energy merit badges. There was a tremendous response to this workshop–it attracted 450 requests within the first week of its announcement. Since October 1991, the YMP has sponsored five such girl scout workshops and four boy scout workshops, attended by a total of 400 scouts. These workshops demonstrate that highly technical subjects can be taught simply through hands-on activities. The idea behind them is not to teach scouts what to think but, rather, how to think. For adults meanwhile, the YMP offers a monthly lecture series, with each lecture averaging 45 minutes in length with 35 people in attendance. These lectures center on such subjects as volcanoes, earthquakes and hydrology. They are usually delivered by YMP technical staff members, who have learned that complex technical issues are best addressed in a small-group format.

28 **Selection of the initial access for the Yucca Mountain Exploratory Studies Facility.** Voegele, M.D. (SAIC, Las Vegas, NV (United States)); Simecka, W.B.; Dyer, J.R.; Elkins, N.Z. pp. 300-305 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC08-87NV10576. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Recent appropriations for the Yucca Mountain Site Characterization Project (YMP) have not included sufficient

funding to proceed with the full design and implementation of the Exploratory Studies Facility (ESF) concept developed by the US DOE. To proceed with a phased Exploratory Studies Facility design and construction schedule, DOE was required to address the selection of the preferred location for the initial access to the ESF. In the fall of 1991, the DOE examined possible phasing of the underground construction and design activities for the ESF; preliminary criteria that potentially could be used to select the initial access were developed. Subsequent to that, a task force compared the accesses of the ESF to develop a recommendation about whether either access would be more likely to provide relevant geotechnical information about potential unsuitability of the site.

29 **An integrated approach toward characterization of radionuclide transport at Yucca Mountain, Nevada.** Simmons, A.M. (DOE, Las Vegas, NV (United States)). pp. 608-617 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Characterization of potential aqueous radionuclide migration from waste containers to the accessible environment, a distance of 5 km, is a key step in understanding the efficacy of the natural barrier to isolate waste because of regulations which stipulate that the site must be able to isolate waste for 10,000 years. The Yucca Mountain Site Characterization Project (YMP) has an integrated radionuclide migration program that combines investigations to characterize processes that affect radionuclide transport, including solubility, speciation, sorption, diffusion, and dispersion, and studies to investigate aspects of the natural system affecting those processes, such as mineralogy, mineral stability, and water chemistry. The program also includes studies to understand the behavior of the natural system under disturbed conditions of the thermal pulse, which would potentially alter the chemistry of both heated water and rock hundreds of meters away from the potential repository. Even though the program does not take retardation credit for sorption in the near-field, it must understand the nature of chemical reactions occurring between rock and heated water of a very different composition from that under ambient conditions. Possible precipitation of minerals along fractures tens of meters from waste packages has implications for sealing fluid pathways and creating a "cap" around the waste packages. Site models developed to support the determination of the natural barrier's efficacy must then support performance assessment modeling. Validation testing is necessary to build confidence in these models; testing occurs at all program levels and all scales, from data collection to site and performance assessment modeling. This paper focuses on the integration of results from numerous geochemical investigations into models for understanding transport processes.

30 **Geochemistry for high level waste: An international comparison.** Cloke, P.L. (SAIC, Las Vegas, NV (United States)). pp. 618-625 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

This paper presents a brief summary of some of the recent and on-going geochemical research related to the disposal of high level radioactive waste. For most categories of research (basic chemical reactions, solubilities, thermochemical data, kinetics, modeling, sorption and ion exchange, colloidal phenomena, isotopic studies, migration, and analytical techniques and chemical analyses) benefits would accrue from increased international communication. This is true in spite of the marked difference in rock type and hydrologic setting between the potential US repository and those of other countries because many of the studies address fundamental characteristics, such as sorption, and because most of the relevant chemistry deals with liquid/solid interactions. In some cases, especially the last three categories noted, much of the research is site specific and of primary interest only to the country in which the site lies.

31 **1992: When things began to move at Yucca Mountain.** Gertz, C.P. (DOE, Las Vegas, NV (United States)); Teitelbaum, S. pp. 806-810 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

On June 29, 1992, Little Skull Mountain, Nevada, located 161 kilometers (100 miles) northwest of Las Vegas, sustained a magnitude 5.6 earthquake. The epicenter of this earthquake was located about 20 km from Yucca Mountain, where suitability studies for an underground nuclear waste repository are ongoing. Though some of the older buildings erected nearby were damaged, studies of adjacent mines and tunnels revealed that the earthquake had caused no comparable damage underground. There were no immediately apparent reasons to discount the area as a suitable location for a potential geologic repository for high-level nuclear waste. The US DOE Office of Civilian Radioactive Waste Management (OCRWM) continues its studies of the mountain. Despite concerted and long-standing political opposition within the state of Nevada that has resulted in long delays, the mountain and its environs teemed with scientific activity throughout 1992. The year, 1993, should prove even more eventful for site characterization. This paper will examine progress made on the Yucca Mountain Site Characterization Project (YMP) during 1992 and continuing into 1993.

32 **Investigation in 3-D of stress distribution in a circular tunnel and vertical emplacement holes due to thermal and overburden loading in tuff.** Kandalaft-Ladkany, N. (Univ. of Nevada, Las Vegas, NV (United States)); Wyman, R.V.; Ladkany, S.G.; Ladkany, P.E. pp. 893-899 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Thermal stress and displacement analysis using two 3-D finite element models, one having a coarse mesh and one having a highly detailed mesh are presented. Results are compared to those obtained by a 2-D plane strain finite element analysis using a coarse mesh. Results indicate that thermal stresses are at least an order of magnitude higher than geothermal and overburden stresses combined. Thermal stresses in the near field rock reach a critical level in the vicinity of the canisters and in some areas around the tunnels which may dictate rock bolting. Local rock collapses may prevent the canisters from being retrieved. Interpolated three-dimensional temperature profiles, used in the analysis, are also presented.

33 **Single-hole in situ thermal probe for hydrothermal characterization at Yucca Mountain.** Danko, G. (Univ. of Nevada, Reno, NV (United States)); Buscheck, T.A. pp. 975-985 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract W-7405-ENG-48. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The REKA thermal probe method, which uses a single borehole to measure in situ rock thermophysical properties and provides for efficient and low-cost site characterization, is analyzed for its application to hydrothermal system characterization. It is demonstrated throughout the evaluation of several temperature fields obtained for different thermal zones that the REKA method can be applied to simultaneously determine (1) two independent thermophysical properties, i.e., heat conductivity and thermal diffusivity and (2) a set of heat transport parameters, which can be used to characterize the behavior of a hydrothermal system. Based on the direct meaning of these transport parameters, the components of the heat transport mechanism in a given time and location of the hydrothermal system can be described. This evaluation can be applied to characterizing and quantifying in situ rock dry-out and condensate shedding at the proposed repository site.

34 **Two-way communication: A case study in improving public interactions.** Reilly, B. (SAIC, Las Vegas, NV (United States)); Austin, P. pp. 995-999 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Successful public interaction requires several key elements. They include: A non-intimidating forum for exchanging information, two-way communication, advance preparation to identify what each party wants to learn, and feedback. There is no single approach that guarantees success. Factors such as technical complexity of the issue, level of support by the public, and trust and confidence among the parties all play a role in determining the most workable approach for any particular situation. By focusing on a specific case involving the communication of nuclear waste issues in Nevada, this paper illustrates lessons learned by the US DOE in communicating controversial issues to the public. In particular, this case study traces the last three years of utilizing various communication approaches with Nevada citizens and identifies an approach that appears to be effective for DOE.

35 **Using an engaging approach to products to help create long-term credibility.** McNeill, G. (SAIC, Las Vegas, NV (United States)); Larkin, E. pp. 1000-1005 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

A long-term, thorough and engaging public information products plan is essential for supporting interaction between Nevadans and the scientists and staff of the US DOE Yucca Mountain Site Characterization Project (YMP). As members of the Institutional and External Affairs office on the YMP in Nevada, our focus is to create successful products for a Nevada audience, in accordance with DOE regulations. Our product plan is broad, but has the same theoretical foundation whether we are developing a new fact sheet of working with a scientist to help him or her communicate effectively. Our goals are to: Create products that help build long-term credibility; communicate honestly about risk; engage the public in meaningful, effective ways; be receptive to hearing Nevadans' concerns and questions; respond in ways that indicate that the public has been heard and respected; and to keep away from the "us" versus "them" orientation, distinguishing our communication approach from others. Explanations of our rationale, products plan, and goals and techniques for achieving them are stated, and related problems are described.

36 **Yucca Mountain student tours: Response, reactions, and results.** Wadkins, M.L. (SAIC, Las Vegas, NV (United States)); Hill, C.R. pp. 1006-1013 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

In March of 1991, the Yucca Mountain Site Characterization Project (YMP) began providing monthly tours for the general public to visit the Yucca Mountain site. The goal of these tours has been to inform the public and to provide direct contact to Project scientists. An overwhelming response has since created a need for expansion of the tour program to meet community demands. This paper describes the development, implementation, and results of the grade 6-12 tour program introduced in the last year to meet the needs of the educational community in particular.

37 **Earthquakes and nuclear waste: A lesson in media relations.** Patrick, S.M. (SAIC, Las Vegas, NV (United States)). pp. 1014-1022 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Little Skull Mountain earthquake on June 29, 1992 marked the beginning of a challenging period for the US DOE's Yucca Mountain Site Characterization Project's (YMP's) Public Affairs department. We needed to relay complicated and difficult to understand scientific principals in an easily understandable fashion to local and national media who were hungry for detailed information. Volumes of quickly accumulating data was swiftly sorted, interpreted, and placed in context with other data in order to be properly presented. The main difficulty in this situation was attempting to assure that the information presented led to an intellectual and not emotional analysis of the earthquake. This paper will discuss some of the processes undertaken to meet both the needs of local media as well as our own needs.

38 **'Procurement quality engineering': A measurement driven system to assure quality at each step in the procurement process.** Rinderman, R.R. (Science Applications International Corporation, Las Vegas, NV (United States)). pp. 1151-1155 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The 'Procurement Quality Function' is an element of the Body of Knowledge of Quality Engineering, as defined by the American Society for Quality Control (ASQC). This paper describes the Procurement Quality function which has been installed as an integral part of the Quality Engineering group of the Technical and Management Support Services (T&MSS) contractor to the United States Department of Energy (DOE) Yucca Mountain Site Characterization Project. Each of the elements of the T&MSS Procurement Quality Engineering (PQE) system is discussed along with the measurements obtained. With the installation and development of the PQE system we have attained more meaningful evaluation of supplier capability, reduction of procurement document review reject ratios from 31% to less than 2% per quarter, more effective measurement and control of supplier performance, and the ability to enter into a meaningful teaming effort with T&MSS suppliers.

39 **The MacCSITS database: A tool for curating samples.** Merritt, D.W. (Science Applications International Corporation, Las Vegas, NV (United States)); Lewis, C.; Linden, L.S. pp. 1182-1186 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Geologic samples are a primary source of data for the Yucca Mountain Site Characterization Project (YMP). The collection and study of the samples is regulated by requirements which mandate complete documentation of their identity and history, so that any data submitted in support of site licensing may be traced accurately to their source. Geologic samples are curated at the Sample Management Facility (SMF) located near Yucca Mountain. The MacCSITS database is a tracking and inventory system designed to ease the task of documenting YMP samples.

40 **Progress on the U.S. Department of Energy's issue resolution process: A status report.** Jones, S.B. (Department of Energy, Las Vegas, NV (United States)); VanCamp Gil, A.; Desell, L.J.; Einberg, C. pp. 1236-1239 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The U.S. Department of Energy (DOE) is studying Yucca Mountain, Nevada, to determine its suitability for a mined geologic repository for high-level nuclear waste. In addition to identifying, clarifying, and resolving technical issues relative to site characterization, DOE has the responsibility to develop a license application for authorization to construct a geologic repository; the license application would be submitted to the U.S. Nuclear Regulatory Commission. In order to assist in managing the complex licensing interactions required, DOE has developed the Issue Resolution process. Issue Resolution provides a means by which any issue, regulatory or technical, can be addressed and clarified. Eight issues are currently active in this process: Erosion, Calcite-Silica, Volcanism, Seismic Hazards, Engineered Barrier System, Disturbed Zone, Substantially Complete Containment, and Ground Water Travel Time. The Issue Resolution organization includes management and staff members with technical and management experience in relevant areas. The Issue Resolution structure has proven to be useful in focusing resources on those areas within the program that need clarification or interpretation and are critical for successful and timely site characterization and licensing of a potential repository.

41 **Reliability modeling of an engineered barrier system.** Ananda, M.M.A. (Univ. of Nevada, Las Vegas, NV (United States)); Singh, A.K.; Flueck, J.A. pp. 1326-1330 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Weibull distribution is widely used in reliability literature as a distribution of time to failure, as it allows for both increasing failure rate (IFR) and decreasing failure rate (DFR) models. It has also been used to develop models for an engineered barrier system (EBS), which is known to be one of the key components in a deep geological repository for high level radioactive waste (HLW). The EBS failure time can more realistically be modelled by an IFR distribution, since the failure rate for the EBS is not expected to decrease with time. In this paper, we use an IFR distribution to develop a reliability model for the EBS.

42 **Significance of geochemical characterization to performance at Yucca Mountain, Nevada.** Simmons, A.M. (Department of Energy, Las Vegas, NV (United States)). pp. 1482-1489 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The U.S. concept for permanent disposal of high-level radioactive waste resembles those of other countries in that it relies upon burial in a deep geologic medium. This concept relies upon multiple barriers to retard transport of radionuclides to the accessible environment; those barriers consist of the waste form, waste container, engineered barrier system (including possible backfill) and retardant properties of the host rock. Because mobilization of radionuclides is fundamentally a geochemical problem, an understanding of past, present, and future geochemical processes is a requisite part of site characterization studies conducted by the U.S. Department of Energy at Yucca Mountain, Nevada. Geochemical information is needed for evaluating three favorable conditions (the rates of geochemical processes, conditions that promote precipitation or sorption of radionuclides or prohibit formation of colloids, and stable mineral assemblages) and four potentially adverse conditions of the site (groundwater conditions that could increase the chemical reactivity of the engineered barried system or reduce sorption, potential for gaseous radionuclide movement, and oxidizing groundwaters) for key issues of radionuclide release, groundwater quality, and stability of the geochemical environment. Preliminary results of long-term heating experiments indicate that although zeolites can be modified by long-term, low temperature reactions, their beneficial sorptive properties will not be adversely affected. Mineral reactions will be controlled by the aqueous activity of silica in groundwater with which the minerals are in contact. Geochemical barriers alone may satisfy release requirements to the accessible environment for many radionuclides; however, additional site specific geochemical and mineralogical data are needed to test existing and future radionuclide transport models.

43 **Software quality assurance on the Yucca Mountain Site Characterization Project.** Matras, J.R. (SAIC, Las Vegas, NV (United States)). pp. 1643-1647 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Yucca Mountain Site Characterization Project (YMP) has been involved over the years in the continuing struggle with establishing acceptable Software Quality Assurance (SQA) requirements for the development, modification, and acquisition of computer programs used to support the Mined Geologic Disposal System. These computer programs will be used to produce or manipulate data used directly in site characterization, design, analysis, performance assessment, and operation of repository structures, systems, and components. Scientists and engineers working on the project have claimed that the SQA requirements adopted by the project are too restrictive to allow them to perform their work. This paper will identify the source of the original SQA requirements adopted by the project. It will delineate the approach used by the project to identify concerns voiced by project engineers and scientists regarding the original SQA requirements. It will conclude with a discussion of methods used to address these problems in the rewrite of the original SQA requirements.

44 **Qualification of existing data for the Yucca Mountain Site Characterization Project.** Bjerstedt, T.W. (Yucca Mountain Site Characterization Project Office, Las Vegas, NV (United States)); Jones, S.B.; Distel, B.W. pp. 1648-1652 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The U.S. Department of Energy (DOE) has completed its first effort to qualify existing data using NUREG-1298 'Qualification of Existing Data for High-Level Nuclear Waste Repositories'. A combination of three methods were used: corroboration, equivalent quality assurance program, and peer review. A technical assessment procedure was used to create the documentation to support the qualification process. The technical assessment team compared the procedures in place at the time of the original work to the procedures in use under an approved quality assurance program, the scientific notebooks that recorded the investigations, the geologic samples studied, and the records of a peer review conducted on one part of the work. The team recommended that the data be qualified. This recommendation was accepted by the DOE in September 1992.

45 **Borehole security on the Yucca Mountain project.** Smith, S.C. (Science Applications International Corp., Las Vegas, NV (United States)); Linden, L.S.; Tynan, M.C. pp. 1686-1690 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

A borehole security plan was developed and is being implemented to address safety, environmental protection and restoration, waste isolation, and security concerns related to boreholes in the area where site characterization studies are being performed by the U.S. Department of Energy at Yucca Mountain, Nevada. Over 250 boreholes have been drilled to provide geologic, hydrologic, and seismologic data for assessing the suitability of Yucca Mountain for storage of high-level nuclear waste. Approximately 150 additional boreholes are planned for future investigations. In this paper we describe the existing conditions, objectives, and work program use to secure these boreholes.

46 **A variation of the housing unit method for estimating the age and gender distribution of small, rural areas: A case study of the local expert procedure.** Carlson, J.F. (SAIC, Las Vegas, NV (United States)); Roe, L.K.; Williams, C.A.; Swanson, D.A. pp. 1918-1923 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

This paper describes the methodologies used in the development of a demographic data base established in support of the Yucca Mountain Site Characterization Project Radiological Monitoring Plan (RadMP). It also examines the suitability of a survey-based procedure for estimating population in small, rural areas. The procedure is a variation of the Housing Unit Method. It employs the use of local experts enlisted to provide information about the demographic characteristics of households randomly selected from residential units sample frames developed from utility records. The procedure is nonintrusive and less costly than traditional survey data collection efforts. Because the procedure is based on random sampling, confidence intervals can be constructed around the population estimated by the technique. The results of a case study are provided in which the total population, and age and gender of the population, is estimated for three unincorporated communities in rural, southern Nevada.

47 **Current progress in implementing the payments-equal-to-taxes (PETT) program in Nevada.** Lundgaard, E.L. (Department of Energy, Las Vegas, NV (United States)); Ellis, C.B. pp. 1930-1934 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Nuclear Waste Policy Act of 1982, as amended (NWPA), requires the Secretary of Energy to make Payments-equal-to-Taxes (PETT) to local units of government that are affected by the potential repository at Yucca Mountain, Nevada. The PETT program is designed to provide affected jurisdictions with the revenue they would have received if the potential repository site was being characterized and possibly developed by a private entity rather than the Federal government. A paper presented at last year's conference described how the PETT Program would be implemented in the State of Nevada. This paper describes the current progress in implementing the program as it relates to the PETT associated with property taxes.

48 **IHLW conference paper Yucca Mountain Site Characterization Project Environmental Protection Program.** Dixon, W.R. (Department of Energy, Las Vegas, NV (United States)); McCann, E.W.; Powers, C.D. pp. 1972-1979 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10.

international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

To ensure the characterization of the Yucca Mountain site is conducted in an environmentally safe and sound manner, the U.S. Department of Energy (DOE) has developed and implemented a comprehensive program that ranges from the acquisition of Federal and State permits to the reclamation of disturbed lands. Among other elements of this program are the following: Identification of relevant environmental regulations, identification of potential environmental impacts, monitoring for potentially significance adverse impacts and mitigation of any impacts that may occur, management of hazardous wastes, waste minimization, and environmental compliance auditing.

49 **Ambient air monitoring to support HLW repository site characterization.** Fransioli, P.M. (Science Applications International Corp., Las Vegas, NV (United States)); Dixon, W.R. pp. 1980-1983 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Site characterization at the Yucca Mountain site includes an ambient air quality and meteorological monitoring program to provide information for environmental and site characterization issues. The program is designed to provide data for four basic purposes: Atmospheric dispersion calculations to estimate impacts of possible airborne releases of radiological material; Engineering design and extreme weather event characterization; Local climate studies for environmental impact analyses and climate characterization; and, Air quality permits required for site characterization work. The program is compiling a database that will provide the basis for analyses and reporting related to the purposes of the program. Except for reporting particulate matter and limited meteorological data to the State of Nevada for an air quality permit condition, the data have yet to be formally analyzed and reported.

50 **Experimental studies to calibrate unsaturated flow models.** Boehm, R. (Univ. of Nevada, Las Vegas, NV (United States)); Krotke, M.; Thota, S.; Xu, Xiang. pp. 2081-2085 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Many aspects of the work related to design and performance assessment of the proposed High Level Nuclear Waste Repository at Yucca Mountain are based upon estimates of moisture migration in the surrounding formations. These estimates are usually made using computer codes that have varying degrees of validation. Since most of the moisture flows are in highly nonhomogeneous media and are unsaturated, the development of experimental data for validating models is a difficult task. Work is described that has been designed to serve as a laboratory calibration of numerical models for unsaturated flow studies. The experiment size is configured large enough that the assumptions applicable to most numerical models should apply, but the size is small enough that the test section can be characterized well and accurately monitored. A large piece of consolidated and fractured medium is used for the main test element. In addition to careful assessment of flows in and out, the moisture content at various locations along the element is monitored. Both electromagnetic and ultrasonic techniques are used in our experiments for the latter estimates. The general experimental method, control system, and data acquisition approach are described.

51 **Functional analysis: The path to effective training.** Rehkop, E.C. (Department of Energy, Las Vegas, NV (United States)); McCarthy, R.A.; Chadwick, P.A. pp. 2133-2137 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The regulatory requirements under which the Yucca Mountain Site Characterization Project (YMP) operates mandate that worker proficiency be achieved and maintained. Individuals performing activities that affect quality should be adequately trained to perform work to a specified standard. Effective training must be structured around the tasks performed and their performance standards which is often an expensive and labor-intensive processing involving many interviews and worker observations. Tasks at YMP include such things as procedure review, data analysis, and test design none of which lend themselves to worker observation. Additionally, budget and time constraints and a small staff of trained job and task analysts have made the analysis process very onerous for everyone. The challenge faced by the YMP training staff was to designed effective initial and continuing training programs for a staff of 700 people filling approximately 550 positions. Crucial to the success of this effort is the collection of valid, sufficiently detailed data on the types of tasks performed and their associated performance standards. This paper describes how the YMP has streamlined the data collection process, cutting the costs and man-hours required while still maintaining the high quality and validity of the data collected.

52 **Project control - the next generation.** Iorii, V.F. (Department of Energy, Las Vegas, NV (United States)); McKinnon, B.L. pp. 2138-2143 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Yucca Mountain Site Characterization Project (YMP) is the U.S. Department of Energy's (DOE) second largest Major System Acquisition Project. We have developed an integrated planning and control system (called PACS) that we believe represents the 'Next Generation' in project control. PACS integrates technical scope, cost, and schedule information for over 50 participating organizations and produces performances measurement reports for science and engineering managers at all levels. Our 'Next Generation' project control too, PACS, has been found to be in compliance with the new DOE Project Control System Guidelines. Additionally, the nuclear utility oversight group of the Edison Electric Institute has suggested PACS be used as a model for other civilian radioactive waste management projects. A 'Next Generation' project control tool will be necessary to do science in the 21st century.

53 (CONF-940225--Vol.1, pp. 479-483) **Status of the Yucca Mountain site characterization program.** Gertz, C.P. (Jacobs Engineering Group, Inc., Albuquerque, NM (United States)); Nelson, R.M.; Blanchard, M.B.; Cloke, P.L.

Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines; New Mexico State Univ., University Park, NM (United States); Waste-Management Education and Research Consortium (WERC), Las Cruces, NM (United States); USDOE, Washington, DC (United States). 1994. From Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994. In *Technology and programs for Radioactive Waste Management and Environmental Restoration. Volume 1.* 814p. Source: Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States).

By its very nature the Yucca Mountain Site Characterization Program (YMP) entails a complex set of activities and issues. Among these are planning for the Exploratory Studies Facility (ESF), site characterization surface-based testing, performance assessment, public outreach and information services, conceptual design of a potential repository, compliance with regulations, environmental issues, transportation of nuclear wastes, and systems engineering. Stringent safety and health standards apply to all these activities, which must also be carried out under rigorous quality assurance controls. This session includes individual papers on several of these topics. The present paper provides a less comprehensive overview. Project goals for fiscal year 1994 focus on the continuation of the following activities: Development of the ESF pursuant to the earliest possible determination of site suitability; advanced conceptual design of both the waste package and repository to the degree necessary for ESF development and the Mined Geologic Disposal system; implementation of the surface-based testing program pursuant to the earliest possible determination of site suitability; compilation of environmental data necessary for the earliest possible determination of site suitability; identification and pursuit of resolution of difficult technical issues that bear on the overall suitability of the site; support for development of a design for standardized spent-fuel containers for storage, transportation, and disposal; needed compliance with all applicable YMP commitments and Department of Energy order and regulations to ensure safety and regulatory compliance for all parts of the program; and definition and implementation of cost reduction initiatives consistent with the overall goals of the Project.

54 (CONF-940225–Vol.1, pp. 485-488) **Yucca Mountain site characterization: The field testing program.** Williams, D.R.; Matthusen, A.C. Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines; New Mexico State Univ., University Park, NM (United States); Waste-Management Education and Research Consortium (WERC), Las Cruces, NM (United States); USDOE, Washington, DC (United States). 1994. From Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994. In *Technology and programs for Radioactive Waste Management and Environmental Restoration. Volume 1.* 814p. Source: Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States).

The Yucca Mountain area was first considered as a site for possible characterization as a high level waste repository in 1977. Since that time preliminary field testing and Congressional directive recommended continued testing and determined in 1987 that Yucca Mountain would be the only site characterized. Following environmental assessment, the development of a site characterization plan, and litigation with the State of Nevada testing from both surface-based perspective and underground in the Exploratory Studies Facility is underway. Data and analyses from the comprehensive testing program will be evaluated on a periodic basis of two year cycles to provide direction to the testing program. The entire testing program will culminate in a determination of site suitability near the end of the twentieth century.

55 (CONF-940225–Vol.1, pp. 489-496) **The exploratory studies facility (ESF) at Yucca Mountain - Description and status.** Simecka, W.B. (Department of Energy, Las Vegas, NV (United States)); Replogle, J.M.; Mckenzie, D.G. Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines; New Mexico State Univ., University Park, NM (United States); Waste-Management Education and Research Consortium (WERC), Las Cruces, NM (United States); USDOE, Washington, DC (United States). 1994. From Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994. In *Technology and programs for Radioactive Waste Management and Environmental Restoration. Volume 1.* 814p. Source: Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States).

The Exploratory Studies Facility (ESF) at Yucca Mountain, Nevada will be a 25 kilometer underground network of inclined ramps, tunnels, and test alcoves. It will serve as an underground laboratory for the execution of a testing program conceived to assess the suitability of Yucca Mountain as a site to host a potential high level nuclear waste repository. This paper contains a description of the ESF, a summary of the major types of tests currently planned, and a report on the current status of the ongoing design and construction activities. The ESF is being designed and constructed in phases. Currently, the Detailed Design, or "Title II Design" is centered on the second of ten major design packages. Construction has begun on excavation of the "starter tunnel" for a Tunnel Boring Machine (TBM) expected to begin operation in late FY 1994. The EFS program will provide information critical to the evaluation of Yucca Mountain as a potential repository site, and will house a suite of state-of-the-art tests designed to gather this information. The ESF is a one of a kind opportunity to examine, in minute detail, all facets of a sites' geology; its thermal, mechanical, and hydrologic properties; and to study the linkages between these properties.

56 (CONF-940225–Vol.1, pp. 505-510) **Total system performance assessment (TSPA-1993) for Yucca Mountain: An iterative refinement addressing scientific, regulatory, and design concerns.** Boak, J.M. (Department of Energy, Las Vegas, NV (United States)); Dockery, H.A.; Andrews, R.W. Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines; New Mexico State Univ., University Park, NM (United States); Waste-Management Education and Research Consortium (WERC), Las Cruces, NM (United States); USDOE, Washington, DC (United States). 1994. From Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994. In *Technology and programs for Radioactive Waste Management and Environmental Restoration. Volume 1.* 814p. Source: Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States).

Sandia National Laboratories (SNL) (1) and Pacific Northwest Laboratory (PNL) (2) completed the first iteration of total-system performance assessment (TSPA-91) for Yucca Mountain during 1991 and 1992. TSPA-93, the successor to TSPA-91, was conducted by SNL and the Civilian Radioactive Waste Management System Management and Operating (M&O) contractor. The TSPA-93 calculations were

formulated based on recommendations generated in TSPA-91. The process models used to describe contaminant mobilization and transport were expanded and the associated parameter sets were improved. Significant improvements include more sophisticated treatments of climate change and percolation flux; saturated zone flow and transport; near-field processes, such as container degradation and radionuclide mobilization; and hydrogeologic and geochemical parameter sets. New features in TSPA-93 include hydrothermal processes associated with elevated thermal loads, alternative waste container packages, and geostatistical representations of the lithologic units. Results of the analyses are shown both as releases and as individual doses, to evaluate the effect of possible changes in standards governing a high-level radioactive waste repository. 10,000-year cumulative releases are similar to those in TSPA-91, and are dominated by gaseous release of ^{14}C. Longer term cumulative releases increase surprisingly little, with gaseous release and aqueous release more nearly equal. However, substantial individual doses are projected at very long times, as a consequence of certain features of the arid environment. Recommendations for future work to support site characterization, design, regulation assessment, and TSPAs are given, based on the results of the two studies.

57 (CONF-940225–Vol.1, pp. 517-519) **The ins the outs and the ups and downs of constituent involvement: The Yucca Mountain project, a case study.** Robison, A.C. (Science Applications International Corporation, Las Vegas, NV (United States)); Seidler, P.; Ulick, M.; Smith, L. Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines; New Mexico State Univ., University Park, NM (United States); Waste-Management Education and Research Consortium (WERC), Las Cruces, NM (United States); USDOE, Washington, DC (United States). 1994. From Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994. In *Technology and programs for Radioactive Waste Management and Environmental Restoration. Volume 1.* 814p. Source: Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States).

The U.S. Department of Energy (DOE) has talked about the need and planned for the involvement of external parties in department decision making for some time. Until recently, however, DOE has not aggressively pursued the implementation of real pre-decisional involvement by its constituents. At the Yucca Mountain Site Characterization Project (YMP), substantive constituent involvement has become the focus of external interactions. In an effort to determine the most effective means to accomplish this, the YMP has initiated a program in which the Project "involves constituents in determining how best to involve them". Though still embryonic in its development, this process has yeilded some early positive results.

58 (CONF-9402115–1) **Focused mined geologic disposal system (MGDS) repository design for the Yucca Mountain Project.** Brodsky, M.G. (USDOE Nevada Operations Office, Las Vegas, NV (United States). Yucca Mountain Project Office); Bhattacharyya, K.K.; Olguin, L.J. TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States). [1994]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. From 2. international workshop on design and construction on final repositories; Winnepeg (Canada); 15-17 Feb 1994. Order Number DE95003024. Source: OSTI; NTIS; INIS; GPO Dep.

This paper outlines a refined design process which will successfully manage Yucca Mountain Project repository design efforts while meeting regulatory and programmatic requirements. Pending changes in the program technical baseline as well as limited resources reflect the program's emerging trend to manage technical and programmatic risks associated with the selection of key assumptions. The decision to utilize a Multiple Purpose Canister (MPC), one of many waste package concepts currently being considered, has promulgated a revised Mined Geologic Disposal System (MGDS) design approach. The key elements are: (1) develop MGDs design concepts which fulfills the technical and programmatic requirements; (2) adopt a design approach which uses management assumptions based on available information and expert engineering and scientific judgment now; (3) substantiate the assumptions as the design is developed; and (4) carry alternative design features which are important to safety and/or waste isolation. Advantages and constraints are discussed.

59 (CONF-940553–52) **Investigation of stress in a circular tunnel due to overburden and thermal loading of horizontally placed 21 PWR multi purpose canisters.** Kandalaft-Ladkany, N.; Wyman, R.V. Nevada Univ., Las Vegas, NV (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE94012149. Source: OSTI; NTIS; INIS; GPO Dep.

The drift of a High Level Nuclear Waste (HLNW) Repository were subjected to 2-D thermal loading resulting from the horizontal emplacement of 125 Ton Multi-Purpose Canisters (MPC). Ten 2-D temperature profiles, resulting from 57 Kw/acre and 114 Kw/acre thermal loading conditions, were used in a finite element analysis of the drift; in which a quadrant of the drift and surrounding rock ±100m above and below the drift were modeled. Our analysis shows that the 114 Kw/acre thermal loading results in compressive stresses around the drift, 60 years after emplacement, that exceed the unconfined compressive strength of the TSW tuff analyzed. Stresses resulting from a 57 Kw/acre thermal loading are within the acceptable limit in tunnel rock. A parametric analysis of the invert backfill material showed that Young's modulus for the invert backfill should closely match that of the surrounding unconfined rock in the tunnel in order to prevent an unacceptable stress rise in both rock and backfill.

60 (CONF-940553–53) **Simulation of heat transfer around a canister placed horizontally in a drift.** Moujaes, S.; Bhargava, A. Nevada Univ., Las Vegas, NV (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE94012152. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project is investigating the feasibility of locating a high level radioactive nuclear waste repository at Yucca Mountain, Nevada. The bore hole and the in-drift waste emplacement schemes are under evaluation as potential repository drift geometries. This paper presents a two-dimensional finite element thermal analysis of the nuclear waste canister placed horizontally in a drift. Simulation has been carried out for 1000 years and the peak temperatures at the walls of the drift and

at the center of the canister have been determined. The effect of the three modes of heat transfer, conduction, natural convection and radiation, is also discussed.

61 (CONF-940553–57) **Experimental heat transfer and fluid flow over drift-emplaced canisters.** Culbreth, W.G.; Pattisam, S. Nevada Univ., Las Vegas, NV (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE94012156. Source: OSTI; NTIS; INIS; GPO Dep.

Drift-emplaced waste canisters are under consideration for the long-term storage of high-level spent fuel in the proposed underground repository at Yucca Mountain. These canisters will be placed on pedestals above the floor of the drifts and exchange heat with the walls of the drift and with air circulating through the repository. To assess the requirements of the repository ventilation system, values of the dimensionless convective heat transfer coefficient and the pressure drop across individual canisters were measured in a experimental model of a drift. The results were curvefitted as functions of the spacing between the canisters and the Reynolds number of the flow. Both natural and forced convection effects were investigated.

62 **Testing the spatial neutrality of the REMI net migration equation.** Barr, C.F. (Science Applications International Corp., Las Vegas, NV (United States)); Perrigo, T.A.; Daneshvary, N.; Rickman, D.S. pp. 40-47 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 373 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The U.S. Department of Energy (DOE), Yucca Mountain Site Characterization Project Office (YMPO) is conducting socioeconomic studies in the State of Nevada in accordance with the Nuclear Waste Policy Act of 1982, as amended. The main purpose of the socioeconomic program is to avoid or minimize adverse socioeconomic impacts of the Yucca Mountain Site Characterization Project (YMP) on local communities, counties, and the state of Nevada. This objective is being met by collecting data that can be used by the DOE and affected units of local government to monitor economic and demographic variables and forecast changes that may occur as a direct result of the YMP. One of the tools being used to develop population and employment forecasts in Clark, Lincoln, and Nye counties in Nevada is Regional Economic Modeling Inc.'s (REMI) Economic-Demographic Forecasting and Simulation (EDFS) model. The REMI model is widely used in applied economics for: forecasting and planning; economic development; transportation; energy and natural resources; taxation, budget, and welfare; United States policies; and environmental policies. This model was chosen by the DOE because it is a dynamic econometric model based on accepted economic theory and principles, and because of its favorable rating compared to other available models. The dynamic nature of the model offers improvements in forecasting capabilities over input-output models. Because the DOE is making extensive use of the REMI model, it is necessary to evaluate the model's forecasting performance. This study is an empirical test of the restrictions in the REMI model's net migration equation. The REMI model pools the data across regions to estimate net migration into each region. For this study we will examine Clark County net migration. We hypothesize that due to the differences among regions (such as distance, and geographic and cultural features specific to each region), pooling the data across regions may not be appropriate.

63 **The interactive process: A formal means to improved relations.** Benson, A. (Dept. of Energy, Washington, DC (United States)); Seidler, P.E.; Ulick, M.D.; Robison, A.C. pp. 56-57 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 373 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

This paper will examine the U.S. Department of Energy's Office of Civilian Radioactive Waste Management's (DOE/OCRWM) continued efforts to improve relations and facilitate communications with officials from Nye County, Nevada, the site of the proposed Yucca Mountain nuclear waste repository. The Protocol on On-Site Representation establishes certain procedures for interactions between Nye County and DOE/OCRWM specific to the host county. These include on-site representation, the County's ability to conduct independent testing and oversight and the timely exchange of information related to site characterization.

64 **Advertising public outreach–going where the people are.** Bradford, D. (Science Applications International Corp., Las Vegas, NV (United States)); Burns, D. pp. 76-82 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 373 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

In a continuing effort to invite new and larger segments of the public to participate in Yucca Mountain Site Characterization Project (YMP) Public Outreach Programs, examination of methods to enhance existing Public Outreach advertising programs began in 1993. Apart from the desire to promote greater public awareness and participation of the YMP, the Project itself is receiving less coverage of its scientific aspects in the local media. Since the public is already comfortable receiving messages in these media, this becomes an additional reason to explore and study advertising as a platform for invitations to the public.

65 **Technology information transfer in public outreach - a new approach.** Peck, J.H. (Science Applications International Corp., Las Vegas, NV (United States)); Wadkins, M.L. pp. 92-97 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 373 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The timely and accurate dissemination to the public of information derived from the site characterization activities on the Yucca Mountain Site Characterization Project (YMP) has sometimes been difficult to achieve. The YMP has many participants who are involved in the gathering and analysis of scientific and engineering data for site characterization. The diversity of the scientific disciplines involved, the uncentralized location of the participant organizations, the difficulty of being able to ask the right questions of the right people, and the translation of technical jargon into understandable

terms are but a few of the challenges. The public outreach program of the YMP has done an excellent job of compiling and distributing information over the past few years, but, with the diversity and expansion of field activities in the last two years, the job has become more formidable. A new approach to help resolve this obstacle was instituted in April of 1993, and has been successful in achieving a much more timely and user-friendly discussion of technical information for the public. What is the new approach? The assignment of a technical expert to the public outreach staff whose job is to know what is going on, who is doing what, and what the results are. Based on that knowledge, factual summaries can be generated rapidly and presented to the public in the context of the overall project goals and in a form suitable for a wide range of audiences.

66 **Urban versus rural risk perception relating to high-level nuclear waste.** Soden, D.L. (Univ. of Nevada, Las Vegas, NV (United States)). pp. 136-141 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 373 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

In this study, the general public's perceptions of risk pertaining to the proposed Yucca Mountain project are investigated across two distinct areas of Nevada– rural and urban. Considerable research has demonstrated that rural Nevada and urban Nevada reflect political and social cultures which lead residents in each region to respond to proposed programs and policies in different ways. Using a multi-dimensional perspective on risk, a preliminary investigation into citizen's attitudes in each region of the state is made.

67 **Growing interest, growing programs, growing pains: Successfully customizing public outreach.** Wadkins, M. (SAIC, Las Vegas, NV (United States)); Hill, C.; Hirsch, T. pp. 232-237 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 373 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Since the mid-1980's, the Institutional and External Affairs staff of the Yucca Mountain Site Characterization Project (YMP) has developed, coordinated, and maintained various public outreach programs to carry out the YMP's open door policy of keeping local communities informed. However, public involvement first requires public knowledge and, therefore, various information programs have been established over the past few years. First came the speakers bureau program, then the exhibits and science centers; and then came the tours and school district educational programs. All these programs were geared toward teaching the mainstream general public about the YMP and issues related to things nuclear. Today, the YMP outreach programs are established and known and the demand from the public has seen a shift. Over 150 top scientists and staff from around the country who have come to work at the YMP have joined the outreach participant pool to speak to the public not only about Yucca Mountain, but about their areas of expertise as well. For this reason, the public has realized a great opportunity for a general science and engineering education resource – the YMP staff themselves. In a panel discussion, "Trust and credibility: The central issue", proceedings of the National Conference on Risk Communication, it was shown that university professors and science teachers were among the most trusted individuals in terms of public perception and that government staff and contractors the least trusted. However, when you utilize the core educated knowledge of a YMP scientist in order to teach general science and math, you have, to some extent, placed that individual in an educational role and thus increased trust. The YMP scientists enjoy talking about their general science knowledge and we have found that the public likes to hear about it too.

68 **Potential economic benefits of the Yucca Mountain Project.** Babcock, R.A. (Univ. of Nevada, Reno, NV (United States)). pp. 642-649 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

This paper summarizes a larger document of the same title that examines some of the potential economic benefits that could accrue to the State of Nevada, the affected counties, and various businesses and institutions within the state as a function of the Yucca Mountain project. A copy of the original document is available from the author.

69 **Population estimation techniques for routing analysis.** Sathisan, S.K. (Univ. of Nevada, Las Vegas, NV (United States)); Chagari, A.K. pp. 658-665 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A number of on-site and off-site factors affect the potential siting of a radioactive materials repository at Yucca Mountain, Nevada. Transportation related issues such route selection and design are among them. These involve evaluation of potential risks and impacts, including those related to population. Population characteristics (total population and density) are critical factors in the risk assessment, emergency preparedness and response planning, and ultimately in route designation. This paper presents an application of Geographic Information System (GIS) technology to facilitate such analyses. Specifically, techniques to estimate critical population information are presented. A case study using the highway network in Nevada is used to illustrate the analyses. TIGER coverages are used as the basis for population information at a block level. The data are then synthesized at tract, county and state levels of aggregation. Of particular interest are population estimates for various corridor widths along transport corridors – ranging from 0.5 miles to 20 miles in this paper. A sensitivity analysis based on the level of data aggregation is also presented. The results of these analysis indicate that specific characteristics of the area and its population could be used as indicators to aggregate data appropriately for the analysis.

70 **Experimental heat transfer and fluid flow over drift-emplaced canisters.** Culbreth, W.G. (Univ. of Nevada, Las Vegas, NV (United States)); Pattisam, S. pp. 772-779 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United

States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Drift-emplaced waste canisters are under consideration for the long-term storage of high-level spent fuel in the proposed underground repository at Yucca Mountain. These canisters will be placed on pedestals above the floor of the drifts and exchange heat with the walls of the drift and with air circulating through the repository. To assess the requirements of the repository ventilation system, values of the dimensionless convective heat transfer coefficient and the pressure drop across individual canisters were measured in an experimental model of a drift. The results were curvefitted as functions of the spacing between the canisters and the Reynolds number of the flow. Both natural and forced convection effects were investigated.

71 **Simulation of heat transfer around a canister placed horizontally in a drift.** Moujaes, S. (Univ. of Nevada, Las Vegas, NV (United States)); Bhargava, A. pp. 801-808 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The Yucca Mountain Site Characterization Project is investigating the feasibility of locating a high level radioactive nuclear waste repository at Yucca Mountain, Nevada. The bore hole and the in-drift waste emplacement schemes are under evaluation as potential repository drift geometries. This paper presents a two-dimensional analysis of the nuclear waste canister placed horizontally in a drift. Simulation has been carried out for 1000 years and the peak temperatures at the walls of the drift and at the center of the canister have been determined. The effect of the three modes of heat transfer, conduction, natural convection and radiation, is also discussed.

72 **Investigation of stress in a circular tunnel due to overburden and thermal loading of horizontally placed 21 PWR multi purpose canisters.** Kandalaft-Ladkany, N. (Univ. of Nevada, Las Vegas, NV (United States)); Wyman, R.V. pp. 860-867 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 DOE Contract FC08-90NV10872. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The drift of a High Level Nuclear Waste (HLNW) Repository were subjected to 2-D thermal loading resulting from the horizontal emplacement of 125 Ton Multi-Purpose Canisters (MPC). Ten 2-D temperature profiles, resulting from 57 Kw/acre and 114 Kw/acre thermal loading conditions, were used in a finite element analysis of the drift; in which a quadrant of the drift and surrounding rock ± 100 m above and below the drift were modeled. Our analysis shows that the 114 Kw/acre thermal loading results in compressive stresses around the drift, 60 years after emplacement, that exceed the unconfined compressive strength of the TSW_2 tuff analyzed. Stresses resulting from a 57 Kw/acre thermal loading are within the acceptable limit in tunnel rock. A parametric analysis of the invert backfill material showed that Young's modulus for the invert backfill should closely match that of the surrounding unconfined rock in the tunnel in order to prevent an unacceptable stress rise in both rock and backfill.

73 **Alternative approaches to reliability modeling of a multiple engineered barrier system.** Ananda, M.M.A. (Univ. of Nevada, Las Vegas, NV (United States)); Singh, A.K. pp. 1030-1036 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The lifetime of the engineered barrier system used for containment of high-level radioactive waste will significantly impact the total performance of a geological repository facility. Currently two types of designs are under consideration for an engineered barrier system, single engineered barrier system and multiple engineered barrier system. Multiple engineered barrier system consists of several metal barriers and the waste form (cladding). Some recent work show that a significant improvement of performance can be achieved by utilizing multiple engineered barrier systems. Considering sequential failures for each barrier, we model the reliability of the multiple engineered barrier system. Weibull and exponential lifetime distributions are used through out the analysis. Furthermore, the number of failed engineered barrier systems in a repository at a given time is modeled using a poisson approximation.

74 **Developing standardized connection analysis techniques for slim hole core rod designs.** Fehr, G. (Science Applications International Corp., Las Vegas, NV (United States)); Bailey, E.I. pp. 1048-1054 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Slim hole core rod design remains essentially in the proprietary domain. API standardization provides the ability to perform engineering analyses and dimensional inspections through the use of documents, ie: Specifications, Bulletins, and Recommended Practices. In order to provide similar engineering capability for non-API slim hole connections, this paper develops the initial phase of what may evolve into an engineering tool to provide at least an indication of relative serviceability between two connection styles for a given application. The starting point for this process will look at bending strength ratios and connection strength calculations. Since empirical data are yet needed to verify the approaches proposed in this paper, it is recognized that the alternatives presented here are only a first step to developing useful rules of thumb which may lead to later standardization.

75 **Impact of nuclear waste traffic on highways.** Sebaaly, P.E. (Univ. of Nevada, Reno, NV (United States)); Siddharthan, R.; Epps, J.A. pp. 1255-1262 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A system was developed to evaluate the impact of nuclear waste traffic on the structural performance of highway pavements throughout the state of Nevada. The associated needs of maintenance and rehabilitations can also be evaluated along with their costs. This paper summarizes the system and provides two sample analyses.

76 An evaluation of rail access routes to Yucca Mountain. Sathisan, S.K. (Univ. of Nevada, Las Vegas, NV (United States)); Parentela, E.M. pp. 1270-1277 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

This paper provides a preliminary evaluation and characterization of potential rail routes for the transport of high level radioactive waste from their current storage locations (76 power plants and 4 federal facilities) to the proposed geologic repository at Yucca Mountain, Nevada. Individual routes were determined for shipments from each origin using the INTERLINE model. They were characterized in terms of shipment distance, number of transfers and states transversed. Additionally, specific routing constraints were imposed for a selected subset of the origins to address policy and operational alternatives such as minimizing shipment distance, number of transfers or number of states traversed. Results of the analysis indicate that the imposition of the routing constraint count result in reducing shipment distances, and the number of states traversed. But a tradeoff between these factors and the number of transfers exists.

77 Analysis of potential highway routes to Yucca Mountain. Sathisan, S.K. (Univ. of Nevada, Las Vegas, NV (United States)); Parentela, E.M.; Lee, M.S. pp. 1278-1285 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

States have been provided the authority to designate routes for the transport of highway route controlled quantity shipments of radioactive materials. The state of Nevada is currently evaluating alternative routes for such designation. This paper provides a preliminary assessment of potential system impacts of Nevada's highway route designation for the shipment of High Level Radioactive Waste (HLRW) to the proposed geologic repository at Yucca Mountain, Nevada. A potential route being evaluated by Nevada was used to specify routing constraints for highway shipments to Yucca Mountain. Individual routes were determined for shipments from each origin using the HIGHWAY model for unconstrained and constrained routing scenarios. Results of the analysis indicate that the imposition of the routing constraint would result in increased travel times and shipment distances. These increases range from about 1.25 percent to about 80 percent. However, the magnitude of such increases is highly dependent on the geographic location of the origin.

78 Natural analogues and performance assessment. Cloke, P.L. (Science Applications International Corp., Las Vegas, NV (United States)). pp. 1329-1336 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

At a high general level this paper presents a number of data types needed for performance assessment (PA) of the potential high level nuclear waste repository at Yucca Mountain, NV. These include hydrology (e.g., fluxes through a breached waste package and to the accessible environment), geochemistry (e.g. water composition and changes thereto due to corrosion and waste dissolution; radionuclide solubilities), the engineered barrier system (e.g. rates and times of container failure; degradation of concrete), the source term, and disruptive scenarios. Some characteristics of three natural analogues, specifically the Taupo Volcanic Zone (New Zealand), Pena Blanca (Mexico), and Cigar Lake (Canada) are then compared against these needs. Each of these sites possesses the potential to provide insights about the long term behavior of the natural system in relation to a few of these characteristics and data needs. The characteristics that pertain to performance at Yucca Mountain differ from site to site and largely do not overlap each other. The paper presents one way of evaluating the potential applicability of studies at a specific site to PA. The way in which such studies would be used by PA is not discussed.

79 Planning and management of change. Nelson, R.M. Jr. (Department of Energy, Las Vegas, NV (United States)); Statton, C.T.; St. Clair, R.K. pp. 1722-1730 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The 1990s promise to be a decade of change. In business, the focus will be on restructuring for purposes of improved productivity and efficiency. The Department of Energy (DOE) has recognized that change is on the horizon. The Yucca Mountain Project, carried out under the Office of Civilian Radioactive Waste Management (OCRWM) within the DOE is under new leadership. This new leadership is restructuring its operations to provide better focus, greater efficiency, meaningful products demonstrating progress and a more open operational environment. Criticisms of past operations have been reviewed and evaluated such that the new management organization derives benefit from the past. In recognition that management concerns may be manifested in other areas, Yucca Mountain Project management believes that reorganization is necessary to maximize efficiency. In designing the new organization, a high priority has been placed upon making changes which enable the federal leadership to exercise appropriate control and make participants more responsible and accountable for their work. Transition to the new organization will be implemented in four phases: (1) establishing the management construct, (2) defining roles and responsibilities of functional management, (3) development of the task performance teams, and (4) subsequent evolution of the "project team" as a whole. A program-wide strategic plan is being prepared which includes a variety of revisions to the program of the past. This plan charts the path the Department will follow in fulfilling its mission. The vision of the new management developed by the DOE focuses on the creation of "teams," both a management team and task performance teams. The new management team will be tasked with implementing the plan.

80 Subsurface transport modeling of the Savannah River and Yucca Mountain Sites. Dunlap, B.E. (Univ. of Nevada, Las Vegas, NV (United States)); Pepper, D.W.; Stephenson, D.E. pp. 1848-1853 of High Level Radioactive

Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

An adaptive two-dimensional finite element method is used to model groundwater flow and contaminant transport in variably saturated porous media. The model is applied to known groundwater contamination at the Savannah River Site, which consists of multiple ground strata. A simulation of the proposed Yucca Mountain Repository Site is also executed to assess potential burial of radioactive waste.

81 **Active versus passive radon monitoring at the Yucca Mountain site.** Griffin, M.D. (Science Applications International Corp., Las Vegas, NV (United States)). pp. 1953-1958 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Federal Regulations have mandated that a baseline assessment for the Yucca Mountain Site be performed. This includes the detection and monitoring of specific radionuclides present at the site. These radionuclides include radon 222, a decay progeny of naturally occurring uranium. Two radon monitoring systems are utilized at the Yucca Mountain site to detect ambient levels of radon. The first is a passive time integrated system, and the second is a continuous radon monitoring (CRM) system.

82 **Development of functional characteristics of vehicle mounted plastic scintillation system.** Follette, J.G. (Science Applications International Corp., Las Vegas, NV (United States)); Briggs, C.T.; Tappen, J.J. pp. 1964-1970 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

To meet the Yucca Mountain Site Characterization Project Office preactivity survey schedules, increase efficiency, and reduce labor costs, SAIC implemented the use of a Vehicle Mounted Radiation Detector (VMRD). The VMRD consists of two systems, a Global Positioning System (GPS) and a Radiation Detection System (RDS). This paper focuses on the functional characteristics of the RDS. The functional characteristics of the TSA Model GPRS-100 Vehicle Mounted Global Positioning Radiometric Scanner were studied. The tests performed during this study were limited to gamma ray energies between 275 keV and 1275 keV, and source strengths between 16 kBq and 318 kBq. The system's efficiency as a function of vehicle speed, gamma ray energy, detector height, and source activity are presented. The system's efficiency as a function of detector height for Cs-137 ranged from 3.14% for a detector height for Cs-137 ranged from 3.14% for a detector height of 15 cm, to 0.91% for a detector height of 60 cm. The system's efficiency is not dependent upon gamma ray energy or source activity for the sources used in this study. It was determined that the system's efficiency as a function of speed falls within a predictable range dependent upon detector height and vehicle speed. For performing large area preactivity surveys a detector height of 60 cm and vehicle speed of less than 2.5 m/s will optimize this system's efficiency.

83 **Investigation of faulted tunnel models by combined photoelasticity and finite element analysis.** Ladkany, S.G. (Univ. of Nevada, Las Vegas, NV (United States)); Huang, Yuping. pp. 1979-1986 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract FC08-90NV10872. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Models of square and circular tunnels with short faults cutting through their surfaces are investigated by photoelasticity. These models, when duplicated by finite element analysis can predict the stress states of square or circular faulted tunnels adequately. Finite element analysis, using gap elements, may be used to investigate full size faulted tunnel system.

84 **Uniaxial strength testing of Calico Hills tuff, Yucca Mountain: Preliminary results.** Li, Qizhi (Univ. of Nevada, Reno, NV (United States)); Schultz, R.A. pp. 2106-2111 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A detailed investigation of the strength properties of Calico Hills tuff was undertaken to further characterize the behavior of this unit. Uniaxial compression test on 47 samples of massive and reworked tuff show a dependence of peak strength and Young's modulus on the total porosity, and thus on the geologic history of the Calico Hills tuff. Controlled deformation of test specimens documents axial splitting and faulting as failure mechanisms in the post-peak region of these brittle tuffs.

85 **Site characterization and related activities at the potential high-level radioactive waste repository site at Yucca Mountain, Nevada.** Gertz, C.P. (Department of Energy, Las Vegas, NV (United States)); Nelson, R.M. Jr.; Blanchard, M.B.; Cloke, P.L. pp. 2291-2296 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The Yucca Mountain Site Characterization Project (YMP) involves a complex set of activities and issues. These include the Exploratory Studies Facility (ESF), site characterization surface-based testing, performance assessment, public outreach and information services, conceptual design of a potential repository, compliance with regulations, environmental issues, transportation of nuclear wastes, and systems engineering. Integration among the scientific and technical activities requires constant attention to keep work focused on determining the suitability of the site and on avoiding irretrievable loss of data. All activities must be conducted with due regard to quality assurance and safety and health. This paper provides a brief summary of the status of these activities as of December, 1993.

86 **Implementation of the underground tests at the exploratory studies facility.** Boyle, W.J. (Department of Energy, Las Vegas, NV (United States)); Elkins, N.Z. pp.

200-202 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Underground testing at Yucca Mountain is required by federal regulations and must be conducted to accordance with the regulation requirements. This has led to a more controlled and formal process for test implementation than would typically be used for underground testing and laboratories not subject to regulation. This paper describes the implementation process used at Yucca Mountain, tests implemented to date, and tests to be implemented in the near term.

87 **Experimental investigation of natural convection about drift-emplaced waste canisters.** Culbreth, W.G. (Univ. of Nevada, Las Vegas (United States)); Wang, Qun. pp. 290-292 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract FC08-90NV10872. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Cylindrical waste canisters placed horizontally in the underground drifts of a nuclear repository will emit decay heat by convection to the surrounding air and by radiation heat transfer. In drifts with no forced air circulation, natural convection about the waste canisters will play an important role in controlling the temperature distribution inside the canisters and on the drift wall. Experiments were conducted to visualize the flow about model canisters and to measure the steady-state temperature distribution about the canister. The results show an enhancement in heat transfer when compared to heat flow between infinitely long eccentric horizontal cylinders. A discussion of the observed flow regimes as a function of Rayleigh number is provided to describe the various experimental results.

88 **Unsaturated flows in a porous medium containing a heated air annulus.** Chen, Y.T. (Univ. of Nevada, Las Vegas (United States)); Manuel, D.; Boehm, R. pp. 349-351 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

An experimental study is reported of moisture penetration into a simulated heated drift. Temperature and humidity traces are given for episodic water input.

89 **On significance of route specific data for transportation risk analysis.** Sathisan, S.K. (Univ. of Las Vegas, Las Vegas, NV (United States)); Madhavapeddi, K. pp. 481-483 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Pursuant to the enactment of federal legislation, the U.S. Department of energy (DOE) is presently evaluating Yucca Mountain as a candidate site for a repository to store spent nuclear fuel (SNF) and high-level radioactive waste (HLRW). Risk analyses could be used to support transportation decisions (such as route and mode selection) pertaining to the repository program. This paper presents a case study of Lincoln County, Nevada to discuss the significance of input data required to support risk analysis (Sathisan and Madhavapeddi 1994). Specifically, the methodology adopted to obtain the key input data indicative of local conditions along transport corridors and the results obtained using the same are discussed. Two key inputs identified were population density and transportation infrastructure characteristics in terms of safety/accident data. A methodology was developed to estimate population density along the transport route. Accident data pertinent to the segments of the transportation network were used as inputs in the risk analysis. The preliminary findings show that Lincoln County could be exposed to different risk levels and risk distribution than the nation as a whole for highway shipments of SNF. One primary issue to be addressed is the need for, and the significance of, route specific analysis versus the use of analyses based on national average data.

90 **Design of a transportation impact analysis system.** Parentela, E.M. (Univ. of Las Vegas, Las Vegas, NV (United States)); Sathisan, S.K. pp. 484-486 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The potential siting of a proposed geologic repository to Yucca Mountain, Nevada needs to consider various transportation impacts to affected states and counties. Evaluation of these impacts requires a transportation plan that identifies routing options and addresses safety concerns. The development and use of a Geographic Information System (GIS) based information management system to support a variety of impact assessments is summarized in this paper.

91 **Software QA for the Yucca Mountain project.** Harris, S.D. (Science Applications International Corporation, Las Vegas, NV (United States)). pp. 519-520 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

A software quality assurance (QA) program has been developed within the U.S. Department of Energy (DOE), Office of Civilian Radioactive Waste Management (OCRWM), to comply with program requirements. A select group of individuals from affected organizations has provided input and direction for this program.

92 **Technical data hierarchy and control at the Yucca Mountain project.** Matras, J.R. (Science Application International Corporation, Las Vegas, NV (United States)). pp. 521-523 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Data as defined by Webster are 'factual information used as a basis for reasoning, discussion, or calculation'.

Technical data are defined by the project as 'scientific, environmental, socioeconomic, and engineering numerical values or factual information resulting from data acquisition or data development activities.' Technical data can be qualitative, quantitative, or graphic. Samples (core, soil, grab, water, etc.) are not in and of themselves technical data. Technical data will be used by the Department of Energy to license a site as a repository for high level radioactive waste. On the Yucca Mountain Site Characterization Office (YMSCO) project this data evolves in many different ways. This paper differentiates between the different technical data evolution methodologies by categorizing these methodologies and establishing a hierarchy and appropriate controls. Six evolution categories of data collected and used on the project are discussed in this paper.

93 **Institutional and technical integration – the real meaning.** Peck, J.H. (SAIC, Las Vegas, NV (United States)). pp. 721-722 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The process of institutional and technical integration for projects like the Yucca Mountain Site Characterization Project (YMP) is not defined by organizational charts or interface documents. It is a progressive interplay of communication among a wide variety of groups which often do not understand each other. Scientists and engineers find it difficult to explain complex technical relationships and analyses to legislators, lawyers or regulatory executives in a way which will allow understanding of the general principles, without complete technical immersion. The institutional groups on the other hand find it difficult to convey to the technical fraternity, their need for simple examples or models in order to base strategy and decision-making on a commonly understandable, yet technically sound foundation. This session will look at three views of the process: (1) what the institutions need to know, (2) what the technical people want to tell, and (3) what works and what does not.

94 **Building trust and confidence: The long road ahead.** Cook, G. (Department of Energy, Las Vegas, NV (United States)); Ulick, M. pp. 734-735 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Over the last few years, a cultural shift within the U.S. Department of Energy (DOE) has highlighted the need for the DOE to engage in measures to build public trust and confidence. The Yucca Mountain Site Characterization Office (YMSCO) is dedicated to pursuing, inviting and continuing open two-way communication between the DOE and the public.

95 **The development of engineering coursework on nuclear waste management.** Culbreth, W.G. (Univ. of Nevada, Las Vegas, NV (United States)). pp. 741-743 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Many nuclear engineering programs offer a course in nuclear waste management to acquaint students with the handling of both high and low-level radioactive waste material and the methods used for their final disposal. Courses on this topic have been taught at the University of Nevada, Las Vegas to serve the needs of the local community involved in Yucca Mountain site characterization and Nuclear Test Site employees. Topic of importance in the engineering curriculum are discussed along with the need for courses at several academic levels.

96 **Distance learning and its application to the Yucca Mountain Site Characterization Project.** Brandt, J. (SAIC, Las Vegas, NV (United States)); Sizemore, J. pp. 753-754 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This paper discusses the concept of distance learning, which is used to exchange information via electronic media with real time interaction. Issues concerning policy, funding, legislation, accessibility, and programming are outlined. Possible applications for education, business, and federal projects, with a focus on the Yucca Mountain Site Characterization Project, are also discussed.

97 **Rural migration decision relating to Yucca Mountain.** Soden, D.L. (Univ. of Nevada, Las Vegas, NV (United States)); Carns, D.E.; Ansell, J.P. pp. 757-758 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Individual and family migration decisions were assessed to ascertain the degree to which the siting of the proposed Yucca Mountain repository would influence decisions to remain, leave, or leave and return to the region. Data collected in Lincoln and Nye Counties in Nevada were used. The results of the two studies show that there is little or no impact of the proposed repository on residential choice decisions.

98 **Public participation practices at work: The process for determining site suitability.** Cook, G. (Department of Energy, Las Vegas, NV (United States)); Summerson, J.; Ulick, M. pp. 781 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This paper briefly describes efforts at the Department of Energy Yucca Mountain Site Characterization Office to improve public participation. A program has been designed to involve the public in decision making. Though still in the early stages of development, the process has been successful.

99 (CONF-950570–21) **Continuous, environmental radon monitoring program at the Yucca Mountain Site Characterization Project.** Liu, N.; Sorensen, C.D.; Tung, C.H.; Orchard, C.R. Science Applications International

Corp., Las Vegas, NV (United States). [1995]. 3p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-87NV10576. From International high-level radioactive waste management conference: progress toward understanding; Las Vegas, NV (United States); 1-5 May 1995. Order Number DE95012123. Source: OSTI; NTIS; INIS; GPO Dep.

A continuous, environmental radon monitoring program has been established in support of the Department of Energy's (DOE) Yucca Mountain Site Characterization Project (YMP). The monitoring program is to characterize the natural radon emissions at the YMP site, to understand the existing radon concentrations in the environmental background, and to assess and control the potential work exposure. Based upon a study of the monitoring results, this paper presents a preliminary understanding of the magnitudes, characteristics, and exposure levels of radon at the YMP site.

100 (CONF-950570–23) **Radon concentration and working level in the Exploratory Studies Facility (ESF).** Stiver, J.H.; Tung, Chao-Hsiung. Science Applications International Corp., Las Vegas, NV (United States). [1995]. 3p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. From International high-level radioactive waste management conference: progress toward understanding; Las Vegas, NV (United States); 1-5 May 1995. Order Number DE95012996. Source: OSTI; NTIS; INIS; GPO Dep.

Radon-222 (^{222}Rn) and ^{222}Rn progeny WL monitoring in the Exploratory Studies Facility (ESF) was initiated to support regulatory compliance. Measurements were taken over two periods, in Test Alcove No. 1 of the ESF, about 60 m from the tunnel entrance. For both periods, ^{222}Rn concentration was less than 10% of the Derived Air Concentration (DAC) set forth in DOE Order 5480.11. Thus, these assessments were sufficient to demonstrate regulatory compliance. Based on these findings, quarterly ^{222}Rn and ^{222}Rn progeny monitoring was initiated. Two systems each were employed for ^{222}Rn and ^{222}Rn progeny measurement. No significant differences were observed between the respective systems. An interesting finding was that at the time the measurements were taken, barometric pressure appeared to be the predominant factor controlling ^{222}Rn concentration in the ESF. This was true even during periods of ventilation shutdown.

101 (CONF-950570–24) **Anisotropy of mechanical properties of tuff at Yucca Mountain.** Karakouzian, M.; Hudyma, N. Nevada Univ., Las Vegas, NV (United States). [1995]. 2p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. From International high-level radioactive waste management conference: progress toward understanding; Las Vegas, NV (United States); 1-5 May 1995. Order Number DE95013014. Source: OSTI; NTIS; INIS; GPO Dep.

The purpose of this study is to investigate anisotropy of mechanical properties, namely, compressive strength and modulus, for Tiva Canyon welded tuff from the starter tunnel at Yucca Mountain. Mechanical properties of Tiva Canyon Tuff are needed for the design of the ramps and drifts within the Tiva Canyon horizon. Approximately one cubic foot block samples, all of which were from the thermo – mechanical unit TCw, were obtained from a muck pile containing excavated rock from the starter tunnel. Specimens were cored from the block samples in two distinct orientations: parallel and perpendicular to the lithophysal cavity orientation. Since lithophysal cavity orientation is predominantly horizontal in the field, parallel specimens can be considered horizontal and perpendicular specimens vertical with respect to the rock mass. The specimens were NX sized (5.4 cm diameter) and had a length-to-diameter ratio of 2:1. The air dried specimens were tested at room temperature in a triaxial chamber at confining pressures of 0.1, 5, and 10 MPa, and at a compressive axial strain rate of 10^{-5} s^{-}. The Young's Modulus values were calculated by a least squares fit of stress - strain data between 10 and 50% of the ultimate strength.

102 (CONF-9506204–1) **TBM tunneling on the Yucca Mountain Project: Proceedings.** Williamson, G.E.; Gowring, I.M. (ed.). Science Applications International Corp., Las Vegas, NV (United States). [1995]. 20p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-87NV10576. From 1995 rapid excavation and tunneling conference; San Francisco, CA (United States); 18-21 Jun 1995. Order Number DE95014249. Source: OSTI; NTIS; INIS; GPO Dep.

The US Department of Energy's (DOE) Yucca Mountain Project (YMP) is a scientific endeavor to determine the suitability of Yucca Mountain for the first long term, high level nuclear waste repository in the United States. Status of this long-term project form the construction perspective is described. A key element is construction of the Exploratory Studies Facility (ESF), which is being excavated with a 7. 6 m(25 ft) diameter tunnel boring machine (TBM). Development of the ESF may include the excavation of over 15 km (9.3 mi) of tunnel varying in size from 3 to 7.6 m(10 to 25 ft). Prior to construction, extensive constructibility reviews were an interactive part of the final design. Intent was to establish a constructible design that met the long-term stability requirements for radiological safety of a future repository while maintaining flexibility for the scientific investigations and acceptable tunneling productivity.

103 (DOE/ER/14352–1, pp. 439-442) **Yucca Mountain Site Characterization Project issues in rock mechanics.** Voegele, M.D. (Science Applications International Corp., Las Vegas, NV (United States)). Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

The U.S. High Level Waste Disposal Program is investigating a site at Yucca Mountain, Nevada to determine whether or not it is suitable location for the development of a deep mined geologic repository. At this time the U.S. Program is investigating a single site, although the past configuration of the program involved successive screening and comparison of alternative locations. The repository design concept is a mined excavation at a depth of approximately 300 m below the crest of Yucca Mountain and at a distance of approximately 300 m above the regional groundwater table. The site is in volcanic rocks, comprising alternating layers of welded and non-welded volcanic tuffs. The non-welded tuffs underlying the proposed repository horizon are extensively zeolitized. The strategy for disposal safety relies on both engineered and natural barriers to form a defense in depth. The strategy builds upon the aridity of the site, the unsaturated character of the host rock, and the deep regional water table. Rock mechanics issues for the Yucca Mountain Site Characterization Project (YMP) derive from regulatory requirements codified at 10 CFR Part 60, the Nuclear Regulatory Commission's (NRC) licensing criteria for a

high-level waste repository. The criteria address safety issues that are embodied in 10 CFR Part 60 as performance objective. These safety issues comprise concerns of repository safety for the time frame prior to permanent closure and for the time frame after permanent closure. For the time frame prior to closure, performance objective deal with issues related to retrieval and worker and public radiological health and safety. For the post closure time frame, the safety issues address concerns related to waste package lifetime, waste package release rate, prewaste emplacement groundwater travel time and compliance with the disposal regulations promulgated by the Environmental Protection Agency (EPA) which are found at 40 CFR 191.

104 (DOE/NV/10872–T91) **Identification and characterization of conservative organic tracers for use as hydrologic tracers for the Yucca Mountain site characterization project: Quality Assurance Project Plan, Revision 1: Quarterly progress report, October 1, 1993–December 31, 1993.** Stetzenbach, K.J. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. 13 Dec 1993. 52p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94007777. Source: OSTI; NTIS; INIS; GPO Dep.

The purpose of this work is to identify and characterize candidate conservative organic tracers for use as hydrologic tracers for experiments to be conducted at the Yucca Mountain C-well complex. During this quarter the main effort was directed towards rewriting the quality assurance program in preparation for a review and audit by the USGS. However, due to budget constraints the review and audit were not carried out. The tracer QA plan and standard operating procedures (SOPs) were revised and copies are included in the report. Instrumental problems were encountered and corrected with the addition of new integration and sample control software. In the sampling, there was an unexplained peak in the chromatograms of the tracers being tested in the light tuff. This was not correctable and these experiments will be repeated in the next quarter.

105 (DOE/NV/10872–T94) **Identification of subsurface microorganisms at Yucca Mountain: Second quarterly report, October 1, 1993–December 31, 1993.** Stetzenbach, L.D. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1993]. 14p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94007780. Source: OSTI; NTIS; GPO Dep.

The primary effort of this past quarter was to develop a procedure where accumulated data files could be evaluated to determine the naming consistency and inter-relationships of the various species which have been identified by the Microbial Identification System (MIDI) system. This involved a series of steps, including the clustering of similarly named organisms in a dendrogram format to determine how closely similarly named isolates are related. The experience of other researchers using the MIDI system has shown that clusters which are joined at a Euclidian distance of 10 or less belong to the same species. Strains which are very similar cluster at less than 6 Euclidian units and clusters below two units have nearly identical fatty acid patterns. When the dendrograms derived from the springs were scrutinized, some organisms were found which did not match the pattern of their named group. Then a decision was made whether to rename the isolates and exclude them from the group or redefine the group. This decision was assisted by plotting the principal components derived from an analysis of the fatty acid composition of members of the genus. Each species can be examined by the same procedure to determine group homogeneity. In these 2-dimensional plots members of the same species are roughly bounded by a box of 100 squared units while closely related strains are grouped more tightly together. The 2-dimensional plot of isolates of Micrococcus luteus demonstrates the presence of three identifiable sub-species.

106 (DOE/NV/10872–T103) **Rural migration in Nevada: Lincoln County. Phase 1, 1992–1993.** Soden, D.L.; Cams, D.E.; Mosser, D.; Conary, J.S.; Ansell, J.P. Nevada Univ., Las Vegas, NV (United States). Southwestern Social Science Research Center. [1993]. 206p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94011946. Source: OSTI; NTIS; INIS; GPO Dep.

The principal objective of this project was to develop insight into the scope of migration of working age Nevadans out of their county of birth; including the collection of data on their skill levels, desire to out or in-migrate, interactions between families of migratory persons, and the impact that the proposed high-level nuclear waste repository at Yucca mountain might have on their individual, and collective, decisions to migrate and return. The initial phase of this project reported here was conducted in 1992 and 1993 in Lincoln County, Nevada, one of the counties designated as "affected" by the proposed repository program. The findings suggest that a serious out-migration problem exists in Lincoln County, and that the Yucca mountain project will likely affect decisions relating to migration patterns in the future.

107 (DOE/NV/10872–T110) **Identification of subsurface microorganisms at Yucca Mountain: Third quarterly report, January 1, 1994–March 31, 1994.** Stetzenbach, L.D. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1994]. 4p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94011953. Source: OSTI; NTIS; INIS; GPO Dep.

Bacteria isolated from ground water samples taken from 31 springs during 1993 were collected and processed according to procedures described in earlier reports. These procedures required aseptic collection of surface water samples in sterile screw-capped containers, transportation to the HRC microbiology laboratory, and culture by spread plating onto R2A medium. The isolates were further processed for identification using a gas chromatographic analysis of fatty acid methyl esters (FAME) extracted from cell membranes. This work generated a presumptive identification of 113 bacterial species distributed among 45 genera using a database obtained from Microbial ID, Inc., Newark, Delaware (MIDI). A preliminary examination of the FAME data was accomplished using cluster analysis and principal component analysis software obtained from MIDI. Typically, bacterial strains that cluster at less than 10 Euclidian distance units have fatty acid patterns consistent among members of the same species. Thus an organism obtained from one source can be recognized if it is isolated again from the same or any other source. This makes it possible to track the distribution of organisms and monitor environmental conditions or fluid transport mechanisms. Microorganisms are seldom found as monocultures in natural environments. They are more likely to be closely associated with other genera with complementary metabolic requirements. An understanding

of the indigenous microorganism population is useful in understanding subtle changes in the environment. However, classification of environmental organisms using traditional methods is not ideal because differentiation of species with small variations or genera with very similar taxonomic characteristics is beyond the capabilities of traditional microbiological methods.

108 (DOE/NV/10872–T124) **Identification and characterization of conservative organic tracers for use as hydrologic tracers for the Yucca Mountain Site characterization study: Progress report, April 1, 1994–June 30, 1994.** Stetzenbach, K. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1994]. 13p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94019223. Source: OSTI; NTIS; GPO Dep.

The work performed during this quarter consists of the continuation of the batch studies of the fluorinated benzoic acids and the evaluation of LC/MS for analysis of the fluorinated benzoic acids.

109 (DOE/NV/10872–T132) **Yucca Mountain Site Characterization Project Harry Reid Center Quality Assurance Support: Quarterly report, April 1, 1994–June 30, 1994.** Cross-Smiecinski, A. Nevada Univ., Las Vegas, NV (United States). [1994]. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94019231. Source: OSTI; NTIS; GPO Dep.

For the cooperative agreement quarters 4/1/94 through 6/30/94, HRC QA staff performed the following: Certification samples were analyzed for inorganics/volatiles, inorganics and inorganics, respectively. The data reports were submitted by HRC to the scoring agencies. Data verification was performed for Fingerprinting and Ground Water Quality Monitoring data. The procedures for data verification and validation are not complete. Field sampling was performed on six well samples and a few more wells were considered as possible sampling sites. Baseline sampling is now complete for the inorganics determinations for all YM-remote accessible sites that were finalized in January 1994.

110 (DOE/NV/10872–T134) **Identification of subsurface microorganisms at Yucca Mountain: 4th Quarterly report, April 1, 1994–June 30, 1994.** Stetzenbach, L.D. Nevada Univ., Las Vegas, NV (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94019233. Source: OSTI; NTIS; GPO Dep.

This progress report details the identification of bacteria in ground water samples from 29 springs at Ash Meadows and Death Valley at Yucca Mountain.

111 (DOE/NV/10872–T136) **Analytical laboratory and mobile sampling platform: Progress report, April 1, 1994–June 30, 1994.** Stetzenbach, K. Nevada Univ., Las Vegas, NV (United States). [1994]. 22p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94019235. Source: OSTI; NTIS; GPO Dep.

For the cooperative agreement quarters 4/1/94 through 6/30/94, HRC QA staff performed the following: Experimentation on the microwave rock digestion continued during this quarter, however no results from the round robin analyses have been received. Data verification was performed for Fingerprinting and Ground Water Quality Monitoring data. The procedures for data verification and validation are not complete. Field sampling was performed on six well samples and a few more wells were considered as possible sampling sites. The HRC is waiting to hear from AMESH regarding pumping of the C-wells complex and the WT wells for an opportunity to collect ground water samples at near-field sites. Analyses of samples collected in May and June will proceed during July. In addition internal analytical and esternal background data are being compiled.

112 (DOE/NV/10872–T140) **Identification of subsurface microorganisms at Yucca Mountain. Quarterly report, July 1, 1994–September 30, 1994.** Stetzenbach, L.D. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95003614. Source: OSTI; NTIS; INIS; GPO Dep.

Bacteria isolated from ground water samples taken from springs at Yucca Mountain during 1993 were collected and processed. Three bacterial genera commonly found in water (Pseudomonas, Hydrogenophaga, and Alteromonas) were selected for extensive review during this quarter. The presence of bacteria representative of these genera in samples from the 18 springs sampled in Ash Meadows and from 14 springs in Death Valley was reviewed. The species level of identification of the three bacterial genera in water samples from the springs were examined by cluster analysis to see how much variation existed within a given species and also to determine if a species with essentially the same FAME pattern was isolated from several springs.

113 (DOE/NV/10872–T141) **Identification and characterization of conservative organic tracers for use as hydrologic tracers for the Yucca Mountain Site Characterization Study. Progress report, July 1, 1994–September 30, 1994.** Stetzenbach, K. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1994]. 20p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95003613. Source: OSTI; NTIS; INIS; GPO Dep.

The work performed during this quarter consists of the continuation of the batch studies for the fluorinated benzoic acids and the evaluation of LC/MS for the analysis of these potential tracers. Column studies for these compounds have also been initiated.

114 (DOE/NV/10872–T143) **Analytical laboratory and mobile sampling platform. Progress report, July 1, 1994–September 30, 1994.** Stetzenbach, K. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95003611. Source: OSTI; NTIS; INIS; GPO Dep.

This report summarizes progress made during the quarter on site characterization studies for the Yucca Mountain Project. Work is continuing on developing a procedure for dissolution of rock, primarily tuff, so that the samples we received from the USGS can be analyzed. The goal of this effort is to provide chemical data that the USGS and the HRC can use to compare the concentration of about 40 elements in ground water and the host rock through which it moves. This work is being coordinated with a similar effort at the NTS to determine if the ground water chemistry can be used to evaluate leakage or mixing between the tuff and carbonate aquifers.

115 (DOE/NV/10872–T158) **A floristic survey of Yucca Mountain and vicinity, Nye County, Nevada.** Niles, W.E.; Leary, P.J.; Holland, J.S.; Landau, F.H. Nevada Univ., Las Vegas, NV (United States). Dec 1994. 51p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95007343. Source: OSTI; NTIS; INIS; GPO Dep.

A survey of the vascular flora of Yucca Mountain and vicinity, Nye County, Nevada, was conducted from March to June 1994. An annotated checklist of recorded taxa was compiled. Voucher plant specimens were collected and accessioned into the Herbarium at the University of Nevada, Las Vegas. Collection data accompanying these specimens were entered into that herbarium's electronic data base. Combined results from this survey and the works of other investigators reveal the presence of a total of 325 specific and intraspecific taxa within the area, these allocated to 162 genera and 53 families. Owing to drought conditions prevalent throughout the area, the annual floristic component was largely absent during the period of study, and it is likely much under-represented in the tabulation of results. No taxon currently listed as threatened or endangered under the Endangered Species Act was encountered during this study. Several candidate species for listing under this Act were present, and distributional data for these were recorded. No change in the status of these candidate species is recommended as the result of this survey.

116 (DOE/NV/10872–T160) **Analytical laboratory and mobile sampling platform. Progress report, October 1, 1994–December 31, 1994.** Stetzenbach, K. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95007341. Source: OSTI; NTIS; GPO Dep.

This paper is a quarterly report describing the use of a new soil gas collection device which allows the collection of soil gas in the field for later analysis in the laboratory. It describes the installation of this sampling device and the procedure for setting the probe, extraction of soil gas beneath the surface, and sealing of the soil gas for transport. The sites used for initial testing was the top of Yucca Mountain and Crystal Spring in Ash Meadows National Wildlife Refuge. The results from this initial test showed no volatile matter present in the soil at these locations.

117 (DOE/NV/10872–T163) **Identification and characterization of conservative organic tracers for use as hydrologic tracers for the Yucca Mountain site characterization study. Progress report, October 1, 1994–December 31, 1994.** Stetzenbach, K.; Farnham, I. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1994]. 26p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95007338. Source: OSTI; NTIS; GPO Dep.

The bromide anion has been used extensively as a tracer for mapping the flow of groundwater. It has proven to be both a safe and reliable groundwater tracer. The goal in this study is to find several tracing compounds with characteristics similar to the bromide anion to be used in multiple well tracing tests. Four groups of fluorinated organic acids were selected as candidates for groundwater tracers. These groups include fluorinated benzoic acids (FBA), fluorinated salicylic acids (FSA), fluorinated toluic acids (FTA), and fluorinated cinnamic acids (FCA). These compounds have been shown to move readily with the flow of water and do not adsorb to soil. They are also non-toxic. In this study, the retention of the fluorinated organic acids on to a soil column is compared to that of the bromide ion. The time required for the elution of each analyte from the soil column is measured using a UV-Vis detector. The soils consist of the light, medium, and dark tuffs used in the batch study. The work performed during this quarter consists of the continuation of the batch studies for the fluorinated benzoic acids and column studies for several potential tracer compounds.

118 (DOE/NV/10872–T186) **DOE Waste Package Project. Quarterly progress report, January 1, 1995–March 31, 1995.** Ladkany, S.G. Nevada Univ., Las Vegas, NV (United States). [1995]. 37p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95011940. Source: OSTI; NTIS; INIS; GPO Dep.

Research progress is reported on the design of containers for high-level radioactive wastes to be emplaced at the Yucca Mountain underground repository. Tasks included: temperature distribution and heat flow around the containers; failure possibility due to mechanical stresses and pitting corrosion; robotic manipulation of the containers; and design requirements of rock tunnel drift for long term storage.

119 (DOE/NV/10872–T190) **Yucca Mountain Site Characterization Project - Harry Reid Center QA support. Quarterly report, January 1, 1995–March 31, 1995.** Cross-Smiecinski, A. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1995]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95011944. Source: OSTI; NTIS; INIS; GPO Dep.

Results pertaining to the state of Nevada U.S. EPA water pollution certification sample scores are presented. This quality assurance program is part of the Yucca Mountain Site Characterization Project.

120 (DOE/NV/10872–T194) **Analytical laboratory and mobile sampling platform. Progress report, January 1, 1995–March 31, 1995.** Stetzenbach, K. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1995]. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95011948. Source: OSTI; NTIS; INIS; GPO Dep.

Rock samples from Nevada, including tuff samples from the Yucca Mountain area, were analyzed. Analytical results are presented.

121 (DOE/NV/10872–T195) **Identification and characterization of conservative organic tracers for use as hydrologic tracers for the Yucca Mountain Site characterization study. Progress report, January 1, 1995–March 31, 1995.** Stetzenbach, K.; Farnham, I. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1995]. 13p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95011949. Source: OSTI; NTIS; INIS; GPO Dep.

Fluorinated organic acids were utilized in a test study as hydrologic tracers for the Yucca Mountain Project. Fluorinated acids included cinnamic acid; benzoic acid, and toluic acid. Results are discussed pertaining to retention time, elution time, and stability.

122 (DOE/NV/10872–T203) **Fingerprinting of ground water by ICP-MS. Progress report, April 1, 1995–June 30, 1995.** Stetzenbach, K. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1995]. 23p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95016294. Source: OSTI; NTIS; GPO Dep.

Data for the Ash Meadows six week study, eight wells south and west of the NTS, J-12, J-13 and Tippipah, Topopah and Cane springs have been verified and are included in this report. The three NTS springs, Tippipah, Topopah and Cane, are being studied under a grant from the NTS, but the data are also included here because of the proximity to the Yucca Mountain Site. Latitude and longitude for each well and the three NTS springs are provided.

123 (DOE/NV/10872–T204) **Identification and characterization of conservative organic tracers for use as hydrologic tracers for the Yucca Mountain Site Characterization study. [Quarterly] progress report, April 1, 1995–June 3, 1995.** Stetzenbach, K.; Farnham, I. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1995]. 30p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95016295. Source: OSTI; NTIS; GPO Dep.

The focus for this quarter has been on completing the laboratory studies in preparation for the C-Well tracer tests. These studies include measuring the solubilities for each of the fluorinated benzoic acids as well as determining the stabilities of these compounds through both batch and column testing. A batch test for four pyridone compounds was also initiated. The Tracer QA procedures were approved by the YM USGS on May 24, 1995. The batch testing was repeated using these procedures.

124 (DOE/NV/10872–T208) **Mechanical properties of tuffaceous rocks under triaxial conditions.** Karakouzian, M.; Hudyma, N. Nevada Univ., Las Vegas, NV (United States). Dept. of Civil and Environmental Engineering. Dec 1994. 152p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95016299. Source: OSTI; NTIS; GPO Dep.

Yucca Mountain has been designated as a potential site for a high level nuclear waste repository. Part of the site characterization program is an investigation of the mechanical properties of, the tuffs which comprise Yucca Mountain. This study tested specimens of TCw tuff in triaxial compression to observe the effects of confining pressure, saturation, strain rate, and anisotropy on the compressive strengths and Young's Moduli of the specimens. Test results have shown that increasing the confining pressure increased the compressive strength and generally increased the Young's Modulus. Saturation appears to lower both the compressive strength and Young's Modulus of the specimens. Increasing strain rates increases the compressive strengths, but lowers the Young's Modulus values. There appears to be a stiffness anisotropy where the specimens are stiffer perpendicular to the orientation of the lithophysal cavity orientation. Correlations with porosity have shown an increase in porosity generally lowers both the compressive strength and the Young's Modulus of the specimens. From the triaxial tests, the Mohr – Coulomb strength parameters have also been determined. A comparison between the strengths and modulus values from this study, values from previous studies and the suggested values reveal that the values computed for this study are generally lower than the previously published data. This discrepancy may be due to sample and specimen differences between the studies.

125 (DOE/NV/10872–T213) **Surface markers. [Quarterly report, January 1–June 30, 1995].** Andrews, W.B. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1995]. 16p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95016305. Source: OSTI; NTIS; GPO Dep.

This research examined information on natural phenomena and human activities to ultimately recommend specific sites for surface markers to warn future generations of the potential hazards of disposed waste. Literature pertaining to previous marker designs was reviewed and summarized. This literature primarily addressed the recommendations of a consultant team for developing a marker system to warn future generations about radioactive waste (WIPP, New Mexico). Literature on archeological markers (e.g., Nazca lines in Peru, pyramids) and their durability was also covered. Application to Yucca Mountain is discussed; sites for possible placement of surface markers are considered.

126 (DOE/NV/10872–T215) **Heat transfer studies. Quarterly report.** Boehm, R.; Chen, Y.T.; Vallebuona, J. Nevada Univ., Las Vegas, NV (United States). Heat Transfer Lab. 20 Jul 1995. 22p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95016307. Source: OSTI; NTIS; GPO Dep.

Nitrogen gas has been used in experimental studies related to understanding issues in the extension of multiphase models to sub-residual saturation conditions during drying. Two different flow rates of 1 SLPM and 0.5 SLPM with a room temperature boundary condition on the aluminum column have been examined. Information about variations of humidity and temperatures is given. It is shown that the situation that exists in the experiments is somewhat different than that found in typical assumptions made by numerical modelers. Work planned for the next quarter is outlined. The apparatus used for the work noted above will be supplemented to allow other temperature conditions than ambient to be evaluated. Temperatures up to 90°C will be used. Other work planned for the next period will involve the use of small-scale simulated repository experiment to determine temperatures and humidities around a horizontal heater within an annulus in a rigid porous medium. The effect of backfill on performance when episodic flows are encountered will be compared to results when backfill is not present (the latter results have been determined earlier).

127 (DOE/NV/10872–T219) **Waste package project quarterly report, April 1, 1995–June 30, 1995.** Ladkany, S.G. Nevada Univ., Las Vegas, NV (United States). 20 Jul 1995. 94p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95016315. Source: OSTI; NTIS; INIS; GPO Dep.

Research activities spanned multidisciplinary areas: structural and stress analysis of the container including nonlinear yield and damage assessment and structural stability studies of the dynamic behavior of the steel multipurpose container under normal and accidental handling conditions; nuclear fission criticality studies in the canisters; investigation of novel canister design concepts and corrosion studies; heat transfer studies of the waste canisters and in adjacent rock drifts; fluid flow in porous media and radionuclide transport in near field rock; stresses and stability of the rock

formations resulting from thermal loading of fuel elements and multi-tunnel concept being analyzed; faulted rock tunnel model; and three link steel robot for remote handling of high level nuclear waste.

128 (DOE/NV/10872–T222) **Heat transfer studies.** Boehm, R.; Chen, Y.T.; Sathappan, A.K. Nevada Univ., Las Vegas, NV (United States). 20 Oct 1995. 22p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE96002964. Source: OSTI; NTIS; GPO Dep.

Work continued from last quarter related to studies of heat transfer and fluid flow in porous media. One experiment focused on issues of drying in subresidually-saturated systems. The other experiment deals with studies of flows in a repository-like geometry around a heated horizontal annulus. In the subresidual saturation studies, elevated temperature environments were considered during this quarter. A 1 in. x 8 ft long heating tape (heating capabilities of 8.6 W/in^2) with an on-off type temperature controller has been used to maintain a constant temperature on the aluminum test section (the latter has been described in earlier reports). Nitrogen gas with a flow rate of 1 SLPM was flowed through a glass-bead medium with an isothermal (90°C) boundary condition. The drying characteristics of this system are reported. In a second experiment, that of flow and heat transfer around a simulated drift, a low, constant heat flux boundary condition on the heater has been used. Two different admitted water quantities, 200 ml and 300 ml, have been used as before. The response of temperatures and relative humidity in the porous medium and annulus are very similar to the results of the high constant heat flux on the case of 300 ml water experiments. This is not the case for the 200 ml water experiment. The low constant heat flux with a small quantity of water is found to have no significant effect on the temperature responses.

129 (DOE/NV/10872–T228) **Nuclear waste criticality analysis quarterly progress report, 1 July 1995–30 September 1995.** Culbreth, W.G. Nevada Univ., Las Vegas, NV (United States). 19 Oct 1995. 15p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE96002970. Source: OSTI; NTIS; GPO Dep.

Control of criticality in spent nuclear fuel is necessary during all phases of fuel management during storage, transportation, and permanent disposal. Work completed to date is described. Tasks in the original proposal include: seek coverage by an approved quality control program, review documents related to criticality, attend criticality meetings and workshops, and maintain an expertise in criticality. Current work is covered by Univ. of Nevada QA plan, however, coverage under a more thorough plan will be sought in order that the results can be used during NRC licensing.

130 (DOE/NV/10872–T234) **Yucca Mountain Project quarterly technical progress report, July 1, 1995–September 30, 1995.** Nevada Univ., Las Vegas, NV (United States). [1995]. 2p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE96002976. Source: OSTI; NTIS; INIS; GPO Dep.

Data are given for corrosion tests on candidate alloys (AISI 1010,825, C-22, Monel, C 71500) in synthetic J-13 water and in the same medium concentrate X10.

131 (DOE/NV/10872–T236) **Identification and characterization of conservative organic tracers for use as hydrologic tracers for the Yucca Mountain Site characterization study. Progress report, July 1, 1995–September 30, 1995.** Stetzenbach, K. (Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies); Farnham, I. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1995]. 20p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE96002978. Source: OSTI; NTIS; GPO Dep.

Laboratory work on tracers to be used for C-Well tracer tests is complete. Solubilities for fluorinated benzoic acids in J13 water were determined and the stability of these compounds to both degradation and sorption on ground tuff measured in batch and column tests.

132 (DOE/NV/11417–4) **Great Basin paleoenvironmental studies project: Technical progress report: Fourth quarter, March–May, 1994.** Nevada Univ., Reno, NV (United States). Desert Research Inst. [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-93NV11417. Order Number DE94014166. Source: OSTI; NTIS; GPO Dep.

Examination of the paleoenvironmental and geomorphic records to determine the local and regional impact of past climates will advance the assessment of Yucca Mountain's suitability as a high-level nuclear waste repository. Paleobotanical studies will reconstruct the response of vegetation to climate change at the community and the organismal levels in order to identify periods of mesic climate at Yucca Mountain and the adjacent region during the last 20,000 to 50,000 years. Constructing a history of Great Basin vertebrates, particularly mammals, will provide empirical evidence of past environmental and climatic conditions within the Great Basin. The objective of the geomorphology component of the program is to document the responses of surficial processes and landforms to the climatic changes documented by studies of packrat middens, pollens, and faunal distributions. The goal of the transportation component is to compare the results from three models (FESWMS-2DH, DAMBRK, and FLO-2D) that have been suggested as appropriate for evaluating flood flows on alluvial fans with the results obtained from the traditional one-dimensional, stochastic model used in previous research for the Yucca Mountain Project. Progress on all these tasks is described.

133 (DOE/NV/11417–5) **Great basin paleoenvironmental studies project: Technical progress report first quarter (year 2), June–August 1994.** Nevada Univ., Reno, NV (United States). Desert Research Inst. [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-93NV11417. Order Number DE95001321. Source: OSTI; NTIS; GPO Dep.

The paleobiotic and geomorphic records are being examined for the local and regional impact of past climates to assess Yucca Mountain's suitability as a high-level nuclear waste repository. The project includes botanical, faunal, and geomorphic components that will be integrated to accomplish this goal Progress reports are presented for: Paleobotenical studies in the Great Basin; Paleofaunas studies in the Great Basin; Geomorphology studies in the Great Basin; and Transportation. The goal of the transportation project is to compare the results from three models (FESWMS-2DH, DAMBRK, and FLO-2D) that have been suggested as appropriate for evaluating flood flows on alluvial fans with the results obtained from the traditional one-dimensional, stochastic model used in previous research performed by DRI for the Yucca Mountain Project.

134 (DOE/NV/11417–6) **Great Basin Paleoenvironmental Studies Project: Technical progress report, Second quarter (Year 2), September–December 1994.** Nevada Univ., Reno, NV (United States). Desert Research Inst. [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-93NV11417. Order Number DE95005122. Source: OSTI; NTIS; GPO Dep.

The paleobiotic and geomorphic records are being examined for the local and regional impact of past climates to assess Yucca Mountain's suitability as a high-level nuclear waste repository. In particular these data are being used to provide estimates of the timing, duration and extremes of past periods of moister climate for use in hydrological models of local and regional recharge that are being formulated by USGS and other hydrologists for the Yucca Mountain area. The project includes botanical, faunal, and geomorphic components that will be integrated to accomplish this goal.

135 (DOE/NV/11432–T4) **TBM tunneling on the Yucca Mountain Project.** Morris, J.P. (Kiewit Construction Co., Las Vegas, NV (United States)); Hansmire, W.H. Reynolds Electrical and Engineering Co., Inc., Las Vegas, NV (United States). [1995]. 19p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-94NV11432. Order Number DE95008139. Source: OSTI; NTIS; INIS; GPO Dep.

The US Department of Energy's (DOE) Yucca Mountain Project (YMP) is a scientific endeavor to determine the suitability of Yucca Mountain for the first long-term, high-level nuclear waste repository in the United States. The current status of this long-term project from the construction perspective is described. A key element is construction of the Exploratory Studies Facility (ESF) Tunnel, which is being excavated with a 7.6 m (25 ft) diameter tunnel boring machine (TBM). Development of the ESF may include the excavation of over 15 km (9.3 mi) of tunnel varying in size from 3.0 to 7.6 m (10 to 25 ft). Prior to construction, extensive constructability reviews were an interactive part of the final design. The intent was to establish a constructable design that met the long-term stability requirements for radiological safety of a future repository, while maintaining flexibility for the scientific investigations and acceptable tunneling productivity.

136 (DOE/OSTI–3406-(Suppl.3)(Add.3)) **Yucca Mountain Site Characterization Project bibliography, January–June 1993. An update.** USDOE Office of Scientific and Technical Information (OSTI), Oak Ridge, TN (United States). Nov 1993. 31p. Sponsored by USDOE, Washington, DC (United States). Order Number DE93015389. Source: OSTI; NTIS; INIS; GPO Dep.

Following a reorganization of the Office of Civilian Radioactive Waste Management in 1990, the Yucca Mountain Project was renamed Yucca Mountain Site Characterization Project. The title of this bibliography was also changed to Yucca Mountain Site Characterization Project Bibliography. Prior to August 5, 1988, this project was called the Nevada Nuclear Waste Storage Investigations. This bibliography contains information on this ongoing project that was added to the Department of Energy's Energy Science and Technology Database from January 1, 1993, through June 30, 1993. The bibliography is categorized by principal project participating organization. Participant-sponsored subcontractor reports, papers, and articles are included in the sponsoring organization's list. Another section contains information about publications on the Energy Science and Technology Database that were not sponsored by the project but have some relevance to it.

137 (DOE/OSTI–3406(Suppl.4)) **Yucca Mountain Site Characterization Project bibliography, 1992–1994. Supplement 4.** USDOE Office of Scientific and Technical Information (OSTI), Oak Ridge, TN (United States). Jun 1992. 304p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94005360. Source: OSTI; NTIS; INIS; GPO Dep.

Following a reorganization of the Office of Civilian Radioactive Waste Management in 1990, the Yucca Mountain Project was renamed Yucca Mountain Site Characterization Project. The title of this bibliography was also changed to Yucca Mountain Site Characterization Project Bibliography. Prior to August 5, 1988, this project was called the Nevada Nuclear Waste Storage Investigations. This bibliography contains information on this ongoing project that was added to the Department of Energy's Energy Science and Technology Database from January 1, 1992, through December 31, 1993. The bibliography is categorized by principal project participating organization. Participant-sponsored subcontractor reports, papers, and articles are included in the sponsoring organization's list. Another section contains information about publications on the Energy Science and Technology Database that were not sponsored by the project but have some relevance to it. Earlier information on this project can be found in the first bibliography DOE/TIC-3406, which covers 1977–1985, and its three supplements DOE/OSTI-3406(Suppl.1), DOE/OSTI-3406(Suppl.2), and DOE/OSTI-3406(Suppl.3), which cover information obtained during 1986–1987, 1988–1989, and 1990–1991, respectively. All entries in the bibliographies are searchable online on the NNW database file. This file can be accessed through the Integrated Technical Information System (ITIS) of the US Department of Energy (DOE).

138 (DOE/OSTI–3406-Suppl.4-Add.1) **Yucca Mountain Site Characterization Project Bibliography, January–June 1993. An update: Supplement 4, Addendum 1.** Stephan, P.M. (ed.). USDOE Office of Scientific and Technical Information (OSTI), Oak Ridge, TN (United States). Jan 1995. 31p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94014499. Source: OSTI; NTIS; INIS; GPO Dep.

Following a reorganization of the Office of Civilian Radioactive Waste Management in 1990, the Yucca Mountain Project was renamed Yucca Mountain Site Characterization Project. The title of this bibliography was also changed to Yucca Mountain Site Characterization Project Bibliography. Prior to August 5, 1988, this project was called the Nevada Nuclear Waste Storage Investigations. This bibliography contains information on this ongoing project that was added to the Department of Energy's Energy Science and Technology Database from January 1, 1994 through June 30, 1994. The bibliography is categorized by principal project participating organization. Participant-sponsored subcontractor reports, papers,and articles are included in the sponsoring organization's list. Another section contains information about publications on the Energy Science and Technology Database that were not sponsored by the project but have some relevance to it.

139 (DOE/OSTI–3406(Suppl.4)(Add.2)) **Yucca Mountain Site Characterization Project Bibliography, July–December 1994: An update.** USDOE Office of Scientific and Technical Information (OSTI), Oak Ridge, TN

(United States). Mar 1995. 76p. Sponsored by USDOE, Washington, DC (United States). Order Number DE95005302. Source: OSTI; NTIS; INIS; GPO Dep.

Following a reorganization of the Office of Civilian Radioactive Waste Management in 1990, the Yucca Mountain Project was renamed Yucca Mountain Site Charactrization Project. The title of this bibliography was also changed to Yucca Mountain Site Characterization Project Bibliography. Prior to August 5, 1988, this project was called the Nevada Nuclear Waste Storage Investigations. This bibliography contains information on this ongoing project that was added to the Department of Energy's Science and Technology Database from July 1, 1994 through December 31, 1994. The bibliography is categorized by principal project participating organization. Participant-sponsored subcontractor reports, papers, and articles are included in the sponsoring organization's list. Another section contains information about publications on the Energy Science and Technology Database that were not sponsored by the project but have some relevance to it.

140 (DOE/RW/00134–T7) **Yucca Mountain Site Characterization Project Technical Data Catalog.** USDOE Yucca Mountain Site Characterization Project Office, Las Vegas, NV (United States). 30 Sep 1993. 428p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94005462. Source: OSTI; NTIS; INIS; GPO Dep.

The March 21, 1993, Department of Energy (DOE)/ Nuclear Regulatory Commission (NRC) Site-Specific Procedural Agreement for Geologic Repository Site Investigation and Characterization Program requires the DOE to develop and maintain a catalog of data which will be updated and provided to the NRC at least quarterly. This catalog is to include a description of the data; the time (date), place, and method of acquisition; and where it may be examined. The Yucca Mountain Site Characterization Project (YMP) Technical Data Catalog is published and distributed in accordance with the requirements of the Site-Specific Agreement. The YMP Technical Data Catalog is a report based on reference information contained in the YMP Automated Technical Data Tracking System (ATDT). The reference information is provided by Participants for data acquired or developed in support of the YMP. The Technical Data Catalog is updated quarterly and published in the month following the end of each quarter. A complete revision to the Catalog is published at the end of each fiscal year. Supplements to the end-of-year edition are published each quarter. These supplements provide information related to new data items not included in previous quarterly updates and data items affected by changes to previously published reference information. The Technical Data Catalog, dated September 30, 1993 (this edition), should be retained as the baseline document for the supplements until the end-of-year revision is published and distributed in October 1994.

141 (DOE/RW/00134–T9) **Yucca Mountain Site Characterization Project: Technical Data Catalog quarterly supplement.** USDOE Yucca Mountain Site Characterization Project Office, Las Vegas, NV (United States). 31 Mar 1994. 300p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94010427. Source: OSTI; NTIS; INIS; GPO Dep.

The March 21, 1993, Department of Energy (DOE)/ Nuclear Regulatory Commission (NRC) Site-Specific Procedural Agreement for Geologic Repository Site Investigation and Characterization Program requires the DOE to develop and maintain a catalog of data which will be updated and provided to the NRC at least quarterly. This catalog is to include a description of the data; the time (date), place, and method of acquisition; and where it may be examined. The Yucca Mountain Site Characterization Project (YMP) Technical Data Catalog is published and distributed in accordance with the requirements of the Site-Specific Agreement. The YMP Technical Data Catalog is a report based on reference information contained in the YMP Automated Technical Data Tracking System (ATDT). The reference information is provided by Participants for data acquired or developed in support of the YMP. The Technical Data Catalog is updated quarterly and published in the month following the end of each quarter. A complete revision to the Catalog is published at the end of each fiscal year. Supplements to the end-of-year edition are published each quarter. These supplements provide information related to new data items not included in previous quarterly updates and data items affected by changes to previously published reference information. The Technical Data Catalog, dated September 30, 1993, should be retained as the baseline document for the supplements until the end-of-year revision is published and distributed in October 1994.

142 (DOE/RW/00134–T19) **Technical Data Catalog: Yucca Mountain Site Characterization Project. Quarterly supplement.** USDOE Yucca Mountain Site Characterization Project Office, Las Vegas, NV (United States). 30 Jun 1995. 172p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE95015529. Source: OSTI; NTIS; INIS; GPO Dep.

This report presents reference information contained in the Yucca Mountain Project Automated Technical Data Tracking System. The Department of Energy is seeking to design and maintain a geologic repository for the disposal of high-level radioactive wastes. However, before this repository can be built, the DOE must first do a comprehensive site evaluation. This evaluation is subject to many regulations. This report fulfills the reporting requirements of the Site-Specific Procedural Agreement for Geologic Repository to develop and maintain a catalog of data which will be updated and provided to the Nuclear Regulatory Commission on a quarterly basis. This catalog contains: description of data; time, place, and method of acquisition; and where data may be examined.

143 (DOE/RW–0434) **Site characterization progress report: Yucca Mountain, Nevada, April 1, 1993–September 30, 1993, No. 9.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). Feb 1994. 362p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94008654. Source: OSTI; NTIS; INIS; GPO Dep.

Prepared in accordance with Nuclear Waste Policy Act (Section 113).

In accordance with requirements of Section 113(b)(3) of the Nuclear Waste Policy Act of 1982, as amended, and 10 CFR 60.18(g), the U.S. Department of Energy has prepared this report on the progress of site characterization activities at Yucca Mountain, Nevada, for the period April 1, 1993, through September 30, 1993. This report is the ninth in a series issued at intervals of approximately six months during site characterization of Yucca Mountain as a possible site for a geologic repository for the permanent disposal of high-level radioactive waste. Also included in this report are activities such as public outreach and international programs

that are not formally part of the site characterization process. Information on these activities is provided to report on all aspects of the Yucca Mountain studies.

144 (DOE/RW–0450) **Site characterization progress report: Yucca Mountain, Nevada, October 1, 1993–March 31, 1994.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). Oct 1994. 323p. Sponsored by USDOE, Washington, DC (United States). Source: OSTI (Free of Charge); INIS.

This report is the tenth in a series issued at intervals of approximately six months during site characterization of Yucca Mountain as a possible site for a geologic repository for the permanent disposal of spent nuclear fuel and high-level radioactive waste. Also included in this report are descriptions of activities such as public outreach and international programs that are not formally part of the site characterization process. Information on these activities is provided to report on all aspects of the Yucca Mountain studies. The Executive Summary is intended to provide a summary of major decisions, activities, accomplishments, and issues of interest during the reporting period. Chapter 1, Introduction, provides background information to assist the reader in understanding the current status of the program. Chapter 2 provides specific detailed discussions of activities conducted during the current reporting period and has two major divisions. Section 2.1, Preparatory Activities, provides information on select preparatory activities necessary to conduct site characterization and design activities. Sections 2.2 through 2.8 provide specific details on studies and activities conducted during the reporting period and follow the original structure of the Department's 1988 Site Characterization Plan. Chapter 3 contains the current summary schedule, while Chapter 4 provides a description of the program outreach, including activities during the reporting period, in both the international program and public outreach. Chapter 5 presents an epilogue of significant events that occurred after the end of the reporting period.

145 (DOE/RW–0463) **Site characterization progress report, April 1, 1994–September 30, 1994: Yucca Mountain, Nevada. Volume 11.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). Mar 1995. 405p. Sponsored by USDOE, Washington, DC (United States). Order Number DE95010517. Source: OSTI; NTIS; INIS; GPO Dep.

The Civil Radioactive Waste Management Program was restructured to provide a new approach to the evaluation of the site for development as a repository and to its licensing. Funding was increased for FY 95, with most of the increase going to the Yucca Mountain site characterization project. During this period, significant progress was made in surface-based testing, advanced conceptual design, performance assessment, planning, licensing support system development activities, and construction of the Exploratory Studies Facility. The report is divided into the following sections: introduction, programmatic activities, site programs, repository design, waste package, performance assessment, and exploratory studies facility design/construction.

146 (DOE/RW–0477) **Site characterization progress report: Yucca Mountain, Nevada, October 1, 1994–March 31, 1995, Number 12. Nuclear Waste Policy Act (Section 113).** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). Aug 1995. 600p. Sponsored by USDOE, Washington, DC (United States). Order Number DE96000156. Source: OSTI; NTIS; INIS; GPO Dep.

During the first half of fiscal year 1995, most activities at the Yucca Mountain Site Characterization Project were directed at implementing the Program Plan developed by the Office of Civilian Radioactive Waste Management. The Plan is designed to enable the Office to make measurable and significant progress toward key objectives over the next five years within the financial resources that can be realistically expected. Activities this period focused on the immediate goal of determining by 1998 whether Yucca Mountain, Nevada, is technically suitable as a possible site for a geologic repository for the permanent disposal of spent nuclear fuel and high-level radioactive waste. Work on the Project advanced in several critical areas, including programmatic activities such as issuing the Program Plan, completing the first technical basis report to support the assessment of three 10 CFR 960 guidelines, developing the Notice of Intent for the Environmental Impact Statement, submitting the License Application Annotated Outline, and beginning a rebaselining effort to conform with the goals of the Program Plan. Scientific investigation and analysis of the site and design and construction activities to support the evaluation of the technical suitability of the site also advanced. Specific details relating to all Project activities and reports generated are presented in this report.

147 (DOE/RW–95014715) **Site environmental report for calendar year 1994, Yucca Mountain Site, Nye County, Nevada.** USDOE Yucca Mountain Site Characterization Project Office, Las Vegas, NV (United States). Jun 1995. 117p. Sponsored by USDOE, Washington, DC (United States). Order Number DE95014715. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization office has established an environmental program to ensure that facilities are operated in order to protect, maintain, and restore environmental quality, minimize potential threats to the environment and the public, and comply with environmental policies and US DOE orders. The status of the environmental program has been summarized in this annual report to characterize performance, confirm compliance with environmental requirements, and highlight significant programs and efforts during CY 1994. Monitoring, archaeology, groundwater, ecosystems, tortoise conservation, waste minimization, etc., are covered.

148 (DOE/YMPO–001) **Final recommendations of the Peer Review Panel on the use of seismic methods for characterizing Yucca Mountain and vicinity.** USDOE Nevada Operations Office, Las Vegas, NV (United States). Yucca Mountain Project Office. 22 Jan 1991. 33p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94014099. Source: OSTI; NTIS; INIS; GPO Dep.

The Peer Review Panel was charged with deciding whether seismic methods, which had been utilized at Yucca Mountain with mixed results in the past, could provide useful information about the Tertiary structure in the Yucca Mountain area. The objectives of using seismic methods at Yucca Mountain are to: (a) obtain information about the structural character of the Paleozoic-Tertiary (Pz-T) contact, and (b) obtain information about the structural and volcanic details within the Tertiary and Quaternary section. The Panel recommends that a four part program be undertaken to test the utility of seismic reflection data for characterizing the structural setting of the Yucca Mountain area. The Panel feels strongly that all four parts of the program must be completed

in order to provide the highest probability of success. The four parts of the program are: (a) drill or extend a deep hole in Crater Flat to provide depth control and allow for the identification of seismic reflectors in an area where good quality seismic reflection data are expected; (b) undertake a full seismic noise test in Crater Flat, test 2D receiver arrays as well as linear arrays; perform an expanding spread test using both P and S wave sources to obtain a quick look at the reflection quality in the area and see if shear wave reflections might provide structural information in areas of unsaturated rock; (c) acquire a P wave seismic reflection profile across Crater Flat through the deep control well, across Yucca Mountain, and continuing into Jackass Flats; and (d) acquire a standard VSP (vertical seismic profiling) in the deep control well to tie the seismic data into depth and to identify reflectors correctly.

149 (DOE/YMSCO–002) **Applications of natural analogue studies to Yucca Mountain as a potential high level radioactive waste repository.** Science Applications International Corp., Las Vegas, NV (United States). Feb 1995. 29p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-87NV10576. Order Number DE95009812. Source: OSTI; NTIS; INIS; GPO Dep.

The 5-member group convened in Las Vegas, Nov. 11-13, 1991, to clarify the extent to which studies of natural analogues can assist the Yucca Mountain site characterization (SC) project. This document is to provide guidance and recommendations to DOE for the implementation of natural analogue studies in the SC program. Performance assessment, integrity of engineered barriers, and communication to the public and the scientific community are stressed. The reference design being developed by Babcock & Wilcox Fuel Company are reviewed. Guidelines for selecting natural analogues are given. Quality assurance is discussed. Recommendations are given for developing an effective natural analogue program within the SC program.

150 (DOE/YMSCO–003) **In-situ thermal testing program strategy.** USDOE Yucca Mountain Site Characterization Project Office, Las Vegas, NV (United States). Jun 1995. 100p. Sponsored by USDOE, Washington, DC (United States). Order Number DE96001065. Source: OSTI; NTIS; INIS; GPO Dep.

In the past year the Yucca Mountain Site Characterization Project has implemented a new Program Approach to the licensing process. The Program Approach suggests a stepwise approach to licensing in which the early phases will require less site information than previously planned and necessitate a lesser degree of confidence in the longer-term performance of the repository. Under the Program Approach, the thermal test program is divided into two principal phases: (1) short-term in situ tests (in the 1996 to 2000 time period) and laboratory thermal tests to obtain preclosure information, parameters, and data along with bounding information for postclosure performance; and (2) longer-term in situ tests to obtain additional data regarding postclosure performance. This effort necessitates a rethinking of the testing program because the amount of information needed for the initial licensing phase is less than previously planned. This document proposes a revised and consolidated in situ thermal test program (including supporting laboratory tests) that is structured to meet the needs of the Program Approach. A customer-supplier model is used to define the Project data needs. These data needs, along with other requirements, were then used to define a set of conceptual experiments that will provide the required data within the constraints of the Program Approach schedule. The conceptual thermal tests presented in this document represent a consolidation and update of previously defined tests that should result in a more efficient use of Project resources. This document focuses on defining the requirements and tests needed to satisfy the goal of a successful license application in 2001, should the site be found suitable.

151 (EGG–11265-1058) **The terrestrial ecosystem program for the Yucca Mountain Project.** Ostler, W.K.; O'Farrell, T.P. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). [1994]. 15p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. (CONF-940225–112: Waste management '94: working towards a cleaner environment, Tucson, AZ (United States), 27 Feb - 3 mar 1994). Order Number DE94012670. Source: OSTI; NTIS; INIS; GPO Dep.

DOE has implemented a program to monitor and mitigate impacts associated with site Characterization Activities at Yucca Mountain on the environment. This program has a sound experimental and statistical base. Monitoring data has been collected for parts of the program since 1989. There have been numerous changes in the Terrestrial Ecosystems Program since 1989 that reflect changes in the design and locations of Site Characterization Activities. There have also been changes made in the mitigation techniques implemented to protect important environmental resources based on results from the research efforts at Yucca Mountain. These changes have strengthened DOE efforts to ensure protection of the environmental during Site Characterization. DOE,has developed and implemented an integrated environmental program that protects the biotic environment and will restore environmental quality at Yucca Mountain.

152 (EGG–11265-1066) **Land reclamation on the Nevada Test Site: A field tour.** Winkel, V.K.; Ostler, W.K. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). [1993]. 4p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. (CONF-9310276–5: 8. wildland shrub and arid land restoration symposium, Las Vegas, NV (United States), 19-21 Oct 1993). Order Number DE94012666. Source: OSTI; NTIS; INIS; GPO Dep.

An all-day tour to observe and land reclamation on the Nevada Test Site was conducted in conjunction with the 8th Wildland Shrub and Arid Land Restoration Symposium. Tour participants were introduced to the US Department of Energy reclamation programs for Yucca Mountain Site Characterization Project and Treatability Studies for Soil Media (TSSM) Project. The tour consisted of several stops that covered a variety of topics and studies including revegetation by seeding, topsoil stockpile stabilization, erosion control, shrub transplanting, shrub herbivory, irrigation, mulching, water harvesting, and weather monitoring.

153 (EGG–11265-1073) **Yucca Mountain Biological Resources Monitoring Program: Progress report, October 1992–December 1993.** EG and G Energy Measurements, Inc., Las Vegas, NV (United States). May 1994. 70p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. Order Number DE94016797. Source: OSTI; NTIS; INIS; GPO Dep.

The US Department of Energy (DOE) is required by the Nuclear Waste Policy Act of (as amended in 1987) to study and characterize the suitability of Yucca Mountain as a potential geologic repository for high-level nuclear waste. During site characterization, the DOE will conduct a variety

of geotechnical, geochemical, geological, and hydrological studies to determine the suitability of Yucca Mountain as a potential repository. To ensure that site characterization activities do not adversely affect the environment at Yucca Mountain, a program has been implemented to monitor and mitigate potential impacts and ensure activities comply with applicable environmental regulations. This report describes the activities and accomplishments of EG&G Energy Measurements, Inc. (EG&G/EM) from October 1992 through December 1993 for six program areas within the Terrestrial Ecosystem component of the environmental program for the Yucca Mountain Site Characterization Project (YMP): Site Characterization Effects, Desert Tortoises (Gopherus agassizii), Habitat Reclamation, Monitoring and Mitigation, Radiological Monitoring, and Biological Support.

154 (EGG–11265-1118) **Secondary plant succession on disturbed sites at Yucca Mountain, Nevada.** Angerer, J.P.; Ostler, W.K.; Gabbert, W.D.; Schultz, B.W. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). Dec 1994. 74p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. Order Number DE96000185. Source: OSTI; NTIS; INIS; GPO Dep.

This report presents the results of a study of secondary plant succession on disturbed sites created during initial site investigations in the late 1970s and early 1980s at Yucca Mountain, NV. Specific study objectives were to determine the rate and success of secondary plant succession, identify plant species found in disturbances that may be suitable for site-specific reclamation, and to identify environmental variables that influence succession on disturbed sites. During 1991 and 1992, fifty seven disturbed sites were located. Vegetation parameters, disturbance characteristics and environmental variables were measured at each site. Disturbed site vegetation parameters were compared to that of undisturbed sites to determine the status of disturbed site plant succession. Vegetation on disturbed sites, after an average of ten years, was different from undisturbed areas. Ambrosia dumosa, Chrysothamnus teretifolius, Hymenoclea salsola, Gutierrezia sarothrae, Atriplex confertifolia, Atriplex canescens, and Stephanomeria pauciflora were the most dominant species across all disturbed sites. With the exception of A. dumosa, these species were generally minor components of the undisturbed vegetation. Elevation, soil compaction, soil potassium, and amounts of sand and gravel in the soil were found to be significant environmental variables influencing the species composition and abundance of perennial plants on disturbed sites. The recovery rate for disturbed site secondary succession was estimated. Using a linear function (which would represent optimal conditions), the recovery rate for perennial plant cover, regardless of which species comprised the cover, was estimated to be 20 years. However, when a logarithmic function (which would represent probable conditions) was used, the recovery rate was estimated to be 845 years. Recommendations for future studies and site-specific reclamation of disturbances are presented.

155 (EGG–11265-1136) **Yucca Mountain Biological Resources Monitoring Program. Progress report, January 1994–December 1994.** EG and G Energy Measurements, Inc., Las Vegas, NV (United States). Jul 1995. 81p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. Order Number DE96000155. Source: OSTI; NTIS; INIS; GPO Dep.

The US Department of Energy (DOE) is required by the Nuclear Waste Policy Act of 1982 (as amended in 1987) to study and characterize the suitability of Yucca Mountain as a potential geological repository for high-level nuclear waste. During site characterization, the DOE will conduct a variety of geotechnical, geochemical, geological, and hydrological studies to determine the suitability of Yucca Mountain as a potential repository. To ensure that site characterization activities do not adversely affect the environment at Yucca Mountain, a program has been implemented to monitor and mitigate potential impacts and ensure activities comply with applicable environmental regulations. This report describes the activities and accomplishments of EG and G Energy Measurements, Inc. (EG and G/EM) from January 1994 through December 1994 for six program areas within the Terrestrial Ecosystem component of the environmental program for the Yucca Mountain Site Characterization Project (YMP): Site Characterization Effects, Desert Tortoises (Gopherus agassizii), Habitat Reclamation, Monitoring and Mitigation, Radiological Monitoring, and Biological Support.

156 (EGG–11265-2029) **Effects of soil quality and depth on seed germination and seedling survival at the Nevada test site.** Blomquist, K.W.; Lyon, G.E. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). [1993]. 22p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. (CONF-9310276–3: 8. wildland shrub and arid land restoration symposium, Las Vegas, NV (United States), 19-21 Oct 1993). Order Number DE94006476. Source: OSTI; NTIS; INIS; GPO Dep.

The Nuclear Waste Policy Act, as amended in 1987, directs the US Department of Energy (DOE) to study Yucca Mountain, in southern Nevada, as a potential site for long-term storage of high-level nuclear waste. DOE policy mandates the restoration of all lands disturbed by site characterization activities and DOE has developed an environmental program that is to be implemented during site characterization activities at Yucca Mountain. DOE is currently conducting reclamation feasibility trials as part of this environmental program. No topsoil was saved on disturbances during early site investigation and minimal soil remains at existing disturbances on Yucca Mountain. A study was developed to test the effects of soil quality and depth on seedling emergence and survival. A series of plots was established and two treatments were tested. The first treatment compared native topsoil to subsoil imported from a borrow pit. The second treatment compared four different depth ranges of both soil types. All plots received identical seeding treatments. Seedling density was measured after emergence. Overall seedling densities were low, averaging 10.3 ± 8.8 (SD) plants/m^2. Statistical analysis revealed a significant interaction between the two treatment factors. The subsoil had increasing densities from the deep soil depths to the shallow depths while the topsoil had increasing densities from the shallow soil depths to the deep depths. The cause of this interaction may have resulted from the bedrock being close to the soil surface of the shallow plots.

157 (EGG–11265-2030) **The influence of annual species composition and density on perennial seedling density in four plant communities in the Northern Mojave Desert.** Hall, P.F. (EG and G Energy Measurements, Inc., Las Vegas, NV (United States)); Angerer, J.P.; Ostler, W.K.; Schultz, B.W. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). [1993]. 25p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. (CONF-9310276–1: 8. wildland shrub

and arid land restoration symposium, Las Vegas, NV (United States), 19-21 Oct 1993). Order Number DE94006475. Source: OSTI; NTIS; GPO Dep.

According to the Nuclear Waste Policy Act of 1982 (as amended in 1987), the US Department of Energy (DOE) must study and characterize Yucca Mountain as a potential site for long-term underground storage of high-level nuclear waste. Part of the overall site characterization program is to monitor potential impacts on the biological resources at Yucca Mountain. A part of the biological monitoring program, assessed vegetation parameters included density of annual and perennial seedlings. This data was used to evaluate: (1) seed germination and seed survival; and (2) if annual plant species density and cover influence perennial seedling survival. Twelve permanent 200 × 200-m ,study plots were established in each of four vegetation associations present in the Yucca Mountain Project area. During the spring of 1992, 20 to 60, 1-m^2 randomly-located quadrats per study plot were measured for perennial seedling density, annual species density, and annual species composition. Perennial seedlings found in 1992 were relocated in the spring of 1993, and survival determined. Cover was measure in the spring of 1992. Annual plant density and cover was greatest in the Larrea-Lycium-Grayia vegetation association, and lowest in the Larrea-Ambrosia vegetation association. Annual seedling density had a negative exponential relationship with perennial seedling density in 1992. However, non-linear regression analysis indicated that 1992 annual seedling density had a greater impact on survival of pemnial seedlings from 1992 to 1993.

158 (EGG–11265-2031) **Plant succession on disturbed sites in four plant associations in the Northern Mojave Desert.** Gabbert, W.D.; Schultz, B.W.; Angerer, J.P.; Ostler, W.K. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). [1993]. 20p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. (CONF-9310276–2: 8. wildland shrub and arid land restoration symposium, Las Vegas, NV (United States), 19-21 Oct 1993). Order Number DE94006482. Source: OSTI; NTIS; GPO Dep.

The US Department of Energy (DOE) is characterizing Yucca Mountain Nevada, as a potential site for long-term underground storage of high-level nuclear waste. DOE is committed to reclaim all lands disturbed by the project, and return them to a stable ecological state, with a composition and productivity similar to predisturbance conditions. A study was implemented to assess plant species which naturally invade disturbed sites in the Yucca Mountain Project Area. In 1991 and 1992 study plots were established on disturbed sites. Sites were characterized by disturbance type (i.e., road, drill pad, etc.), disturbance severity, vegetation association, time since abandonment, and topographic placement. Density of all perennial plant species was measured on disturbed and undisturbed plots. The species with the highest density in disturbed sites was Chrysothamnus teretifolia. This species was not a major contributor in undisturbed sites. In the undisturbed sites Ambrosia dumosa had the highest density of perennial plant species but was also high in density in the disturbance sites. Total species density was higher in undisturbed sites compared to disturbed sites. Plant species density analysis compared disturbed and undisturbed vegetation associations. Results will be used to design reclamation field trails and to finalize the Yucca Mountain Project Reclamation Implementation Plan.

159 (EGG–11265-2035) **The effect of drought on four plant communities in the northern Mojave Desert.** Schultz, B.W. (Desert Research Inst., Reno, NV (United States)); Ostler, W.K. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). [1993]. 18p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. (CONF-9310276–12: 8. wildland shrub and arid land restoration symposium, Las Vegas, NV (United States), 19-21 Oct 1993). Order Number DE95004166. Source: OSTI; NTIS; GPO Dep.

Desert plant communities contain many perennial plant species that are well adapted to arid environments; therefore, one would intuitively believe that perennial desert species readily survive drought conditions. Abundant research on plant-soil-water relationships in North American deserts has shown that many species can maintain water uptake and growth when the soil-water potential is low. Little research, however, has focused on how prolonged drought conditions affect plant species in vegetation associations in desert ecosystems. A prolonged and widespread drought occurred in much of the western United States, including the Northern Mojave Desert, from 1987 through 1991. During this drought period vegetation characterization studies, initiated in 1990, by the US Department of Energy (DOE) at Yucca Mountain, Nevada, allowed EG and G Energy Measurements to collect data that could be used to infer how both desert vegetation associations and desert plant species reacted to a prolonged drought. This paper presents the preliminary results.

160 (EGG–11265-2036) **Species and community response to above normal precipitation following prolonged drought in the northern Mojave Desert.** Schultz, B.W. (Nevada Univ., Reno, NV (United States). Desert Research Inst.); Ostler, W.K. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). [1993]. 21p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. (CONF-9310276–7: 8. wildland shrub and arid land restoration symposium, Las Vegas, NV (United States), 19-21 Oct 1993). Order Number DE94013571. Source: OSTI; NTIS; GPO Dep.

Little information is available on how desert plant communities that are dominated by perennial species respond to normal and above normal precipitation following prolonged drought. Intuitively, one would expect total canopy cover to increase. Whether a concomitant increase in the density of perennial species also occurs is unknown. Even less is known about how individual species respond to above normal precipitation following drought. From 1987 through 1991 a prolonged drought occurred in much of the western United States, including the northern Mojave Desert. In March 1991 the northern Mojave Desert received well above normal precipitation. The following two winters (December–March) also had above normal precipitation (150 to 200 % of normal, unpublished data). Ongoing vegetation characterization studies by the US Department of Energy (DOE) at Yucca Mountain, Nevada, allowed EG&G Energy Measurements to collect data that could be used to infer how both vegetation associations and individual species respond to above normal precipitation following prolonged drought. This paper reports the preliminary results.

161 (LBL–30043, pp. 148-183) **A mechanical model for repeated slip events along normal faults in the basin and range: Applications to Yucca Mountain, Nevada.** Kemeny, J.M. Lawrence Berkeley Lab., CA (United States).

Dec 1990. DOE Contract AC03-76SF00098. In *Geotechnical support and topical studies for nuclear waste geologic repositories: Annual report, fiscal year 1989.* 186p. Order Number DE94003377. Source: OSTI; NTIS; INIS.

A mechanical model has been developed to calculate the effects of repeated slip events along pre-existing normal faults in the Basin and Range. The model calculates the aseismic and seismic deformation due to the propagation of slip along the normal fault, and the moment and energy release associated with seismic motion. Also, the model calculates regional stress changes associated with a slip event, from which changes in the level of the water table are estimated. The model is used to predict the effects of a slip event on normal faults in the vicinity of Yucca Mountain, Nevada, which is the proposed site for underground nuclear waste storage.

162 (LBL–35381) **Thermal modeling for a potential high-level nuclear waste repository at Yucca Mountain, Nevada.** Pruess, K. (Lawrence Berkeley Lab., CA (United States). Earth Sciences Div.); Tsang, Y. Lawrence Berkeley Lab., CA (United States). Mar 1994. 83p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. Order Number DE94011016. Source: OSTI; NTIS; INIS; GPO Dep.

Repository performance models based on numerical simulation of fluid and heat flows have recently been developed by several different groups. Model conceptualizations generally focus on large-scale average behavior. This comparison finds that current performance assessment (PA) models use generally similar approximations and parameters. Certain differences exist in some performance-relevant parameters, especially absolute permeabilities, characteristic curves, and thermal conductivities. These reflect present uncertainties about the most appropriate parameters applicable to Yucca Mountain and must be resolved through future field observations and laboratory measurements. For a highly heterogeneous fractured-porous hydrogeologic system such as Yucca Mountain, water infiltration through the unsaturated zone is expected to be dominated by highly localized phenomena. These include fast channelized flow along preferential paths in fractures, and frequent local ponding. The extended dry repository concept proposed by the Livermore group is reviewed. Predictions of large-scale drying around the repository on the average for large thermal loads cannot be taken to indicate that waste packages will not be contacted by liquid water, and that aqueous-phase transport of contaminants is not possible. Specifically, the authors find that modest water infiltration, on the order of a few millimeters per year, would be sufficient to overwhelm the vaporization capacity of the repository heat and inundate the waste packages within a time frame of a few thousand years. A preliminary analysis indicates that channelized flow of water may persist over large vertical distances. The vaporization-condensation cycle has a capacity for generating huge amounts of ponded water. A small fraction of the total condensate, if ponded and then episodically released, would be sufficient to cause liquid phase to make contact with the waste packages.

163 (PNC-TN–1100-94-003, pp. IV/19-IV/28) **Total system performance assessment for Yucca Mountain.** Boak, J.M. (USDOE Yucca Mountain Site Characterization Project Office, Las Vegas, NV (United States)). Power Reactor and Nuclear Fuel Development Corp., Tokyo (Japan). 1994. (CONF-9311199–: International workshop on research and development of geological disposal, Tokai (Japan), 15-19 Nov 1993). In *Proceedings of technical session on research and development of geological disposal.* 379p. Order Number DE95757546. Source: OSTI; NTIS; INIS.

As part of the U.S. Department of Energy's evaluation of site suitability for a potential high-level radioactive waste repository, the long-term behavior of the mined geologic disposal system must be determined. This determination requires a knowledge of the characteristics of the present natural system, waste-package and engineered-system designs, a description of the environment around the emplacement zone, and descriptions of possible perturbations that may affect the nature of the engineered and natural systems. In 1991, participants in the Yucca Mountain Site Characterization Project completed a preliminary assessment of the likely performance of a potential repository at Yucca Mountain, Nevada. This preliminary assessment evaluated aqueous and gaseous flow, future climatic conditions, and disturbances to the system by basaltic volcanism and inadvertent human intrusion. A second total system performance evaluation is currently in progress. This second iteration is building on the previous analyses in a number of ways. More recent site characterization information and a much more complex model representing the source term are being incorporated. Multiple waste package designs, emplacement modes, and areal power densities are being analyzed. (author).

164 (SAIC–94-001) **A comparison of two potential repositories: The Waste Isolation Pilot Plant and Yucca Mountain.** Pflum, C.G. Science Applications International Corp., Las Vegas, NV (United States). 11 Jul 1994. 29p. Sponsored by USDOE, Washington, DC (United States). Order Number DE95012990. Source: OSTI; NTIS; INIS; GPO Dep.

Two repositories in the same country, yet Congress and the DOE manage them differently. While Congress encumbers WIPP with unanticipated oversight and inappropriate regulations, Congress streamlines the commercial repository program and promises improved regulations for Yucca Mountain. While DOE encouraged science at the expense of the WIPP infrastructure, DOE postponed its scientific investigations at Yucca Mountain and constructed an infrastructure, large enough to support an ambitious program that was never realized. Somewhere between WIPP and Yucca Mountain lies an ideal repository program. A program where consistent national policy promotes progress; where lucid regulations inspire confidence; where science and infrastructure are balanced; and where oversight groups do not become the tail that wags the dog. Neither WIPP nor Yucca Mountain are ideal programs, but each has its advantages that approach the ideal. Consistent national policy would steer the ideal repository program in a predictable direction. Here Yucca Mountain has the advantage. Successive legislation has streamlined the siting process and promises better regulations. From the beginning, the ideal program would know its regulators and regulations. Again, Yucca Mountain has the advantage. More familiar with regulators and regulations, the Yucca Mountain program had the foresight not to declare HLW to be hazardous and subject to dual regulations. The ideal program would equitably balance its science and infrastructure. Here neither program has the advantage and could possibly represent extremes. The WIPP's emphasis on scientific investigations left it with little or no infrastructure to deal with regulations and oversight. A regulatory infrastructure, for example, could have forewarned WIPP that its in situ tests were not relevant to the

regulations. On the opposite extreme, the Yucca Mountain's emphasis on infrastructure left it with less money for scientific investigations.

165 (SAIC–94-002) **A review of the methods used by the US Environmental Protection Agency to assess the financial impacts of the repository regulations.** Pflum, C.G.; Mattson, S.R.; Matthusen, A.C. Science Applications International Corp., Las Vegas, NV (United States). 16 Feb 1994. 24p. Sponsored by USDOE, Washington, DC (United States). Order Number DE95012991. Source: OSTI; NTIS; INIS; GPO Dep.

All Federal agencies must consider the financial impacts of their regulations. When costs significantly outweigh benefits, the Office of Management and Budget can recommend that Congress not provide the funds needed to implement the regulation. Without funds, the agency is forced to either revise or retract the regulation. This has happened previously with a regulation on uranium mill tailings proposed by the US Nuclear Regulatory Commission (NRC) and it could happen again with the US Environmental Protection Agency (EPA) regulations that govern the disposal of high-level radioactive waste (HLW). The EPA (1985, 1992) claims that its regulation: "Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste" (40 CFR Part 191 or standards) does not increase costs above what the US Department of Energy (DOE) would spend anyway or, at most, what the DOE would spend to comply with 10 CFR Part 60: a regulation promulgated by the NRC. This report reviews and disputes the EPA claim. In Chapter 2 a summary of the basis for the EPA claim is presented and in Chapter 3 a critique of the basis of the claim is presented. This critique finds the EPA basis unrealistic, incomplete, and misleading. According to the EPA, a repository at Yucca Mountain would easily meet 40 CFR Part 191 even without the use of special engineered barriers. Because the NRC regulation (10 CFR Part 60) requires engineered barriers, the EPA places the onus for regulatory costs on the NRC. We disagree; the EPA standards drive regulatory costs as much as NRC regulations. The EPA has the higher responsibility for setting the overall standard for safety while the NRC can only implement this standard.

166 **Waste package/engineered barrier system design concepts for the direct disposal of spent fuel in the potential United States' repository at Yucca Mountain, Nevada.** Stahl, D. (B and W Fuel Co., Las Vegas, NV (United States)); Harrison, D.J. pp. 9-15 of Proceedings of the 1993 international conference on nuclear waste management and environmental remediation. Volume 1: Low and intermediate level radioactive waste management. Alexandre, D.; Baker, R.; Kohout, R.; Marke, J. (eds.). American Society of Mechanical Engineers, New York, NY (United States) (1993). pp. 776 (CONF-930906–: '93 international conference on nuclear waste management and environmental remediation, Prague (Czech Republic), 5-11 Sep 1993).

The goal of the US Department of Energy's (DOE) Yucca Mountain Site Characterization Project (YMP) waste package development program is to design a waste package and associated engineered barrier system (EBS) that meets the applicable regulatory requirements for safe disposal of spent nuclear fuel and solidified high-level waste (HLW) in a geologic repository. Attainment of this goal relies on a multibarrier approach, the unsaturated nature of the Yucca Mountain site, consideration of technical alternatives, and sufficient resolution of technical and regulatory uncertainties. To accomplish this, an iterative system engineering approach will be used. The NWPA of 1982 limits the content of the first US repository to 70,000 metric tons of heavy metal (MTHM). The DOE Mission Plan describes the implementation of the provisions of the NWPA for the waste management system. The Draft 1988 approach will involve selecting candidate designs, evaluating them against performance requirements, and then selecting one or two preferred designs for further detailed evaluation and final design. The reference design of the waste package described in the YMP Site Characterization Plan is a thin-walled, vertical borehole-emplaced waste package with an air gap between the package and the rock wall. The reference design appeared to meet the design requirement. However, the degree of uncertainty was large. This uncertainty led to considering several more-robust design concepts during the Advanced Conceptual Design phase of the program that include small, drift-emplaced packages and higher capacity, drift-emplaced packages, both partially and totally self-shielded. Metallic as well as ceramic materials are being considered.

167 **Determining importance and grading of items and activities for the Yucca Mountain Project.** DeKlever, R. (Raytheon Services Nevada, Las Vegas, NV (United States)); Verna, B. pp. 195-202 of Nuclear materials management. 34th Annual meeting proceedings: Volume 22. Institute of Nuclear Materials Management, Northbrook, IL (United States) (1993). pp. 1190 DOE Contract AC08-91NV10833. (CONF-930749–: 34. annual meeting of the Institute of Nuclear Materials Management, Scottsdale, AZ (United States), 18-21 Jul 1993).

Raytheon Services Nevada (RSN), in support of the Department of Energy's (DOE) Yucca Mountain Project, has been responsible for the Title 2 designs of the initial structures, systems, and components for the Exploratory Studies Facility (ESF), and the creation of the design output documents for the Surface-Based Testing (SBT) programs. The ESF and SBT programs are major scientific contributors to the overall site characterization program which will determine the suitability of Yucca Mountain to contain a proposed High Level Nuclear Waste (HLNW) repository. Accurate, traceable and objective characterization and testing documentation that is germane to the protection of public health and safety, and the environment, and that satisfies all the requirements of 10 CFR Part 60(1), must be established, evaluated and accepted. To assure that these requirements are satisfied, specific design functions and products, including items and activities depicted within respective design output documents, are subjected to the requirements of an NRC and DOE-approved Quality Assurance (QA) program. An evaluation (classification) is applied to these items and activities to determine their importance to radiological safety (ITS) and waste isolation (ITWI). Subsequently, QA program controls are selected (grading) for the items and activities. RSN has developed a DOE-approved classification process that is based on probabilistic risk assessment (PRA) techniques and that uses accident/impact scenarios. Results from respective performance assessment and test interference evaluations are also integrated into the classification analyses for various items. The methodology and results of the RSN classification and grading processes, presented herein, relative to ESF and SBT design products, demonstrates a solid, defensible methodological basis for classification and grading.

168 Operational safety assessment of underground test facilities for mined geologic waste disposal. Elder, H.K. (Dept. of Energy, Las Vegas, NV (United States). Yucca Mountain Site Characterization Project); Caudill, C.J. pp. 319-327 of Proceedings of the 1993 international conference on nuclear waste management and environmental remediation. Volume 1: Low and intermediate level radioactive waste management. Alexandre, D.; Baker, R.; Kohout, R.; Marek, J. (eds.). American Society of Mechanical Engineers, New York, NY (United States) (1993). pp. 776 (CONF-930906–: '93 international conference on nuclear waste management and environmental remediation, Prague (Czech Republic), 5-11 Sep 1993).

This paper describes the operational safety assessment for the underground facilities for the exploratory studies facility (ESF) at the Yucca Mountain Project. The systematic identification and evaluation of hazards related to the ESF is an integral part of the systems engineering process; whereby safety is considered during planning, design, testing, and construction. A largely qualitative approach based on the analysis of potential accidents was used since radiological safety analysis was not required. The risk assessment summarized credible accident scenarios and the design provides mitigation of the risks to a level that the facility can be constructed and operated with an adequate level of safety. The risk assessment also provides reasonable assurance that all identifiable major accident scenarios have been reviewed and design mitigation features provided to ensure an adequate level of safety.

169 Pyritic ash-flow tuff, Yucca Mountain, Nevada. Castor, S.B. (Univ. of Nevada, Reno NV (United States). Nevada Bureau of Mines and Geology); Tingley, J.V.; Bonham, H.F. Jr. *Economic Geology;* 89(2): 401-407 (Mar-Apr 1994).

The Yucca Mountain site is underlain by a 1,500-m-thick Miocene volcanic sequence that comprises part of the southwestern Nevada volcanic field. Rocks of this sequence, which consists mainly of ash-flow tuff sheets with minor flows and bedded tuff, host precious metal mineralization in several areas as near as 10 km from the site. In two such areas, the Bullfrog and Bare Mountain mining districts, production and reserves total over 60 t gold and 150 t silver. Evidence of similar precious metal mineralization at the Yucca Mountain site may lead to mining or exploratory drilling in the future, compromising the security of the repository. The authors believe that most of the pyrite encountered by drilling at Yucca Mountain was introduced as pyroclastic ejecta, rather than by in situ hydrothermal activity. Pyritic ejecta in ash-flow tuff are not reported in the literature, but there is no reason to believe that the Yucca Mountain occurrence is unique. The pyritic ejecta are considered by us to be part of a preexisting hydrothermal system that was partially or wholly destroyed during eruption of the tuff units. Because it was introduced as ejecta in tuff units that occur at depths of about 1,000 m, such pyrite does not constitute evidence of shallow mineralization at the proposed repository site; however, the pyrite may be evidence for mineralization deep beneath Yucca Mountain or as much as tens of kilometers from it.

170 Yucca Mountain reveals its secrets to scientists. Gertz, C.P. (Yucca Mountain Site Characterization Project, Las Vegas, NV (United States)); Teitelbaum, S. *Forum for Applied Research and Public Policy;* 9(3): 106-112 (Fal 1994).

US nuclear power plants have generated some 20,000 metric tons of waste, according to Carl P. Gertz, former Department of Energy (DOE) project manager for Yucca Mountain Site Characterization, and Sheldon Teitelbaum, senior writer for the Las Vegas-based Science Application International Corporation. In the search for disposal methods, DOE fixed on Yucca Mountain, Nevada, a "sprawling heap of volcanic tuff" situated on a parcel of federally owned land 90 miles northwest of Las Vegas. The authors maintain that Yucca Mountain's sparse population, dry climate, deep watertable, and 5,000-foot-thick layer of compressed volcanic rock may make it a suitable long-term storage facility. Nevertheless, Gertz and Teitelbaum say, much research must be done before the site is formally adopted as a repository and begins to receive shipments of high-level nuclear waste.

171 Site characterization at the potential high-level radioactive waste repository site at Yucca Mountain, Nevada. Gertz, C.P. (DOE, Las Vegas, NV (United States)); Cloke, P.L. *Transactions of the American Nuclear Society;* 69: 58 (1993). (CONF-931160–: American Nuclear Society (ANS) winter meeting, San Francisco, CA (United States), 14-18 Nov 1993).

This paper provides a brief summary of recent site characterization activities at Yucca Mountain, Nevada, located in southern Nevada ~100 miles northwest of Las Vegas. Current and future investigations will supply scientific and technical data for evaluating whether the site is suitable for the disposal of high-level nuclear waste. On July 9, 1991, surface-based testing recommenced following several years devoted to U.S. Nuclear Regulatory Commission (NRC) reviews, development, and implementation of an NRC-accepted quality assurance program and the obtaining of required permits. During the past 16 months, numerous trenches and test pits have been excavated or deepened, and many drill holes have been completed.

CRWMS M&O, LAS VEGAS

172 (BNL–52468) Release of radon contaminants from Yucca Mountain: The role of buoyancy driven flow. Sullivan, T.M.; Pescatore, C. Brookhaven National Lab., Upton, NY (United States). Feb 1994. 55p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC02-76CH00016. Order Number DE95011521. Source: OSTI; NTIS; INIS; GPO Dep.

The potential for the repository heat source to promote buoyancy driven flow and thereby cause release of radon gas out of Yucca Mountain has been examined through a critical review of the theoretical and experimental studies of this process. The review indicates that steady-state buoyancy enhanced release of natural radon and other contaminant gases should not be a major concern at Yucca Mountain. Barometric pumping and wind pumping are identified as two processes that will have a potentially greater effect on surface releases of gases.

173 Progress in waste package and engineered barrier system performance assessment and design. Van Luik, A. (CRWMS M&O/Intera, Inc., Las Vegas, NV (United States)); Stahl, D.; Harrison, D. pp. 663-673 of Scientific basis for nuclear waste management XVI. Interrante, C.G. (ed.); Pabalan, R.T. (ed.). Materials Research Society,

Pittsburgh, PA (United States) (1993). pp. 959 From 16. Materials Research Society (MRS) fall meeting; Boston, MA (United States); 30 Nov - 5 dec 1992.

As part of the U.S. Department of Energy's evaluation of site suitability for a potential high-level radioactive waste repository, long-term interactions between the engineered barrier system and the site must be determined. This requires a waste-package/engineered-system design, a description of the environment around the emplacement zone, and models that simulate operative processes describing these engineered/natural systems interactions. Candidate designs are being evaluated, including a more robust, multibarrier waste package, and a drift emplacement mode. Tools for evaluating designs, and emplacement mode are the currently available waste-package/engineered-system performance assessment codes development for the project. For assessments that support site suitability, environmental impact, or licensing decisions, more capable codes are needed. Code capability requirements are being written, and existing codes are to be evaluated against those requirements. Recommendations are being made to focus waste-packaging/engineered-system code-development.

174 Operational considerations in drift emplacement of waste packages. Benton, H.A. (B&W Fuel Co., Las Vegas, NV (United States)). pp. 544-550 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

This paper discusses the operational considerations as well as the advantages and disadvantages of emplacing waste packages in drifts in a repository. The considerations apply particularly to the potential repository for spent nuclear fuel and high-level waste glass at Yucca Mountain, although most of the considerations and the advantages and disadvantages discussed in this paper do not necessarily represent the official views of the DOE or of the Management and Operations Contractor, since most of these considerations are still under active discussion and the final decisions will not be made for some time - perhaps years. This paper describes the issues, suggests some principles upon which decisions should be based, and states some of the most significant advantages and disadvantages of the emplacement modes, and the associated waste package types and thermal loadings.

175 Waste Packager and Areal Power Density Approximator (WPA3) computer code. King, J. (TRW Environmental Safety Systems Inc., Vienna, VA (United States)); Rhodes, C.; Byrne, J. pp. 563-567 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Areal Power Density (APDs) can be used in conjunction with spent fuel characteristics to predict temperature profiles in the proposed Mines Geologic Disposal System (MGDS) at Yucca Mountain. A microcomputer-based computer code called Waste Packager and Areal Power Density (APD) Approximator (WPA3) has been developed to compute waste package inventories and track individual assembly characteristics so that heat output at any point in time can be calculated. The waste package inventories are emplaced using a simple, serial emplacement model to estimate overall APDs and Local APDs (LAPDs) for a realistic, time-phased emplacement of an actual waste stream produced by a system-level model. WPA3 can also be used to aggregate individual waste packages into equivalent, lumped source terms for more realistic and robust thermal analyses.

176 Systems implications of repository thermal loading. Gottlieb, P. (TRW Environmental Safety Systems Inc., Vienna, VA (United States)); Packer, B.; King, J.; Bailey, W. pp. 874-879 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

A study was conducted to determine if implementation of a hot, cold or intermediate repository thermal loading strategy would have specific impacts on the overall civilian Radioactive Waste Management System. For the three thermal loading strategies examined, no significant impacts were found for the waste acceptance, transportation, or storage elements of the system unless it becomes necessary (1) to thermally levelize the waste stream by blending spent fuel or acceptance or at the MRS, (2) to age spent fuel before emplacement, or unless the utilities require acceptance of youngest fuel first. Impacts on the MGDS were found to fall into three categories: Waste package capacity, underground emplacement area requirements, and performance assessment issues (not addressed in this study).

177 The annotated outlined process for a mined geologic disposal system license application. Williamson, T.M. (Duke Engineering & Services, Inc., Las Vegas, NV (United States)); VanCamp Gil, A. pp. 1240-1242 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The U.S. Department of Energy (DOE) is studying Yucca Mountain, Nevada, as a potential site for a mined geologic repository for high-level nuclear waste. DOE has the responsibility to license the potential repository; if the site is found suitable, a license application would be submitted to the U.S. Nuclear Regulatory Commission (NRC). Current plans are to submit the license application in 2001. To manage development of the license application, DOE has developed the Mined Geologic Disposal System Annotated Outline for License Application (AO). The AO provides a method to verify the site characterization program and to implement the guidance given by the NRC in their draft regulatory guide on the license application. In addition, the AO facilities focused interactions with the NRC and will contribute to the clarification of the regulations. The development of the AO is an interactive process; revisions are produced semiannually, and transmitted to the NRC to provide information and to facilitate NRC's staff guidance to DOE. The AO is an effective method to manage the complex and challenging regulatory and technical information requirements for development of the license application.

178 Thinking through the 'rethinking report'. Taylor, E.C. (TRW Environmental Safety Systems Inc., Vienna, VA (United States)). pp. 1259-1262 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States)

(1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Congressional action in late 1992 set aside the existing standards for post-closure safety of a possible repository at Yucca Mountain, Nevada. The Environmental Protection Agency (EPA) must develop new standards based on yet-to-be-completed studies by the National Academy of Sciences. It is not clear when there will be a new standard, and we cannot know what the National Academy studies will reveal. However, we can assess the possible impact by extrapolating a 1990 National Academy position statement that was based on their review of the regulatory features of the high-level radioactive waste disposal program. The analysis here proceeds from basic principles recommended in the position statement, and it develops the implied approach to demonstrating safety. The approach has the desired characteristics proposed in the position statement, but is also depends on and continues what the Department of Energy is already doing at the Yucca Mountain candidate repository site. Its new features are in its approach to organizing the post-closure safety demonstration, and these features are consistent with current planning principles at the Yucca Mountain Site Characterization Project Office. We conclude that if in fact the site is safe, and if the new regulations are consistent with the 1990 National Academy position statement, then these principles can lead to reasonable assurance of safety.

179 Assessments of system impacts of spent fuel thermal characteristics and emplacement rates. Rickertsen, L.D. (TRW Environmental Safety Systems Inc., Vienna, VA (United States)). pp. 1372-1376 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Analysis conducted to evaluate the impacts spent fuel thermal characteristics and emplacement rates might have on the thermal conditions in a candidate geologic repository at the Yucca Mountain site are reported here. These analyses considered the effect of the current projections for the burnup of the spent fuel, the variability in waste thermal characteristics, and the sequence and location of waste emplacement on the repository temperatures relative to those predicted for the Yucca Mountain Site Characterization Plan (SCP). The results show that, for the same conceptual design, the temperatures in the repository would be significantly higher than those considered for the SCP. These results could affect the evaluations of alternative thermal loading strategies for the candidate repository.

180 Integrated test evaluation decision framework for the Yucca Moutain Project. Judd, B.R. (Decision Analysis Co., Portola Valley, CA (United States)); Hoxie, D.T.; Mattson, S.R.; Younker, J.L. pp. 1623-1632 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

An Integrated Test Evaluation decision framework and computer model were developed to help prioritize site-characterization tests at Yucca Mountain. An initial application of the framework evaluated studies described in the Department of Energy's Site Characterization Plan. Priorities were based on the ability of tests to detect unsuitable site conditions, to demonstrate compliance with regulatory requirements, and to build confidence and support within the scientific community. Testing costs were also considered. Results showed priorities to depend most on estimates of the abilities of tests to build scientific confidence and least on estimates of the ability to detect unsuitable site conditions.

181 Yucca Mountain Site Characterization Project performance based 'Q' list. Hulbert, D.I. (TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States)); Blanchard, M.B.; Barton, R.V.; Voegele, M.D. pp. 1653-1656 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

In mid-1992, the Yucca Mountain Site Characterization Project (YMP) initiated a performance based 'Q' List development effort. This effort is intended to evolve a 'Q' List based upon the quantitative technical characteristics of the engineered and natural features of the prospective Mined Geologic Disposal System (MGDS). The resulting 'Q' List determinations will replace the existing list which was formulated on a very conservative basis because of the conceptual nature of the initial MGDS designs. The evolved, performance based 'Q' List will enable the selection of the optimum set of controls to be employed during execution of activities associated with natural and engineered items comprising the MGDS.

182 Detachment faults-regulatory implications for the Yucca Mountain site. Cline, K.M. (Woodward-Clyde Federal Services, Washington, DC (United States)); Fenste, D.F.; Rogers, R.; Summerson, J.R. pp. 1826-1834 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Site characterization investigations at the Yucca Mountain site, Nye County, Nevada consist of a combination of scientific data collection and analysis, and compliance with regulatory requirements. These investigations include studies to evaluate the presence or absence of detachment faults and their significance to assessing site suitability and complying with NRC regulatory requirements. This paper discusses selected structural/tectonic models proposed for Yucca Mountain and the surrounding region that include detachment faults. The presence of detachment faults and their significance are some of the more controversial aspects of the tectonic models and of the geologic setting of Yucca Mountain. The implications of these models with respect to regulatory compliance is addressed. Based on a preliminary evaluation, and depending on the tectonic model(s) adopted, the presence of detachment faults must be considered as potential pathways for long-term performance evaluations, and as a mechanism for marking buried strike-slip faults and distributed faulting at the surface. The detachment faults recognized in the field thus far have no suggestion of being seismogenic sources.

183 Yucca Mountain Site Characterization Project exploratory studies facilities construction status. Allan, J.N. (Morrison Knudsen Corp., Las Vegas, NV (United States)); Leonard, T.M. pp. 2115-2117 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United

States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

This paper discusses the progress to date on the construction, planning and development of the Yucca Mountain Site Characterization Project (YMP) Exploratory Studies Facilities (ESF). The purpose of the ESF is to determine early site suitability and to characterize the subsurface of the Yucca Mountain site to assess its suitability for a potential high level nuclear waste repository. The present ESF configuration concept is for two main ramps to be excavated by tunnel boring machines (TBM) from the surface to the Topopah Spring Member of the Paintbrush Tuff Formation. From the main ramps, slightly above Topopah Spring level, supplemental ramps will be penetrated to the Calico Hills formation below the potential repository. There will be exploratory development drifts driven on both levels with the Main Test Area being located on the Topopah Spring level, which is the level of the proposed repository. The Calico Hills formation lies below the Topopah Spring member and is expected to provide the main geo-hydrologic barrier between the potential repository and the underlying saturated zones in the Crater Flat Tuff.

184 **Demonstration of safety for geologic disposal.** Taylor, E.C. (TRW Environmental Safety Systems, Vienna, VA (United States)); Ramspott, L.D.; Sprecher, W.M. pp. 199-207 of Scientific basis for nuclear waste management XVII. Barkatt, A. (ed.); Van Konynenburg, R.A. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1994). pp. 964 From Fall meeting of the Materials Research Society (MRS); Boston, MA (United States); 29 Nov - 3 dec 1993.

The US Department of Energy (DOE) is developing a nuclear waste management system that will accept high-level radioactive waste, transport it, store it, and ultimately emplace it in a deep geologic repository. The key activity now is determining whether Yucca Mountain, Nevada is suitable as a site for the repository. If so, the crucial technological advance will be the demonstration that disposal of nuclear waste will be safe for thousands of years after closure. This paper assesses the impact of regulatory developments, legal developments, and scientific developments on such a demonstration.

185 (CONF-940225–Vol.1, pp. 497-503) **Management of change.** Nelson, R. (Jacobs Engineering Group, Inc., Albuquerque, NM (United States)); Statton, C.T.; St. Clair, R.K. Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines; New Mexico State Univ., University Park, NM (United States); Waste-Management Education and Research Consortium (WERC), Las Cruces, NM (United States); USDOE, Washington, DC (United States). 1994. From Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994. In *Technology and programs for Radioactive Waste Management and Environmental Restoration. Volume 1.* 814p. Source: Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States).

The Department of Energy has recognized that change is on the horizon. The Yucca Mountain Project is being carried out under the purview of the Office of Civilian Radioactive Waste Management (OCRWM) within the Department, OCRWM, the program and the project are under new leadership. This new leadership is restructuring its operations. This has resulted in a reorganization of the Federal management structure at the Yucca Mountain Project Office. The reorganization is designed to formalize and clarify lines of responsibility and accountability and move the Project Office towards a task oriented organization focused on the science and technology required to determine the suitability of Yucca Mountain. This Federal staffing reorganization is a precursor to the appropriate integration and clarification of the roles and responsibilities of the contractors supporting the project. A high priority has been placed upon making changes which enable the federal leadership to exercise appropriate control and make participants more responsible and accountable for their work. Transition to the new organization will be implemented in four phases: (1) establishing the management construct, (2) defining roles and responsibilities of functional management, (3) development of the task performance teams, and (4) subsequent evolution of the "project team" as a whole. The Yucca Mountain Project is an extremely complex, multi-disciplinary project that is a first-of-a-kind. The complexity of the task has demanded a larger number of project participants that include the best of the nation's resources.

186 **A critically educated public explores high level radioactive waste management.** Blum, J.E. (TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States)). pp. 224-231 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 373 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

It is vital to the citizens of Nevada that they and their children are given an opportunity to explore all sides of the characterization of Yucca Mountain as a potential repository site for spent nuclear fuel. The state-wide, national and international implications demand a reasoned and complete approach to this issue, which has become emotionally and irrationally charged and fueled by incomplete perception and information. The purpose of this paper is to provide curriculum suggestions and recommend concomitant policy developments that will lead to the implementation of a Critical Thinking (CT) approach to High Level Radioactive Waste Management.

187 **Integration of regulations and science for HLW disposal.** Ramspott, L.D. (TRW Environmental Safety Systems, Inc., Livermore, CA (United States)). pp. 292-295 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 373 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

It is difficult to integrate the uncertain, experimental, and evolving nature of science with the specificity that characterizes regulations. The scientific community has criticized the EPA standard and the NRC implementing regulation for being overly prescriptive and inflexible. On the other hand, some interest groups see flexibility as permission to subjugate safety to schedule and cost considerations. A proposed integration is based on three ideas that are specific to Yucca Mountain: (1) total containment of waste over long time-periods is a simple concept that is amenable to regulation, (2) partial mitigation of releases over long time-periods is a complex concept that is not readily amenable to regulation, and (3) retrievably placing waste in the unsaturated zone presents an opportunity for building assurance about containment with long-term confirmatory measurements. A

complete safety argument can be presented to obtain a construction authorization, with uncertainty to be reduced and resolved prior to closure of repository. The focus of regulatory concern in the construction authorization phase of licensing would be on measurements that demonstrate the conceptual repository will prevent water from reaching the waste for a very long time. In this demonstration, large-scale long-term effects of waste heat on water would be treated theoretically. In the confirmatory period leading to closure, the regulatory focus would be on measurements that provide assurance that the repository as designed and built will indefinitely limit the contact of water with waste to negligible amounts. In this demonstration, large-scale long-term effects of waste heat on water would be driven by emplaced waste.

188 **Integrating scientific results for a post-closure safety demonstration.** Taylor, E.C. (TRW Environmental Safety Systems, Inc., Vienna, VA (United States)); Ramspott, L.D.; Sinnock, S.; Sprecher, W.M. pp. 301-305 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 373 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The U.S. Department of Energy (DOE) is developing a nuclear waste management system that will accept high-level radioactive waste, transport it, store it, and ultimately emplace it in a deep geologic repository. The key activity now is determining whether Yucca Mountain, Nevada is suitable as a site for the repository. If so, the crucial technological advance will be the demonstration that disposal of nuclear waste will be safe for thousands of years after closure. Recent regulatory, legal, and scientific developments imply that the safety demonstration must be simple. The scientific developments taken together support a simple set of hypotheses that constitute a post-closure safety argument for a repository at Yucca Mountain. If the understanding of Yucca Mountain hydrology presented in the Site Characterization Plan proves correct, then these hypotheses might be confirmed by combining results of Surface-Based Testing with early testing results in the Exploratory Studies Facility.

189 **Robust EBS design and source-term analysis for the partially saturated Yucca Mountain Site.** Apted, M. (Intera Information Technologies, Inc., Denver, CO (United States)). pp. 485-490 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The concept of robust repository design and assessment is examined. Successful demonstration of decoupling of near-field and far-field performance is a central principle in achieving robustness. An innovative design for the engineered barrier system (EBS) for the partially saturated conditions at Yucca Mountain is described based on this principle of robustness.

190 **Ventilation considerations for repository subsurface advanced conceptual design.** Yang, H. (Morrison Knudsen Corp., Las Vegas, NV (United States)); Bhattacharyya, K.K. pp. 530-537 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A number of preliminary concepts of underground ventilation have been developed recently, as a part of the initial studies of the Advanced Conceptual Design (ACD) for the potential nuclear waste repository at Yucca Mountain. This paper presents the ventilation considerations for the current repository subsurface ACD, and analyzes the methodology that may be applied to future design efforts. The introductory study concentrates on the requirements of air flow rates and the concepts of ventilating air distribution. Analysis includes ventilation considerations for three typical operations stages of the repository: initial excavation, operations (development and emplacement simultaneously), and retrieval of waste. Temperature variations of the ventilating air due to different modes of heat transfer between underground rock, airflow, and waste packages are investigated. This initial ventilation study provides a fundamental first step toward a comprehensive ventilation study for the ACD.

191 **FY93 thermal loading systems study.** Saterlie, S.F. (TRW Environmental Safety Systems, Las Vegas, NV (United States)); Thomson, B.H. pp. 573-585 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 DOE Contract AC01-91RW00134. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The ability to meet the overall performance requirements for the proposed Mined Geologic Disposal System (MGDS) at Yucca Mountain, Nevada, requires the two major subsystems (natural barriers and engineered barriers) to positively contribute to containment and radionuclide migration retardation. In addition to the postclosure performance, the proposed repository must meet certain preclosure requirements of safety, retrievability, operability, and also must take into consideration cost and schedule. The thermal loading strategy chosen for such a repository may significantly affect both the postclosure and preclosure performance of the proposed repository. The FY93 Thermal Loading Systems Study was conducted to start developing the structured, detailed technical basis that will be ultimately required to make a thermal loading decision. Various thermal analyses were done and hydrothermal predictions made to evaluate effects on postclosure performance, operability, monitoring, cost, and worker safety. The results show that sufficient technical justification exists so that a recommendation can be made to narrow the range of thermal loading to between 24 and 100 MTU/acre. To emplace waste below 24 MTU/acre would require more area for the full 63,000 MTU of spent nuclear fuel than exists in the primary area plus the three most likely expansion areas of the Site Characterization Plan Conceptual Design of a Repository (SCP CDR). Compelling evidence was found that, above 100 MTU/acre, the conditions would be "too hot" with most of the thermal goals being violated.

192 **Thermal response of the waste package/MPC and EBS.** Bahney, R.H. III (B&W Fuel Co./Management and Operating Contractor, Las Vegas, NV (United States)); Doering, T.W. pp. 809-815 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Thermal evaluations of the multi-Purpose Canister in repository emplacement have been performed by the Yucca Mountain Site Characterization Project Managing and Operating Contractor (YMP-M&O). Thermal effects have been a major study area of the Mined Geologic Disposal System (MGDS). In the past the project has concentrated primarily on borehole-emplaced waste packages, but the Multi-Purpose Canister (MPC) with a capacity of twenty-one pressurized water reactor (PWR) fuel assemblies (or more) will likely be drift emplaced with a multi-barrier disposal container or overpack. This study investigates the thermal behavior of the waste package/MPC and its effect on the repository near-field. Results indicate that peak internal temperatures occur one to five years post emplacement, and the timing of the peak is highly dependent on the choice of design basis fuel and thermal loading. The maximum acceptable capacity of the MPC, with ten year old fuel, was determined to be twenty-one PWRs based on the current peak temperature goal of 350°C; however, higher capacities can be achieved if older fuel is substituted.

193 **Long term nuclear criticality potential in waste packages.** Thomas, D.A. (B&W Fuel Co./Management and Operating Contractor, Las Vegas, NV (United States)); Doering, T.W. pp. 838-844 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Title 10 CFR 60.131.(b).(7) requires that the radioactive waste disposed of in the Mined Geologic Disposal System (MGDS) remain subcritical during the period of isolation. The period of waste isolation, approximately 10,000 years, represents a time period greater than any previously examined for criticality control of spent fuel. Change in the criticality potential over long time periods for the Multi-Purpose Canister (MPC) waste package conceptual design has been examined and methods of criticality control over this time have been investigated.

194 **Implications of waste package heat output distributions resulting from waste stream variability.** King, J.F. (TRW Environmental Safety Systems, Inc., Vienna, VA (United States)); Rhodes, C.J.; Saterlie, S.F. pp. 868-876 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

This paper describes work performed by the Office of Civilian Radioactive Waste Management (OCRWM) Management and Operating (M&O) Contractor. The work presented in this paper resulted from waste stream analyses conducted in support of the M&O Phase 1 and 2 Repository Thermal Loading Studies. These analyses integrated system design with underground design. The Phase 1 study in particular examined the effects of various system configurations and operating concepts on the waste stream arriving at the proposed repository at Yucca Mountain.

195 **Site characterization plan thermal goals reevaluation.** Saterlie, S.F. (TRW Environmental Safety Systems, Las Vegas, NV (United States)); Garza, J.C. de la. pp. 882-889 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 DOE Contract AC01-91RW00134. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Because performance standards are not established for the Yucca Mountain Site (the Environmental Protection Agency (EPA) standards have been remanded), it is necessary to define surrogate or derived criteria to evaluate performance. The Site Characterization Plan (SCP) in 1988 attempted to define surrogate criteria that could be used to establish repository performance. Since that time, new knowledge has become available and some additional analyses of thermal loading have been performed. Thus it became clear that the thermal goals established in the SCP should be reevaluated. This paper reports on a two month effort undertaken to reevaluate the SCP thermal goals using an expert Working Group. Fifteen thermal goals identified in various sections of the SCP were evaluated by the Working Group. It was recommended that two goals be deleted: (1) to keep borehole wall temperature < 275 degrees C and keep the mid-drift temperature < 100 degrees C. It was also recommended that one goal be added to establish a thermal loading that would not degrade the Upper Paintbrush Tuff Formation (Lowermost Tiva Canyon; Yucca Mountain; Pah Canyon; and Uppermost Topopah Spring Members) (Vitric nonwelded) (PTn) barrier. Two other thermal goals and a process statement were reworded to afford compatibility with any emplacement mode, not just the vertical borehole. A recommendation was made to increase the conservatism of a goal to limit potential impact on the surface environment by limiting temperature rise to < 2 degrees C rather than < 6 degrees C. This revised set of goals was used in the Thermal Loading Systems Study.

196 **Waste package materials selection process.** Roy, A.K. (B&W Fuel Co./M&O Contractor, Las Vegas, NV (United States)); Fish, R.L.; McCright, R.D. pp. 993-999 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The office of Civilian Radioactive Waste Management (OCRWM) of the United States Department of Energy (USDOE) is evaluating a site at Yucca Mountain in Southern Nevada to determine its suitability as a mined geologic disposal system (MGDS) for the disposal of high-level nuclear waste (HLW). The B&W Fuel Company (BWFC), as a part of the Management and Operating (M&O) team in support of the Yucca Mountain Site Characterization Project (YMP), is responsible for designing and developing the waste package for this potential repository. As part of this effort, Lawrence Livermore National Laboratory (LLNL) is responsible for testing materials and developing models for the materials to be used in the waste package. This paper is aimed at presenting the selection process for materials needed in fabricating the different components of the waste package.

197 **Subrepository scale hydrothermal analysis in support of total system performance assessment at Yucca Mountain.** Mishra, S. (CRWMS M&O/INTERA Inc., Las Vegas, NV (United States)). pp. 1202-1213 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American

Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 DOE Contract AC01-91RW00134. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A coupled thermo-hydrologic model is developed to investigate the impact of emplacing high-level nuclear wastes on heat and fluid flow at the subrepository scale, and to develop abstracted results for input to the current total system performance assessment (TSPA) of Yucca Mountain. Numerical computations are carried out in 2-D axisymmetric geometry, using a range of thermal loads, to generate spatial/temporal evolutions in temperature and saturation fields within individual emplacement panels. These results are analyzed to understand the general nature of liquid movement in the repository due to waste heat, and also to define various temperature dependent mechanistic and phenomenological coefficients for predicting waste package and geosphere performance.

198 Radiation effects from uranium ore bodies. Duguid, J.O. (Intera, Inc., Vienna, VA (United States)). pp. 1337-1343 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

An approach to developing environmental regulations for high-level waste repositories is by comparison of the effects of natural analogs to the effects of a geologic repository. This paper examines representative uranium ore bodies based on the premise that a geologic repository should pose no more risk than the unmined uranium ore from which the waste was derived. The US Environmental Protection Agency (EPA) initially examined the effects of uranium ore bodies in developing standards for repositories, and later dropped the comparison in their supporting documentation of the standard (40 CFR 191). Because of the Nuclear Waste Policy Act of 1992, regulations for a repository at Yucca Mountain are again being considered, and information on the effects of uranium ore bodies may contribute to new standard development. This paper develops two repository equivalent uranium ore bodies (in chemically reducing and oxidizing environments) and examines the doses to an individual based on drinking groundwater down gradient from these representative ore deposits. The number of health effects integrated over 10,000 years and the ore body releases are also calculated and compared to the EPA Standard.

199 Repository program licensing approach. Williamson, T.M. (Duke Engineering and Services, Inc., Las Vegas, NV (United States)); Gil, A.V. pp. 1585-1592 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Yucca Mountain, Nevada is currently being studied by the US Department of Energy (DOE) as a potential site for a mined geologic repository for high-level nuclear waste. DOE has the responsibility to determine the suitability of the site and to develop a license application (LA) for authorization to construct the potential repository. If the site is suitable, the license application would be submitted to the US Nuclear Regulatory Commission (NRC). The repository program licensing approach is focused on the timely acquisition of information needed in licensing and the resolution of potential licensing issues with the NRC staff. Licensing involves an iterative process requiring refinements as data are acquired, analyzed, and evaluated. The repository licensing approach presented in this paper ensures that the information is available when needed to facilitate the licensing process. Identifying the information needed to evaluate compliance with the performance objectives in 10 CFR 60, monitoring the acquisition of such information, and developing a successful license application are integral elements of DOE's repository program licensing approach. Activities to characterize the site are being systematically conducted as planned in the Site Characterization Plan (SCP). In addition, DOE is implementing the issue resolution initiative, the license application annotated outline (LAAO) process, and interim licensability evaluations to update the early planning in the SCP and to focus site characterization, design, and performance assessment activities on the acquisition of information needed for a site suitability determination and licensing. Collectively, the issue resolution initiative, LAAO process, and interim licensability evaluations are key elements of a transition to the iterative process to answer the question: "When do we have enough data to support licensing?"

200 Systems engineering applied to the development of the Yucca Mountain project design requirements documents. Rindskopf, M.S. (TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States)); Royer, D.C. pp. 1634-1640 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM) along with its Management and Operating Contractor (M&O) developed a new document hierarchy. The development of the documents, which make up the primary elements of the Yucca Mountain Site Characterization Project requirements baseline, was performed using Systems Engineering Processes tailored to meet the needs of the Yucca Mountain Site Characterization Project.

201 DOE's topical report on a methodology to assess vibratory ground motion and fault displacement hazards at the Yucca Mountain site. Fenster, D.F. (TRW Environmental Safety Systems Inc., Vienna, VA (United States)); Quittmeyer, R.C. pp. 2260-2265 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The DOE's Office of Civilian Radioactive Waste Management is in the process of characterizing the Yucca Mountain site, Nye County, Nevada, to evaluate its suitability for development of a geologic repository for spent fuel and high-level radioactive waste. If the site is found suitable, much of these data and analyses can be used in an application for a license to the Nuclear Regulatory Commission. The topical report and methodology described in this paper represent a revision of the deterministic and probabilistic approaches to

assessing seismic hazards described in DOE's Site Characterization Report. The proposed probabilistic methodology incorporates experience gained while siting and licensing nuclear power plants and other critical facilities during the past decade. In contrast to the traditional deterministic approach, this methodology incorporates all available geologic, geophysical, and seismological data; frequency of occurrence; and variability and uncertainty in both conceptual models and parameters. It also integrates the hazard from all potential sources. Probabilistic approaches have been used primarily to assess hazards from vibratory ground motion, but this approach also applies to assessing fault displacement hazards. The proposed methodology will provide input for design of surface and subsurface facilities (pre- and postclosure periods) and for performance assessment.

202 **Joint spacing criterion for equivalent continuum model.** Tsai, F.C. (Woodward Clyde Federal Services, Las Vegas, NV (United States)). pp. 1-2 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Currently, the Yucca Mountain Site Characterization Project is investigating the feasibility of the disposal of high-level radioactive waste in the unsaturated Topopah Spring formation. The Topopah Spring formation is a heavily fractured, predominantly vertically jointed, welded tuff, and the potential disposal area is cut by the Ghost Dance fault and bounded by several other fault structures. The joints in the tuff and the faults may have an impact on the emplacement drift or borehole stability, as well as on the movement of fluids through the rock mass. The design of the repository drifts and layout, the waste emplacement scheme, and the thermomechanical performance of the rock mass will be analyzed using various numerical models. These models may be based on different assumptions regarding the representation of the fracture behavior under given applied stresses, and will range from discrete models where individual mechanically active fractures are treated distinctly, to continuum models where the joint behavior is smeared over a representative volume. There is always the question of applicability of a model with respect to a given material domain to be analyzed.

203 **Flow and transport simulation in Yucca Mountain using dual-porosity model.** Zhou, W. (Intera Information Technologies, Inc., Denver, CO (United States)); Apted, M.J. pp. 160-162 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Flow and transport of radionuclides in fractured tuff is simulated using the dual-porosity model in a multiphase simulator ECLIPSE. A two-dimensional model is constructed to simulate a cross section of Yucca Mountain, including stratification and heterogeneity. Both a dual-porosity dual-permeability model and a dual-porosity single-permeability model are used. The flow field is simulated and the steady-state flow field is then used to simulate the transport of ^{239}Pu, ^{240}Pu, ^{241}Am, and ^{99}Tc. The matrix diffusion is also included. Pathways for radionuclide transport and radionuclide arrival time to the water table are evaluated.

204 **Parametric analysis of a 1-D infiltration model for Yucca Mountain.** Xiang, Y. (M&O/INTERA, Inc., Las Vegas, NV (United States)); Mishra, S. pp. 188-190 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 Project AC01-91RW00134. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The hydrogeological properties of the formations at Yucca Mountain have been characterized by log-normal distribution. Different realizations of the randomly described formation may assume different hydrological behaviors, and different property variations may exert influences of different significance levels. This study presents a parametric sensitivity and uncertainty analyses of steady-state infiltration through a representative column of the formations at Yucca Mountain.

205 **Approach to calculation of pre-waste-emplacement ground-water travel time.** Berkowitz, L. (TRW Environmental Safety Systems, Washington, DC (United States)); Duguid, J.; Barnard, R. pp. 217-219 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The U.S. Department of Energy (DOE) is developing a methodology for calculating the pre-waste-emplacement ground-water travel time at the Yucca Mountain site in Nevada as part of the work it is doing to determine whether the site is suitable for development as a repository and, if it is suitable, to obtain authorization and a license from the U.S. Nuclear Regulatory Commission (NRC) to construct and operate a geologic repository at the site. The task of developing the methodology is formidable because flow in the unsaturated zone at the site is complex and because the methodology must be consistent with DOE's interpretation of its requirement. This paper describes the DOE approach, which incorporates model development work being conducted by the Sandia National Laboratory and the U.S. Geological Survey, to developing the required methodology.

206 **Testing the abstractions used in total system performance assessments.** Nelson, R.W. (INTERA, Inc./PMO, Las Vegas, NV (United States)). pp. 264-266 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Multiple levels of complexity and detail are involved in the performance assessment models used in the Yucca Mountain project (YMP). Included are the detailed process-level models, and various higher level abstractions or idealizations of those process models, that may be used in the simpler total system simulators for performance assessments. Abstractions are applied to reduce the complex process models to simpler overall simulators for more direct total system analyses. Although seldom done in the past, the abstractions require appropriate testing to demonstrate that each is an appropriate simpler system representation. To be adequate, such testing must either: (1) Demonstrate that essential processes, conceptual representations, and the

parameter variations in the original process-level models are neither lost nor the performance results unduly altered by applying the abstractions, or (2) Show that any significance lost is appropriately bounded by the abstraction assumptions and that subsequent assessments using such bounding assumptions still provide appropriate margins of safety in the overall repository performance. Failure to satisfy one of the above conditions requires changing the abstraction being test until it, in fact, verifies the representation is adequate. Such testing provides the foundation necessary for technically defensible performance assessments using the abstracted total system models. The objective of this paper is to outline an approach for testing any proposed or specific future abstractions of the process-level models used to obtain simpler system simulators for application in total system performance assessments (TSPAs).

207 **A current evaluation of Licensing Support System requirements and implementation.** Dickerson, F. (M&O/Logicon RDA, Washington, DC (United States)); Boone, J.M. pp. 278-280 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The Yucca Mountain Site Characterization Office chartered a working group to perform an evaluation of the Licensing Support System (LSS). The working group developed an understanding of LSS requirements, a current view of costs, and the necessary implementation and resource schedules to support a license application date of 2001.

208 **The many barriers of Yucca Mountain.** Sinnock, S. (TRW, Las Vegas, NV (United States)). pp. 281-283 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

A repository at Yucca Mountain would provide many barriers to prevent or delay escape of radioactive wastes from the mountain. The site's natural characteristics would interact with engineered systems to provide a set of multiple, independent barriers. By itself, each barrier would provide some assurance that some or all of the wastes would be separated from humans to the degree necessary for regulatory compliance. Acting in concert, the suite of barriers provides very high confidence in the ability of a repository at Yucca Mountain to protect people from hazards posed by the wastes. This paper briefly identifies the salient features of several barriers offered by a repository at Yucca Mountain. Quantitative treatment of the effectiveness of these barriers is given in performance assessment reports are considered in this paper.

209 **Transport processes in unsaturated soils at sub-residual saturations.** Lingineni, S. (CRWMS M & O/Intera, Inc., Las Vegas, NV (United States)); Chen, Y.T.; Boehm, R.F. pp. 297-298 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Understanding transport phenomena at very low liquid saturations in coarse porous materials is essential to predict near-field hydrothermal conditions within the backfill of waste emplacement drifts. Limitations involved in employing multi-phase flow and transport models to simulate transport processes in sub-residual saturation regimes are discussed. uncertainties introduced into the thermo-hydrologic results due to numerical extensions to the capillary pressure - saturation relationships are examined.

210 **Hydrothermal analyses at the waste-package scale for a potential high-level waste repository at Yucca Mountain.** Lingineni, S. (CRWMS M & O/Intera, Inc., Las Vegas, NV (United States)); Reeves, M.; Mishra, S. pp. 316-318 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

A near-field hydrothermal model to predict the temperature and saturation variations in the vicinity of heat-generating waste packages is presented in this paper. Various suites of thermo-hydrologic simulations were performed using FEHM and TOUGH2, with three areal power densities and two infiltration rates. The thermal and saturation predictions from both of these codes at various time levels were compared in order to benchmark their performance in terms of simulating near-field multi-phase fluid flow and heat transport. Results from the current near-field hydrothermal analyses indicate that liquid saturations near the waste package are significantly different from the average repository saturations predicted by repository scale hydrothermal models.

211 **Preliminary evaluation of waste package releases using drift-scale thermo-hydrologic analyses.** McNeish, J.A. (M&O/INTERA, Austin, TX (United States)); Reeves, M.; Dale, T.F. pp. 319-322 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

In a 1993 performance assessment, the uncertainty associated with using panel-scale thermo-hydrologic analyses to define the near-field environment in the vicinity of the waste packages was identified as one of the major factors impacting the predicted performance. This was because of the impact of the thermo-hydrologic regime on the initiation of aqueous corrosion as well as the rate of corrosion, rate of waste form dissolution (due to the uncertainty in the percent of the waste form surface covered by water film), solubility limits, and the effective diffusion through the waste package and engineered barrier. This document presents an initial attempt to incorporate, in a more representative fashion, the anticipated thermo-hydrologic response in the vicinity of in-drift emplaced waste packages into the post-closure performance assessment. It illustrates some of the issues which must be resolved prior to justifying the inclusion of these representations into the assessment.

212 **Drift scale thermomechanical analysis for thermal loading and retrievability studies.** Tsai, F.C. (M&O/Woodward Clyde Federal Services, Las Vegas, NV (United States)). pp. 355-356 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.;

American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The repository portion of the Mined Geologic Disposal System for the disposal of spent nuclear fuel and high-level radioactive waste is currently in the advanced conceptual design stage. In support of systems studies, a numerical method was used to estimate the stability of emplacement drifts. Thermomechanical analyses, using the Discontinuous Deformation Analysis code, were performed using input data from Yucca Mountain documents. The analysis found that the stresses produced in the rock at thermal loads of 27.4 kilograms uranium per m2 (KgU/m2) would exceed stability criteria and could result in tunnel instability. At thermal loads between 20.5 KgU/m2, the drift is predicted to be stable and its structural integrity remains after thermal loading. In this case, the smaller diameter drift emplacement appears to have better stability. However, local rock spalling may occur. According to the numerical prediction, more rock fall may occur during the retrieval period due to the stress relaxation caused by the rapid cooling in the immediate drift area.

213 **Preclosure radiological safety assessment for the ground support system in the exploratory studies facility.** Smith, A.J. (M&O/INTERA, Las Vegas, NV (United States)); Tsai, F.C. pp. 373-375 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

An initial probabilistic safety assessment was performed for the exploratory studies facility underground opening to determine whether the ground support system should be classified as an item important to safety. The initiating event was taken to be a rock fall in an operational facility impacting a loaded waste transporter. Rock fall probability rates were estimated from data reported by commercial mining operations. This information was retrieved from the data base compiled by the Mining Safety and Health Administration from the mandatory reporting of incidents. The statistical distribution of the rock fall magnitude was estimated from the horizontal and vertical spacing fractures measured at the Yucca Mountain repository horizon. Simple models were developed to estimate container deformation and radionuclide releases arising from the projected distribution of impacts. Accepted techniques were used to calculate atmospheric dispersion and obtain the committed dose to individuals.

214 **Effects of exploratory studies facility construction water on radionuclide release.** Houseworth, J.E. (INTERA Inc./CRWMS M&O, Las Vegas, NV (United States)). pp. 376-378 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The Exploratory Studies Facility (ESF) is a planned underground laboratory to conduct subsurface exploration and testing in support of site suitability determination and license application for a potential high-level nuclear waste repository at Yucca Mountain. The ESF design includes a 7.6 m diameter, 7.8 km long tunnel loop consisting of two main access ramps from the surface down to a main drift along the conceptual repository horizon in a fractured, welded tuff called the Topopah Spring member of the Paintbrush Tuff. The ESF main drift is planned to be at least 37 m from the closest waste package emplacement zone. Standard underground excavation methods require the use of water primarily for dust control. The unsaturated condition of rock comprising the potential repository horizon is an important characteristic that will be affected by the introduction of construction water. An analysis bounding the effects of water lost to the geologic environment on radionuclide release from waste packages has been developed to help identify appropriate controls for ESF construction water use. The approach is to determine the dominant radionuclide release process, estimate natural variability in radionuclide release, and then bound water saturation changes so that changes in radionuclide release stays within natural variations. The use of water during excavation of the ESF is expected to have negligible effects on radionuclide release from waste packages, provided the volume of water lost to the geologic environment is limited to 7.4 m^3/m of linear excavation.

215 **Comparison of EPRI and Sandia performance assessments assumptions.** McGuire, R.K. (Risk Engineering, Inc., Boulder, CO (United States)); Vlasity, J.A. pp. 388-390 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This study was performed to compare the assumptions made in the Electric Power Research Institute (EPRI) and Sandia National Laboratory performance assessments of a potential high-level waste repository at Yucca Mountain, Nevada. A second goal was to compare the effects of these assumptions on performance assessment calculations, to determine which assumptions are critical and which are not. Two models of aqueous flow used in the EPRI and TSPA-1993 projects were examined individually: fast fracture flow and composite porosity models. Although there is good agreements between calculational procedures, the results may be similar by chance. Several important differences in assumptions between the two studies exist and require further scrutiny.

216 **Preliminary evaluation of predicted peak release rates from the engineered barrier system for a potential repository at Yucca Mountain, Nevada.** Andrews, R.W. (M&O/INTERA, Las Vegas, NV (United States)); McNeish, J.A.; Lee, J.H. pp. 397-399 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Any potential repository for the ultimate disposal of the nation's high-level radioactive wastes is subject to meeting post-closure regulatory requirements as specified by the Nuclear Regulatory Commission (NRC). Three NRC subsystem performance measures are relevant to the evaluation of the Yucca Mountain site and possible engineered barriers. These performance requirements are specified in 10 CFR 60. These include the substantially complete containment requirement, the engineered barrier system (EBS) release requirement, and the pre-waste emplacement groundwater

travel time requirement. The present paper documents an initial evaluation of the peak EBS release rates.

217 **Approach to compliance with the NRC substantially complete containment requirement at the potential repository at Yucca Mountain.** Stahl, D. (B&W Fuel Company, Las Vegas, NV (United States)); Nesbit, S.P.; Berkowitz, L. pp. 423-425 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

An approach to compliance with the U.S. Nuclear Regulatory Commission (NRC) substantially complete containment (SCC) requirement found in the Title 10 Part 60 of the Code of Federal Regulations (CFR) was developed by the Department of Energy (DOE). The approach is consistent with the regulation and is based on a new performance goal of a mean waste-package lifetime well in excess of 1,000 years. The NRC considers that achieving the DOE goal would be a reasonable implementation of the SCC requirement. The NRC has asked several additional questions. The DOE has responded to these questions and the DOE and the NRC are engaged in an ongoing dialog to resolve them.

218 **Bounding potential diesel exhaust impacts produced from North Ramp construction.** Sassani, D.C. (INTERA Inc./CRWMS M&O, Las Vegas, NV (United States)); Houseworth, J.E. pp. 615-617 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Diesel exhaust that may be produced during construction of the Yucca Mountain Project's Exploratory Studies Facility (ESF) North Ramp will introduce potentially permanent chemical constituents into the geochemical system. Therefore, the potential impacts from diesel exhaust constituents which may be retained permanently underground should be bounded. To provide some guidance, conservative bounding calculations have been used to predict the potential for peturbation to the existing geochemical environment. A local peturbation of 10% of ambient conditions, which is well below the observed natural variations, has been assumed conservatively as the limit for negligible impact to waste isolation. The geochemical peturbations at the closest potential waste package have been computed using estimates of the quantity and distribution of each constituent deposited in the North Ramp; and a three-dimensional advection-dispersion transport calculation. Based on estimated usage of diesel equipment, calculations suggest that, if exhaust constituent concentrations are at or below the low average values, there is minimal risk to the waste isolation capabilities of the site.

219 **System safety analysis of the Yucca Mountain tunnel boring machine.** Smith, M.G. (TRW Environmental Safety Systems, Inc., Vienna, VA (United States)); Booth, L.; Eisler, L. pp. 637-639 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The purpose of this analysis was to systematically identify and evaluate hazards related to the tunnel boring machine to be used at Yucca Mountain. This analysis required three steps to complete the risk evaluation: hazard/scenario identification, consequence assessment, and frequency assessment. The result was a 'risk evaluation' of the scenarios identified in this analysis in accordance with MIL-STD-882C. The risk assessment in this analysis characterized the accident scenarios associated with the TBM in terms of relative risk and included recommendations for mitigating all identified risks.

220 (CONF-950570–25) **Mined Geologic Disposal System Concept of Operations.** Heidt, R.M. TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States). 8 Jun 1995. 4p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. From International high-level radioactive waste management conference: progress toward understanding; Las Vegas, NV (United States); 1-5 May 1995. Order Number DE95012255. Source: OSTI; NTIS; INIS; GPO Dep.

A Concept of Operations has been developed for the disposal of high-level radioactive waste in the potential geologic repository at Yucca Mountain. The Concept of Operations has been developed to document a comion understanding of how the repository is to be operated. It is based on the repository architecture identified in the Initial Summary Report for Repository/Waste Package Advanced Conceptual Design and describes the operation of the repository from the initial receipt of waste through repository closure. Also described are operations for waste retrieval.

221 (DOE/RW/00134–T5) **Site characterization plan thermal goals reevaluation.** TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States). 8 Sep 1993. 50p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94004175. Source: OSTI; NTIS; INIS; GPO Dep.

The Site Characterization Plan (SCP) (DOE, 1988) attempted to define surrogate criteria that could be used to establish potential repository performance. These criteria or SCP thermal goals were developed from knowledge existing at the time and, as a reference case, emphasized performance for waste emplacement in a vertical borehole. Since that time, new knowledge has become available and some additional analyses of thermal loading have been performed. Additionally, other emplacement modes such as in-drift emplacement are being considered to accommodate larger waste packages. New concepts such as "extended hot" are also being considered as possible methods to achieve improved waste isolation. Thus it became clear that the thermal goals established in the SCP should be reevaluated. A Working Group was formed to reassess the SCP thermal goals to determine whether each goal was still valid, if there were goals that needed to be added, and what if any effort was needed to reduce the uncertainty associated with a particular goal. The objectives of the effort were to: (1) provide thermal goals that would support the FY 1993 Thermal Loading Systems Study; (2) help focus the planned testing and analysis efforts; and (3) acquire data that potentially could be used to initiate a change to the project technical baseline. Sixteen thermal goals were evaluated; fifteen were from various sections of the SCP; one goal was added, and another was split into two to include in-drift emplacement. The group's findings and recommendations are presented.

222 (DOE/RW/00134–T6) **Review and selection of unsaturated flow models.** INTERA, Inc., Las Vegas, NV (United States). 10 Sep 1993. 288p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94004174. Source: OSTI; NTIS; INIS; GPO Dep.

Under the US Department of Energy (DOE), the Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O) has the responsibility to review, evaluate, and document existing computer ground-water flow models; to conduct performance assessments; and to develop performance assessment models, where necessary. In the area of scientific modeling, the M&O CRWMS has the following responsibilities: To provide overall management and integration of modeling activities. To provide a framework for focusing modeling and model development. To identify areas that require increased or decreased emphasis. To ensure that the tools necessary to conduct performance assessment are available. These responsibilities are being initiated through a three-step process. It consists of a thorough review of existing models, testing of models which best fit the established requirements, and making recommendations for future development that should be conducted. Future model enhancement will then focus on the models selected during this activity. Furthermore, in order to manage future model development, particularly in those areas requiring substantial enhancement, the three-step process will be updated and reported periodically in the future.

223 (DOE/RW/00134–T8) **Yucca Mountain Site Characterization Project Technical Data Catalog (Quarterly supplement).** TRW, Inc., Fairfax, VA (United States). 31 Dec 1993. 71p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94008425. Source: OSTI; NTIS; GPO Dep.

The March 21, 1993, Department of Energy (DOE)/ Nuclear Regulatory Commission (NRC) Site-Specific Procedural Agreement for Geologic Repository Site Investigation and Characterization Program requires the DOE to develop and maintain a catalog of data which will be updated and provided to the NRC at least quarterly. This catalog is to include a description of the data; the time (date), place, and method of acquisition; and where it may be examined. The Yucca Mountain Site Characterization Project (YMP) Technical Data Catalog is published and distributed in accordance with the requirements of the Site-Specific Agreement. The YMP Technical Data Catalog is a report based on reference information contained in the YMP Automated Technical Data Tracking System (ATDT). The reference information is provided by Participants for data acquired or developed in support of the YMP. The Technical Data Catalog is updated quarterly and published in the month following the end of each quarter. A complete revision to the Catalog is published at the end of each fiscal year. Supplements to the end-of-year edition are published each quarter. These supplements provide information related to new data items not included in previous quarterly updates and data items affected by changes to previously published reference information. The Technical Data Catalog, dated September 30, 1993, should be retained as the baseline document for the supplements until the end-of-year revision is published and distributed in October 1994.

224 (DOE/RW/00134–T10) **Calculations supporting evaluation of potential environmental standards for Yucca Mountain.** Duguid, J.O. (INTERA, Inc., Las Vegas, NV (United States)); Andrews, R.W.; Brandstetter, E.; Dale, T.F.; Reeves, M. TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States); INTERA, Inc., Las Vegas, NV (United States). Apr 1994. 210p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94015897. Source: OSTI; NTIS; INIS; GPO Dep.

The Energy Policy Act of 1992, Section 801 (US Congress, 1992) provides for the US Environmental Protection Agency (EPA) to contract the National Academy of Sciences (NAS) to conduct a study and provide findings and recommendations on reasonable standards for the disposal of high-level wastes at the Yucca Mountain site. The NAS study is to provide findings and recommendations which include, among other things, whether a health-based standard based on dose to individual members of the public from releases to the accessible environment will provide a reasonable standard for the protection of the health and safety of the public. The EPA, based upon and consistent with the findings and recommendations of the NAS, is required to promulgate standards for protection of the public from releases from radioactive materials stored or disposed of in a repository at the Yucca Mountain site. This document presents a number of different "simple" analyses of undisturbed repository performance that are intended to provide input to those responsible for setting appropriate environmental standards for a potential repository at the Yucca Mountain site in Nevada. Each of the processes included in the analyses has been simplified to capture the primary significance of that process in containing or isolating the waste from the biosphere. In these simplified analyses, the complex waste package interactions were approximated by a simple waste package "failure" distribution which is defined by the initiation and rate of waste package "failures". Similarly, releases from the waste package and the engineered barrier system are controlled by the very near field environment and the presence and rate of advective and diffusive release processes. Release was approximated by either a simple alteration-controlled release for the high solubility radionuclides and either a diffusive or advective-controlled release for the solubility-limited radionuclides.

225 (DOE/RW/00134–T11) **Review and selection of unsaturated flow models.** Reeves, M. (INTERA, Inc., Las Vegas, NV (United States)); Baker, N.A.; Duguid, J.O. TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States); INTERA, Inc., Las Vegas, NV (United States). 4 Apr 1994. 321p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94015954. Source: OSTI; NTIS; INIS; GPO Dep.

Since the 1960's, ground-water flow models have been used for analysis of water resources problems. In the 1970's, emphasis began to shift to analysis of waste management problems. This shift in emphasis was largely brought about by site selection activities for geologic repositories for disposal of high-level radioactive wastes. Model development during the 1970's and well into the 1980's focused primarily on saturated ground-water flow because geologic repositories in salt, basalt, granite, shale, and tuff were envisioned to be below the water table. Selection of the unsaturated zone at Yucca Mountain, Nevada, for potential disposal of waste began to shift model development toward unsaturated flow models. Under the US Department of Energy (DOE), the Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O) has the responsibility to review, evaluate, and document existing computer models; to conduct performance

assessments; and to develop performance assessment models, where necessary. This document describes the CRWMS M&O approach to model review and evaluation (Chapter 2), and the requirements for unsaturated flow models which are the bases for selection from among the current models (Chapter 3). Chapter 4 identifies existing models, and their characteristics. Through a detailed examination of characteristics, Chapter 5 presents the selection of models for testing. Chapter 6 discusses the testing and verification of selected models. Chapters 7 and 8 give conclusions and make recommendations, respectively. Chapter 9 records the major references for each of the models reviewed. Appendix A, a collection of technical reviews for each model, contains a more complete list of references. Finally, Appendix B characterizes the problems used for model testing.

226 (DOE/RW/00134–T12) **Total System Performance Assessment, 1993: An evaluation of the potential Yucca Mountain repository.** Andrews, R.W.; Dale, T.F.; McNeish, J.A. INTERA, Inc., Las Vegas, NV (United States). Mar 1994. 410p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94015955. Source: OSTI; NTIS; INIS; GPO Dep.

Total System Performance Assessments are an important component in the evaluation of the suitability of Yucca Mountain, Nevada as a potential site for a mined geologic repository for the permanent disposal of high-level radioactive wastes in the United States. The Total System Performance Assessments are conducted iteratively during site characterization to identify issues which should be addressed by the characterization and design activities as well as providing input to regulatory/licensing and programmatic decisions. During fiscal years 1991 and 1992, the first iteration of Total System Performance Assessment (hereafter referred to as TSPA 1991) was completed by Sandia National Laboratories and Pacific Northwest Laboratory. Beginning in fiscal year 1993, the Civilian Radioactive Waste Management System Management and Operating Contractor was assigned the responsibility to plan, coordinate, and contribute to the second iteration of Total System Performance Assessment (hereafter referred to as TSPA 1993). This document presents the objectives, approach, assumptions, input, results, conclusions, and recommendations associated with the Management and Operating Contractor contribution to TSPA 1993. The new information incorporated in TSPA 1993 includes (1) revised estimates of radionuclide solubilities (and their thermal and geochemical dependency), (2) thermal and geochemical dependency of spent fuel waste alteration and glass dissolution rates, (3) new distribution coefficient (k_d) estimates, (4) revised estimates of gas-phase velocities and travel times, and (5) revised hydrologic modeling of the saturated zone which provides updated estimates of the advective flux through the saturated zone.

227 (DOE/RW/00134–T14) **Yucca Mountain Site Characterization Project: Technical Data Catalog (quarterly supplement), June 30, 1994.** TRW, Inc., Fairfax, VA (United States). 30 Jun 1994. 111p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE95002190. Source: OSTI; NTIS; INIS; GPO Dep.

The DOE/NRC Site-Specific Procedural Agreement for Geologic Repository Site Investigation and Characterization Program requires the DOE to develop and maintain a catalog of data which will be updated and provided to the NRC at least quarterly. This catalog is to include a description of the data; the date, place, and method of acquisition; and where it may be examined. The Yucca Mountain Site Characterization Project (YMP) Technical Data Catalog is published and distributed in accordance with the requirements of the Site-Specific Agreement. The YMP Technical Data Catalog is a report based on reference information contained in the YMP Automated Technical Data Tracking System (ATDT). The reference information is provided by Participants for data acquired or developed in support of the YMP. The Technical Data Catalog is updated quarterly and published in the month following the end of each quarter. A complete revision to the catalog is published at the end of each fiscal year. Supplements to the end-of-year edition are published each quarter. These supplements provide information related to new data items not included in previous quarterly updates and data items affected by changes to previously published reference information. The Technical Data Catalog, dated September 30, 1993, should be retained as the baseline document for the supplements until the end-of-year revision is published and distributed in October 1994.

228 (DOE/RW/00134–T15-Vol.1-Rev.1) **FY 93 thermal loading systems study final report: Volume 1. Revision 1.** Saterlie, S.F.; Thomson, B.H. TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States). 29 Aug 1994. 188p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE95006912. Source: OSTI; NTIS; INIS; GPO Dep.

The ability to meet the overall performance requirements for the proposed Mined Geology Disposal System at Yucca Mountain, Nevada requires the two major subsystem (natural barriers and engineered barriers) to positively contribute to containment and radionuclide isolation. In addition to the postclosure performance the proposed repository must meet preclosure requirements of safety, retrievability, and operability. Cost and schedule were also considered. The thermal loading strategy chosen may significantly affect both the postclosure and preclosure performance of the proposed repository. Although the current Site Characterization Plan reference case is 57 kilowatts (kW)/acre, other thermal loading strategies (different areal mass loadings) have been proposed which possess both advantages and disadvantages. The objectives of the FY 1993 Thermal Loading Study were to (1) place bounds on the thermal loading which would establish the loading regime that is "too hot" and the loading regime that is "too cold", to (2) "grade" or evaluate the performance, as a function of thermal loading, of the repository to contain high level wastes against performance criteria and to (3) evaluate the performance of the various options with respect to cost, safety, and operability. Additionally, the effort was to (4) identify important uncertainties that need to be resolved by tests and/or analyses in order to complete a performance assessment on the effects of thermal loading. The FY 1993 Thermal Loading Study was conducted from December 1, 1992 to December 30, 1993 and this final report provides the findings of the study. Volume 1 contains the Introduction; Performance requirements; Input and assumptions; Near-field thermal analysis; Far-field thermal analysis; Cost analysis; Other considerations; System analysis; Additional thermal analysis; and Conclusions and recommendations. 71 refs., 54 figs.

229 (DOE/RW/00134–T15-Vol.2-Rev.1) **FY 93 thermal loading systems study final report: Volume 2. Revision 1.** TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States). 29 Aug 1994. 256p. Sponsored by USDOE, Washington, DC (United States). DOE Contract

AC01-91RW00134. Order Number DE95006913. Source: OSTI; NTIS; INIS; GPO Dep.

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230 (DOE/RW/00134–T16) **Yucca Mountain Site Characterization Project technical data catalog: Quarterly supplement.** TRW, Inc., Fairfax, VA (United States). 31 Dec 1994. 151p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE95007580. Source: OSTI; NTIS; GPO Dep.

The Department of Energy (DOE)/Nuclear Regulatory Commission (NRC) Site-Specific Procedural Agreement for Geologic Repository Site Investigation and Characterization Program requires the DOE to develop and maintain a catalog of data which will be updated and provided to the NRC at least quarterly. This catalog is to include a description of the data; the time (date), place, and method of acquisition; and where the data may be examined. The Yucca Mountain Site Characterization Project (YMP) Technical Data Catalog is published and distributed-in accordance with the requirements of the Site-Specific Agreement. The YMP Technical Data Catalog is a report based on reference information contained in the YMP Automated Technical Data Tracking System (ATDT). The reference information is provided by Participants for data acquired or developed in support of the YMP. The Technical Data Catalog is updated quarterly and distributed in the month following the end of each quarter. A complete revision to the catalog is published at the end of each fiscal year. Supplements to the end-of-year edition are published each quarter. These supplements provide information related to new data items not included in previous quarterly updates and data items affected by changes to previously published reference information. The Technical Data Catalog, dated September 30, 1994, should be retained as the baseline document for the supplements until the end-of-year revision is published and distributed in October 1995.

231 (DOE/RW/00134–T17) **Yucca Mountain Site Characterization Project technical data catalog quarterly supplement.** TRW, Inc., Fairfax, VA (United States). 31 Mar 1995. 179p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE95013073. Source: OSTI; NTIS; GPO Dep.

The Department of Energy (DOE)/Nuclear Regulatory Commission (NRC) Site-Specific Procedural Agreement for Geologic Repository Site Investigation and Characterization Program requires the DOE to develop and maintain a catalog of data which will be updated and provided to the NRC at least quarterly. This catalog is to include a description of the data; the time (date), place, and method of acquisition; and where the data may be examined. The Yucca Mountain Site Characterization Project (YMP) Technical Data Catalog is published and distributed in accordance with t requirements of the Site-Specific Agreement. The YMP Technical Data Catalog is a report based on reference information contained in the YMP Automated Technical Data Tracking System (ATDT). The reference information is provided by Participants for data acquired or developed in support of the YMP. The Technical Data Catalog is updated quarterly and distributed in the month following the end of each quarter. A complete revision to the catalog is published at the end of each fiscal year. Supplements to the end-of-year edition are published each quarter. These supplements provide information related to new data items not included in previous quarterly updates and data items affected by changes to@ previously published reference information. The Technical Data Catalog, dated September 30, 1994, should be retained as the baseline document for the supplements until the end-of-year revision is published and distributed in October 1995.

232 (DOE/RW/00134–T18) **Nevada potential repository preliminary transportation strategy: Study 1.** TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States). Apr 1995. 169p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE95013302. Source: OSTI; NTIS; INIS; GPO Dep.

Limited feasible options exist when considering the shipment of spent nuclear fuel and high-level radioactive waste. These options are rail or truck; because of the weight associated with transportation casks (68.0 to 113.4 tonnes/75 to 125 tons), heavy-haul trucks are also considered. Yucca Mountain currently lacks rail service or an existing right-of-way for rail; it also lacks a dedicated highway suitable for heavy-haul trucks. Approximately 11,230 shipments by rail are planned from waste producer sites to Nevada, with an additional 1,041 shipments by legal-weight truck from four reactor sites not capable of upgrading for rail shipment. This study identifies the reasonable alternatives for waste transport to the potential repository site, describes the evaluation process performed to identify those alternatives, and discusses the reasons for elimination of transportation routes deemed to be not reasonable. The study concluded that heavy haul truck transportation is feasible-cost is very favorable when compared to rail-but route restrictions must be further evaluated. In addition to restrictions due to seasonal weather conditions, specific routes have additional restrictions, including no travel on holidays or weekends, and travel during daylight hours only. Further restrictions will be imposed by the U.S. Department of Transportation based on

routing of radioactive materials by highway. Operation and maintenance costs for heavy-haul over a 24-year period, based on preliminary information, were calculated on an estimated operational cost of $15,000 per trip, with an estimated 468 trips per year average (11,230 total trips), for an estimated cost of $171 million to $173 million, depending on the route used. Because the initial costs and the total system life cycle costs of heavy-haul are approximately 50 percent lower than the lowest rail cost, this option will continue to be evaluated.

233 **Release modes and processes relevant to source-term calculations at Yucca Mountain.** Apted, M.J. (Intera Information Technologies, Denver (United States)). *Radioactive Waste Management and Environmental Restoration;* 19(1-3): 1-19 (1994).

Special issue Yucca Mountain.

The feasibility of permanent disposal of radioactive high-level waste (HLW) in repositories located in deep geologic formations is being studied world-wide. The most credible release pathway is interaction between groundwater and nuclear waste forms, followed by migration of radionuclide-bearing groundwater to the accessible environment. Under hydrologically unsaturated conditions, vapor transport of volatile radionuclides is also possible. The near-field encompasses the waste packages composed of engineered barriers, while the far-field includes the natural barriers. Taken together, these two subsystems define a series of multiple, redundant barriers that act to assure the safe isolation of nuclear waste. In the U.S., the Department of energy (DOE) is investigating the feasibility of safe, long-term disposal of high-level nuclear waste at the Yucca Mountain site in Nevada. The proposed repository horizon is located in non-welded tuffs within the unsaturated zone (i.e. above the water table) at Yucca Mountain. The purpose of this paper is to describe the source-term models for radionuclide release from waste packages at Yucca Mountain site. The first section describes the conceptual release modes that are relevant for this site and waste package design, based on a consideration of the performance of currently proposed engineered barriers under expected and unexpected conditions. No attempt is made to asses the reasonableness nor probability of occurrence for any specific release mode. The following section reviews the waste-form characteristics that are required to model and constrain the release of radionuclides from the waste package. The next section present mathematical models for the conceptual release modes, selected from those that have been implemented into a probabilistic total system assessment code developed for the Electric Power Research Institute (EPRI). (author) 4 figs., 35 refs.

234 **Summary of heat management concepts for an unsaturated tuff repository.** Ramspott, L.D. *Transactions of the American Nuclear Society;* 71: 95-97 (1994). (CONF-941102--: Winter meeting of the American Nuclear Society (ANS), Washington, DC (United States), 13-18 Nov 1994).

Yucca Mountain, Nevada, is being evaluated as a potential repository site for high-level nuclear waste and spent reactor fuel. Vitrified reprocessing waste will generate significant heat for hundreds of years, whereas spent reactor fuel will do so for up to a hundred thousand years. Thermal loads evaluated for repository conceptual design have been in the range of 20 to 120 kW/acre at emplacement, compared with a flux resulting from the geothermal gradient of 0.2 kW/acre. This heat could have significant consequences for repository performance. The repository horizon is an unsaturated tuff with ~15% porosity. About two-thirds of the rock-pore-volume contains liquid water. The remaining third contains air near 100% relative humidity. At these saturation levels at an ambient temperature of 25°C, water does not flow into openings except along occasional fractures. However, heat from emplaced waste mobilizes water in the rock and might cause increased flow of liquid water into the openings.

235 **Potential releases of gaseous ^{14}C from Yucca Mountain: A limited role for buoyancy as compared to other flow inducing phenomena.** Sullivan, T.M. (Brookhaven National Lab., Upton, NY (United States)); Pescatore, C. *Waste Management;* 14(5): 435-444 (1994).

The issue of gas flow and contaminant transport out of the potential high-level waste (HLW) and spent nuclear fuel repository site at Yucca Mountain, NV, has recently received much attention. An important concern exists over whether or not heating of the rock mass by the waste may generate convective currents resulting from buoyancy. This could significantly reduce (relative to the half-life of the element) the travel time of gaseous contaminants, such as $^{14}CO_2$ (g), to the surface of the mountain. The studies that rely on a full-fledged analysis of the system of coupled equations representing nonisothermal flow in porous media discount the effect of buoyancy; the more simplified analyses do not. To reconcile the contradictory results, the authors have performed a review of the general literature, including studies not directly concerned with flow at Yucca Mountain. The authors conclude that there is convincing theoretical and experimental indications to exclude net mass flows of air to the surface of the mountain resulting only from buoyancy. Therefore, the buoyancy effect, alone, would not cause ^{14}C releases. On the other hand, the authors identify barometric pumping and topographically assisted flow as the most relevant mechanisms for the release of this radionuclide. Coupling between these effects and buoyancy may enhance these surface-driven processes.

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236 **Mineralogic alteration history and paleohydrology at Yucca Mountain, Nevada.** Levy, S.S. (Los Alamos National Lab., NM (United States)). pp. 477-485 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The importance of paleohydrology to the Yucca Mountain Site Characterization Project derives from the role water will play in radioactive waste repository performance. Changes in hydrologic conditions during the lifetime of the repository may be estimated by investigating past hydrologic variations, including changes in the static water-level position. Based on the distribution of vitric and zeolitized tuffs and the structural history of the site, the highest water levels were reached and receded downward 11.6 to 12.8 myr ago. Since that time, the water level at central Yucca Mountain has probably not risen more than about 60 m above its present position. The history of the high potentiometric gradient running through northern Yucca Mountain may be partly elucidated by the study of tridymite distribution in rocks that have experienced saturated conditions for varying periods of time.

237 Fracture-lining minerals in the lower Topopah Spring Tuff at Yucca Mountain. Carlos, B.A. (Los Alamos National Lab., NM (United States)); Bish, D.L.; Chipera, S.J. pp. 486-493 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Fracture-lining minerals in the lower Topopah Spring Member of the Paintbrush Tuff at Yucca Mountain, Nevada, are being examined to characterize potential flow paths within and away from the candidate repository horizon. Fracture coatings within this interval can be divided into five categories based on rock matrix and type of fracture. Fracture coatings in the densely welded tuff above the basal vitrophyre, near the candidate repository horizon, include (1) those related to lithophysal cavities; (2) mordenite and manganese oxides on nearly planar fractures; (3) later fracture coatings consisting of zeolites, smectite, and calcite. Fracture-coating minerals in the vitrophyre are fine-grained and consist of smectite and a variety of zeolites. The non- to partially-welded vitric and/or zeolitic tuff below the vitrophyre contains fractures mostly lined by cristobalite and clinoptilolite.

238 Radionuclide migration as a function of mineralogy. Triay, I.R. (Los Alamos National Lab., NM (United States)); Mitchell, A.J.; Ott, M.A. pp. 494-498 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The migration of radionuclides is studied as a function of mineralogy utilizing batch sorption and column experiments. The transport behavior of alkaline, alkaline-earth, and transition metals and actinide species is studied in pure mineral separates. The solid phases utilized for these investigations are silicates, alumino-silicates, carbonates, and metal oxides and oxyhydroxides. The results of this effort are utilized to aid in the elucidation of the dominant chemical mechanisms of radionuclide migration; the prediction of radionuclide transport in conditions similar to those expected at the candidate high-level nuclear waste repository site at Yucca Mountain, Nevada; and the identification of materials that act as natural geological barriers or that can be utilized as strong sorbers in engineered barriers.

239 Preliminary assessment of clinoptilolite K/Ar results from Yucca Mountain, Nevada, USA: A potential high-level radioactive waste repository site. Wolde-Gabriel, G. (Los Alamos National Lab., NM (United States)); Broxton, D.E.; Bish, D.L.; Chipera, S.J. pp. 457-461 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

At Yucca Mountain, evidence for at least three distinct temporal groups of clinoptilolites can be delineated from the preliminary K/Ar dates (2 - 3 Ma; 4 - 5 Ma; 7 - 11 Ma). The older K/Ar dates that are similar to published illite/smectite ages (9-12 Ma) may be crystallization ages, whereas the younger dates probably represent continued diagenetic reactions of older clinoptilolites with percolating fluids. The K/Ar dates increase with depth, suggesting minimal argon loss in the deeper samples. internal consistency of the clinoptilolite K/Ar results at different levels within the drill holes suggest that dating of K-rich zeolites may provide useful information for assessing the zeolitization at Yucca Mountain. Variations in the K/Ar dates are probably related to Ar loss during dissolution of older clinoptilolites and to contamination by finely crystalline feldspars. 18 refs., 1 tab.

240 Precipitation of calcite, dolomite, sepiolite and silica from evaporated carbonate and tuffaceous waters of southern Nevada, USA. Vaniman, D.T. (Los Alamos National Lab., NM (United States)); Ebinger, M.H.; Bish, D.L.; Chipera, S.J. pp. 687-691 of Water-Rock Interaction: Proceedings. Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

Calcite and sepiolite commonly form on evaporation of either carbonate-source or tuff-source waters in southern Nevada. However, dolomite and Mg-smectites precipitate only from carbonate-source waters and silica minerals appear to be more common and less ordered in deposits from tuff-source waters. Thus it may be possible to determine the nature of the source water, based on the deposits left behind after evaporation. Petrographic observations and modeling indicate that in both types of water either calcite or dolomite (or both) precipitate first, followed by sepiolite and ultimately silica phases. Waters from carbonate sources tend to retain dolomite throughout most of their evaporative evolution, whereas waters from silicic igneous sources either do not precipitate dolomite or dissolve their early dolomite precipitates after ~5-10x evaporative increase in the solute/water ratio. The relative proportion of dolomite among the precipitation would lead to formation of opal rather than sepiolite in all waters. However, the common occurrence of sepiolite in deposits from both types of water suggests that silica precipitation is suppressed. The results from modeling indicate that the high terminal silica content of evaporated tuff-source waters may lead to late precipitation of abundant but poorly ordered silica phases (opal-A/opal-CT), unlike the rarer but more ordered silica phases (opal-CT/quartz) precipitated from carbonate-source waters. 12 refs., 2 figs., 1 tab.

241 Chemical changes associated with zeolitization of the tuffaceous beds of Calico Hills, Yucca Mountain, Nevada, USA. Broxton, D.E. (Los Alamos National Lab., NM (United States)). pp. 699-703 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

The chemistry of the tuffaceous beds of Calico Hills was examined in samples collected over a 100 km^2 area south of the Timber Mountain-Oasis Valley caldera complex to determine regional geochemical patterns during zeolitization. Samples of 58 vitric and zeolitic tuffs were analyzed for 48 elements by a combination of X-ray fluorescence, atomic absorption spectrophotometry, and neutron activation analysis. Major and trace element concentrations for zeolitic tuffs vary significantly from those for vitric tuffs. Complex, geographically-controlled patterns of elemental enrichment and depletion in the zeolitic tuffs are found for Na, K, Ca, Mg, U, Rb, Sr, Ba and Cs. Vitric and zeolitic tuffs generally have the same SiO_2 contents on an anhydrous basis, but

minor net silica gain or loss has occurred in some samples. Zeolitic tuffs from the northern part of the study area, adjacent to the caldera complex, are notably K-rich and Na- and U-poor compared to zeolitic tuffs to the south. The compositions of the K-rich zeolitic tuffs are similar to those found in other areas of the western US where volcanic rocks are affected by potassium metasomatism. Alteration of vitric tuffs took place in an open chemical system and geographic control of major element compositions probably reflects regional variations in ground water chemistry and temperature during alteration. The K-rich zeolitic tuffs in the northern part of the study area were probably altered by moderate-temperature hydrothermal fluids whereas tuffs further south were altered by lower-temperature regional ground waters. 9 refs., 3 figs.

242 **Water-rock interaction and the pH stability of groundwaters from Yucca Mountain, Nevada, USA.** Ebinger, M.H. (Los Alamos National Lab., NM (United States)). pp. 783-786 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

Titrations of acidic solutions in waters from the tuff and carbonate aquifers at Yucca Mountain were simulated using the geochemical codes PHREEQE and EQ3/6. The simulations tested pH stability of the waters in the presence of different minerals and in their absence. Two acidic solution, 10^{-4}M HCl and 10^{-4}M $UO_2(NO_3)_2$, were titrated in to the water. Little pH and/or compositional changes resulted in the groundwater when the HCl solution was titrated, but significant pH and CO_2 fugacity changes were observed when $UO_2(NO_3)_2$ was titrated. Water interactions with alkali feldspar, quartz or cristobalite, and Ca-smectite buffered the pH and compositional changes in the carbonate water and decreased the magnitude of pH and compositional changes when small volumes of $UO_2(NO_3)_2$ added to the tuffaceous waters. 5 refs., 3 figs., 2 tabs.

243 **Transport of neptunium through Yucca Mountain tuffs.** Triay, I.R. (Los Alamos National Lab., NM (United States)); Robinson, B.A.; Mitchell, A.J.; Overly, C.M.; Lopez, R.M. pp. 797-802 of Scientific basis for nuclear waste management XVI. Interrante, C.G. (ed.); Pabalan, R.T. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1993). pp. 959 From 16. Materials Research Society (MRS) fall meeting; Boston, MA (United States); 30 Nov - 5 dec 1992.

Neptunium has a high solubility in groundwaters from Yucca Mountain. Uranium in nuclear reactors produces ^{237}Np which has a half-life of 2.14×10^6 years. Consequently, the transport of ^{237}Np through tuffs is of major importance in assessing the performance of a high-level nuclear waste repository at Yucca Mountain. The objective of this work is to determine the amount of Np retardation that is provided by the materials in Yucca Mountain tuffs as a function of groundwater chemistry.

244 **Testing models of flow and transport in unsaturated porous media.** Springer, E.P. (Los Alamos National Lab., NM (United States)); Hopkins, P.L.; Siegel, M.D.; Glass, R.J. pp. 336-347 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The design of an intermediate-scale flow and transport experiment in an unsaturated porous media is described. This experiment will be conducted a 3-m-diameter by 6-m-long caisson filled with silica sand. The study has been designed to minimize uncertainties in the conceptual model governing flow and transport of nonreactive tracers and to evaluate predictions of field tracer migration using laboratory data. Data from laboratory characterization of hydraulic and geochemical properties of the sand and tracer were used in preliminary modeling and sensitivity analyses to determine optimal fluid flux, influent tracer concentrations, and locations of sensors and sampling devices. Alternative approaches to compare observed and predicted data for model evaluation are discussed.

245 **Prioritization of ESF testing and integration with design and construction.** Elkins, N.Z. (Los Alamos National Lab., Las Vegas, NV (United States)). pp. 521-523 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The developmental strategy for underground site characterization testing in the Exploratory studies Facility (ESF) of the Yucca Mountain Site Characterization Program is outlined. The history and rationale behind ESF test program development, and each step in the test prioritization and planning process leading up to field implementation, is described. A major challenge for the Yucca Mountain Site Characterization Project Office (YMPO) is the definition and implementation of a testing program that is fully responsive to major characterization objectives and milestones while optimally integrated with, and minimally impactive to, ESF design construction activity. The outlined strategy provides YMPO a technically sound, defensible process for defining, planning, integrating, and ultimately fielding a comprehensive underground testing program in the ESF.

246 **Control of tracers, fluids, and materials for the Yucca Mountain Site Characterization Project.** Kalia, H.N. (Los Alamos National Lab., Las Vegas, NV (United States)). pp. 524-529 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

This paper describes use and control of tracers, fluids, and materials (TFM) at the Yucca Mountain Site Characterization Project, Management of TFM is necessary to ensure that site characterization activity does not introduce TFM that may have impact on Yucca Mountain's ability to isolate high-level radioactive waste from the accessible environment. All participants must identify TFM used for testing and construction and have the TFM evaluated to ascertain any impact on waste isolation capabilities of the site or on adjacent tests. Two data bases are created to track TFM: a working data base managed by Los Alamos National Lab. and a permanent data base managed by EG&G, which will contain information on actual TFM used.

247 **Neptunium retardation with tuffs and groundwaters from Yucca Mountain.** Triay, I.R. (Los Alamos National Laboratory, NM (United States)); Robinson, B.A.; Lopez, R.M.; Mitchell, A.J.; Overly, C.M. pp. 1504-1508 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park,

IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The retardation of neptunium was studied using batch sorption and column techniques. Pure mineral separates, tuffs and groundwaters from Yucca Mountain were used for these experiments. Our results indicate that Np sorption increases rapidly as the pH of the water increases in cases where surface complexation is thought to be the dominant sorption mechanism. Oxide minerals (such as hematite) sorb Np strongly; therefore; these minerals even at trace levels in Yucca Mountain tuffs can result in significant Np retardation. Neptunium in groundwaters from Yucca Mountain exhibited a significant amount of sorption onto quartz. Neptunium sorption onto quartz is important because of the large quantity of silica in the tuffs. Elution of neptunium solutions in groundwater through columns made of crushed tuff yielded sorption coefficients that agree with the sorption results obtained using batch sorption techniques. Agreement between batch and column experiments indicates a neptunium sorption mechanism that is linear, reversible, and instantaneous.

248 Dependence of radionuclide sorption on sample grinding surface area, and water composition. Rogers, P.S.Z. (Los Alamos National Laboratory, NM (United States)); Meijer, A. pp. 1509-1516 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

In its 1987 technical position paper, 'Determination of Radionuclide Sorption for High-Level Nuclear Waste Repositories', the Nuclear Regulatory Commission (NRC) review panel delineated several studies needed to show that experimental sorption coefficients could accurately model radionuclide sorption behavior along release pathways. In particular, they focused on the potential problems involved with the use of crushed rock samples, stating 'If crushed solids are used, it is essential to show that laboratory experiments involving sorption on crushed solids are relevant to the repository site. The surfaces of crushed material may be significantly different from the surfaces of intact material, both porous and fractured. Grinding may expose the surfaces of solid phases different from those which groundwater would contact in a repository and/or may change the reactivity of the same mineral surfaces with dissolved radionuclides. The surface of crushed mineral scan be enriched in certain elements by factors of two and three relative to the bulk composition...'. The experiments reported here were performed in direct response to the NRC technical position paper. They were designed to quantify the dependence of sorption properties and surface area on the crushed-particle size of the rock samples used in batch sorption experiments. To this end, nine different size fractions of tuff samples, ranging from 2 to 4 mm down to less than 38 μm, were prepared by grinding, sieving, and washing bulk samples. These were reacted with solutions containing three different radioactive sorbers, ^{137}Cs, ^{85}Sr, and ^{237}Np, the solid and solution fractions were separated, and both fractions were gamma counted to determine partitioning of the radioactive sorber. Surface areas of each sample were determined by BET analysis. From this information, the sorption coefficient (Rd) of each tracer on each particle-size fraction, and its correlation with surface area, was calculated.

249 Diffusion of sorbing and non-sorbing radionuclides. Triay, I.R. (Los Alamos National Laboratory, NM (United States)); Birdsell, K.H.; Mitchell, A.J.; Ott, M.A. pp. 1527-1532 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Diffusion is considered one of the most important retardation mechanisms in fractured media. The diffusion experiments conducted involved solid tuff and groundwater from Yucca Mountain. The uptake of radionuclides by the tuff was studied utilizing containers made of tuff in the the form of beakers. The solution containing the radionuclides of interest was placed in the tuff beaker cavity and the uptake of the radionuclides by the tuff was measured as a function of time. Our results indicate that the diffusion coefficient for nonsorbing radionuclides into saturated Yucca Mountain tuff is on the order of 10^{-6} cm^2/s. Large anions, such as pertechnetate are excluded from tuff pores and their diffusion coefficients are on the order of $10^{-7}cm^2/s$. Comparison of the predictions for the uptake of sorbing radionuclides by the tuff with the actual data obtained indicates that conservative transport calculations will result from predicting diffusion using the batch sorption coefficient for the sorbing radionuclide and the diffusion coefficient obtained for tritiated water.

250 Calcite deposits in fractures at Yucca Mountain, Nevada. Vaniman, D.T. (Los Alamos National Laboratory, NM (United States)). pp. 1935-1939 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Calcite is one of the latest-formed minerals within fractures at Yucca Mountain. Petrographic and chemical studies of these calcites have the potential, in conjunction with fluid-inclusion and isotopic studies, of determining the locations of transmissive regions in unsaturated tuffs. Preliminary chemical data for the fracture calcites from Yucca Mountain indicate a common composition for most unsaturated-zone calcites (low abundances of transition elements; chondrite-normalized lanthanide-element patterns with prominent negative Ce and Eu anomalies) that is distinct from most calcites in the saturated zone. Exceptions to this general characterization occur in drill core USW G-4; the reasons for these deviations are as yet unknown, but the rich variety of calcite compositions suggests that much information is to be gained from further studies.

251 Aperture characteristics, saturated fluid-flow and tracer-transports calculations for a natural fracture. Reimus, P.W. (Los Alamos National Laboratory, NM (United States)); Robinson, B.A.; Glass, R.J. pp. 2009-2016 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The overall objective of this study is to conduct tracer-transport experiments in natural fractures in support of the Yucca Mountain Site Characterization Program. We used surface-profile data taken with a noncontact laser profilometer to determine the aperture distribution within a natural fracture and found the surfaces and apertures to be isotropic. The aperture distribution could be described

equally well by either a normal or a lognormal distribution, although we had to adjust the standard deviation to 'fit' the data. The aperture spatial correlation varied over different areas of the fracture, with some areas being much more correlated than others. The fracture surfaces did not have a single fractal dimension over all length scales, which implied that they were not-self-similar. We approximated the saturated flow field in the fracture by solving a finite-difference discretization of the fluid-flow continuity tracer breakthrough curves using a particle-tracking method. Comparing the breakthrough curves obtained using both coarse- and fine-resolution aperture data (0.4- and 0.05-mm spacing between points, respectively) over the same subset of the fracture domain suggests that the spacing between the aperture data points must be less than the correlation length to obtain accurate predictions of fluid flow and tracer transport. In the future, we will perform tracer experiments and numerical modeling studies to determine exactly how fine the aperture data resolution must be (relative to the correlation length) to obtain accurate predictions.

252 Exploratory studies facility test implementation and integration with construction and design. Boak, D.M. (Los Alamos National Lab., Las Vegas, NV (United States)); Elkins, N.Z.; Kovach, R.; Oliver, R.D. pp. 1770-1773 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The Exploratory Studies Facility (ESF) is a critical component of the US Department of Energy's Yucca Mountain Site Characterization Project Office (YMPO) program to identify and characterize a potentially suitable site for licensing and construction of the nation's first geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. The mission of the ESF is to conduct a site characterization program that (1) is fully integrated with ESF design and construction, (2) minimizes potential adverse impacts to other tests, (3) protects waste isolation capabilities of the site, and (4) protects the environment. Tests performed in the ESF include unique, irretrievable data collection and in situ site characterization activities which provide a critical complement to surface-based and laboratory tests. In addition, the site characterization program must ensure that critical, irretrievable data are gathered with minimal impacts to other portions of the project and that a process exists for real-time integration of tests. Underground testing in the ESF began concurrently with construction of the ESF north ramp starter tunnel in 1993. This paper discusses the implementation of ESF north ramp starter tunnel tests, planning and implementation of radial borehole and hydrochemistry tests in the first test alcove, and real-time integration of tests with design, construction, and long-term site characterization test planning.

253 Selenite transport in unsaturated tuff from Yucca Mountain. Conca, J.L. (WSU Tri-Cities, Richland, WA (United States)); Triay, I.R. pp. 2175-2182 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Direct measurements of unsaturated selenite retardation coefficients and unsaturated hydraulic conductivity were obtained on two tuff samples from Yucca Mountain using the UFA™ technology. The retardation factor for the selenite species was only 2.5 in both Yucca Mountain vitric member at 62.6% saturation and zeolitized nonwelded tuff from G-tunnel at 52.8% saturation with respect to J-13 well water from the Nevada Test Site contaminated with selenium at 1.31 mg/l (ppm). In batch tests on the same material using 1.2 mg/l (ppm), the average K_d was determined to be 13, giving retardation factors higher than the UFA column breakthrough tests by an order of magnitude. The difference could result from preferential flow paths in the UFA column as might occur in the field or differences in residence times between the two types of tests. The unsaturated hydraulic conductivities during the experiments were 2.49×10^{-8} cm/s for the Yucca Mountain vitric member and 1.16×10^{-8} cm/s for the zeolited nonwelded tuff.

254 Radionuclide release rates from natural analogues of spent nuclear fuel. Curtis, D.B. (Los Alamos National Lab., NM (United States)); Fabryka-Martin, J.; Dixon, P.; Aguilar, R.; Cramer, J. pp. 2228-2236 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Measurements of ^{99}Tc, ^{129}I, ^{239}Pu and U concentrations in rock samples from uranium deposits at Cigar Lake and Koongarra have been used to estimate radionuclide release rates from uranium minerals. Rates of release have been immeasurably slow at Cigar Lake. At Koongarra release rates appear to have been faster, producing small deficiencies of ^{99}Tc, and larger ones of ^{129}I. The differences in model radionuclide release rates are consistent with expected differences in uranium mineral degradation rates produced by the differing hydrogeochemical environments at the two sites. The model release rates are orders of magnitude less than those used to simulate mineral alteration rates in the initial Sandia Total Safety Performance Assessment.

255 Inferences of paleoenvironment from petrographic, chemical and stable-isotope studies of calcretes and fracture calcites. Vaniman, D.T. (Los Alamos National Lab., NM (United States)); Whelan, J.F. pp. 2730-2737 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Past research has indicated a genetic connection between calcite formed in calcretes at the surface of Yucca Mountain, Nevada, and calcites deposited in underlying fractures of the unsaturated zone. This common genesis suggests that paleoenvironmental information, as well as the timing and pathways of past recharge episodes, might be obtained from studies of the deposits in both the calcretes and the unsaturated fractures. Chemical and isotopic modification of calcite-precipitating fluids appears to begin at the surface, largely under the influence of plant roots and their decay products. Chemical characteristics of the deeper calcites are either initiated or largely defined within the first few meters of fluid migration into the unsaturated tuffs beneath

the calcretes. However, petrographic and isotopic data indicate a very unique low-$\delta^{13}C$ microenvironment that is localized at the upper surfaces of the calcretes. These surfaces form an interface in the soil horizon where infiltration may pond above the underlying carbonate "plug". In order to decipher the chemistry and petrology of past recharge events, it is important to first understand microenvironments such as this that contribute to mineral precipitation/dissolution events in the pedogenic environment.

256 **Eolian-deposited minerals around drill hole USW SD-9, Yucca Mountain, Nevada.** Guthrie, G.D. Jr. (Los Alamos National Lab., NM (United States)); Raymond, R. Jr.; Chipera, S. pp. 135-136 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Eolian-deposited minerals around drill hold USW SD-9 were investigated to evaluate the potential long term impact to the environmental of activities at Yucca Mountain. Many activities (e.g., drilling-related activities) have the potential to release dusts with a mineral content that differs from those of dusts generated by non-anthropogenic activities. However, dusts trapped in boulder deposits close to USW SD-9 have a mineral content that is consistent with the mineral contents of natural dusts in boulder deposits throughout the Yucca Mountain area, suggesting that activities have not impacted the mineral content of eolian dusts significantly.

257 **Colloid stability in a potential nuclear waste repository.** Wistrom, A.O. (Univ. of California, Riverside, CA (United States)); Triay, I.R. pp. 242-244 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The stability of colloids in Yucca Mountain groundwaters is of great importance in assessing colloid-facilitated radionuclide transport at the potential nuclear waste repository. Aggregation experiments were performed to evaluate colloid stability of silica and clay colloids as a function of ionic strength in a carbonate rich synthetic groundwater. When the concentration of electrolyte is increased to induce aggregation, the aggregate growth proceeds at an exponential rate, is irreversible, and the rate of aggregation increases with increasing electrolyte strength. The rate of particle aggregation for both types of colloids was estimated using autocorrelation photon spectroscopy, (APS). The stability ratio, W, was determined using the Smoluchowski rate expression for irreversible aggregation. Aggregation of silica particles and Kaolinite clay particles was not detected for an electrolyte concentration, C_{NaCl} below 300 mM and 100 mM, respectively. However, it is possible that reversible aggregation does occur in this concentration range.

258 **Scientific issues and public interactions: The Yucca Mountain project.** Crowe, B.M. (Los Alamos National Lab., Las Vegas, NV (United States)). pp. 725-726 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This report provides a review of impressions obtained from public interactions regarding the risk of volcanism for underground storage of radioactive waste. These impressions were gained through participation in numerous contacts for the Yucca Mountain Site Characterization Project during the last six years. A conclusion emerging from public interactions is that scientists and those responsible for policy decisions must become more familiar with risk assessment, risk communication, and the requirements of objectively examining decision options for defining acceptable risk.

259 **Risk perception and technical interactions: Volcanism studies for the Yucca Mountain Site Characterization Project.** Crowe, B.M. (Los Alamos National Lab., Las Vegas, NV (United States)). pp. 766-767 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This paper summarizes probabilistic approaches to evaluating the risk of volcanism at Yucca Mountain. Interactions with the State of Nevada, regulatory agencies, and review groups concerning the volcanism issue have been extensive, and some of these groups have developed alternative models for assessing volcanism. The results of different models are briefly compared.

260 (DOE/ER/14352–1, pp. 447-450) **Planning and implementation of underground testing in the ESF.** Elkins, N.Z. (Los Alamos National Lab., Albuquerque, NM (United States)). Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

The Exploratory Studies Facility (ESF) is a critical component of the US Department of Energy (DOE) program to identify and characterize a suitable site for licensing and constructing the nation's first geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. As interpreted from the Nuclear Waste Policy Act of 1982 and the Nuclear Waste Policy Amendments Act of 1987, the mission of the ESF is to conduct subsurface exploration and testing in support of site suitability determination and license application, in a manner that protects the environment and waste isolation capabilities of the site. The Yucca Mountain Site Characterization Project Office (YMPO) is developing a strategic program for subsurface testing that is fully integrated with other scientific efforts and with the design and excavation/construction of the ESF. The major challenge for ESF testing is to sequentially implement a site characterization program that is responsive to Project priorities and objectives and simultaneously ensures that critical, irretrievable data are gathered with minimal impacts to schedule and cost of ESF construction and operation. The guiding strategy for ESF testing is initially focused on determining the site suitability of Yucca Mountain. Prioritized tests and observations underground will be required to complete an early evaluation of site suitability.

261 (LA–11844-MS) **The Yucca Mountain Project prototype air-coring test, U12g tunnel, Nevada test site.**

Ray, J.M. (Los Alamos National Lab., NM (United States)); Newsom, J.C. Los Alamos National Lab., NM (United States). Dec 1994. 140p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95005745. Source: OSTI; NTIS; INIS; GPO Dep.

The Prototype Air-Coring Test was conducted at the Nevada Test Site (NTS) G-Tunnel facility to evaluate standard coring techniques, modified slightly for air circulation, for use in testing at a prospective nuclear waste repository at Yucca Mountain, Nevada. Air-coring technology allows sampling of subsurface lithology with minimal perturbation to ambient characteristic such as that required for exploratory holes near aquifers, environmental applications, and site characterization work. Two horizontal holes were cored, one 50 ft long and the other 150 ft long, in densely welded fractured tuff to simulate the difficult drilling conditions anticipated at Yucca Mountain. Drilling data from seven holes on three other prototype tests in nonwelded tuff were also collected for comparison. The test was used to establish preliminary standards of performance for drilling and dust collection equipment and to assess procedural efficiencies. The Longyear-38 drill achieved 97% recovery for HQ-size core (-2.5 in.), and the Atlas Copco dust collector (DCT-90) captured 1500 lb of fugitive dust in a mine environment with only minor modifications. Average hole production rates were 6-8 ft per 6-h shift in welded tuff and almost 20 ft per shift on deeper holes in nonwelded tuff. Lexan liners were successfully used to encapsulate core samples during the coring process and protect core properties effectively. The Prototype Air-Coring Test demonstrated that horizontal air coring in fractured welded tuff (to at least 150 ft) can be safely accomplished by proper selection, integration, and minor modification of standard drilling equipment, using appropriate procedures and engineering controls. The test also indicated that rig logistics, equipment, and methods need improvement before attempting a large-scale dry drilling program at Yucca Mountain.

262 (LA–12411-SR) **Status report on ESF-related prototype testing.** Oliver, R.D.; Kalia, H.N. (comps.). Los Alamos National Lab., NM (United States). Dec 1992. 316p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94008703. Source: OSTI; NTIS; INIS; GPO Dep.

This report provides information on the Prototype Testing performed in the G-Tunnel on the Nevada Test Site by the Yucca Mountain Project form April 1988 to November 1989. The Testing Program was implemented to ensure that the Exploratory Shaft Facility (ESF) tests can be completed in the time available and to develop instruments, equipment, and procedures so the ESF tests can collect reliable and representative site characterization data. This report summarizes the ESF prototype tests and presents preliminary results.

263 (LA–12563-MS) **Measured solubilities and speciations from oversaturation experiments of neptunium, plutonium, and americium in UE-25p No. 1 well water from the Yucca Mountain region: Milestone report 3329-WBS1.2.3.4.1.3.1.** Nitsche, H. (Lawrence Berkeley Lab., CA (United States)); Roberts, K.; Prussin, T.; Mueller, A.; Becraft, K.; Keeney, D.; Carpenter, S.A.; Gatti, R.C. Los Alamos National Lab., NM (United States). Apr 1994. 103p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94008790. Source: OSTI; NTIS; INIS; GPO Dep.

Solubility and speciation are important in understanding aqueous radionuclide transport through the geosphere. They define the source term for transport retardation processes such as sorption and colloid formation. Solubility and speciation data are useful in verifying the validity of geochemical codes that are a part of predictive transport models. Results are presented from solubility and speciation experiments of $^{237}NpO_2^+$, $^{239}Pu^{4+}$, and $^{241}Am^{3+}/Nd^{3+}$ in a modified UE-25p No. 1 groundwater (from the Yucca Mountain region, Nevada, which is being investigated as a potential high-level nuclear waste disposal site) at two different temperatures (25° and 60°C) and three pH values (6.0, 7.0, 8.5). The solubility-controlling steady-state solids were identified and the speciation and/or oxidation states present in the supernatant solutions were determined. The neptunium solubility decreased with increasing temperature and pH. Plutonium concentrations significantly decreased with increasing temperature at pH 6 and 7. The concentration at pH 8.5 hardly decreased at all with increasing temperature. At both temperatures the concentrations were highest at pH 8.5, lowest at pH 7, and in between at pH 6. For the americium/neodymium solutions, the solubility decreased significantly with increasing temperature and increased somewhat with increasing pH.

264 (LA–12573-MS) **Distribution of potentially hazardous phases in the subsurface at Yucca Mountain, Nevada.** Guthrie, G.D. Jr.; Bish, D.L.; Chipera, S.J.; Raymond, R. Jr. Los Alamos National Lab., NM (United States). May 1995. 41p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95011012. Source: OSTI; NTIS; INIS; GPO Dep.

Drilling, trenching, excavation of the Exploratory Studies Facility, and other surface and underground-distributing activities have the potential to release minerals into the environment from tuffs at Yucca Mountain, Nevada. Some of these minerals may be potential respiratory health hazards. Therefore, an understanding of the distribution of the minerals that may potentially be liberated during site-characterization and operation of the potential repository is crucial to ensuring worker and public safety. Analysis of previously reported mineralogy of Yucca Mountain tuffs using data and criteria from the International Agency for Research on Cancer (IARC) suggests that the following minerals are of potential concern: quartz, cristobalite, tridymite, opal-CT, erionite, mordenite, and palygorskite. The authors have re-evaluated the three-dimensional mineral distribution at Yucca Mountain above the static water level both in bulk-rock samples and in fractures, using quantitative X-ray powder diffraction analysis. Erionite, mordenite, and palygorskite occur primarily in fractures; the crystalline-silica minerals, quartz, cristobalite, and tridymite are major bulk-rock phases. Erionite occurs in the altered zone just above the lower Topopah Spring Member vitrophyre, and an occurrence below the vitrophyre but above the Calico Hills has recently been identified. In this latter occurrence, erionite is present in the matrix at levels up to 35 wt%. Mordenite and palygorskite occur throughout the vadose zone nearly to the surface. Opal-CT is limited to zeolitic horizons.

265 (LA–12596-MS) **Measurement of unsaturated hydraulic conductivity and chemical transport in Yucca Mountain Tuff: Milestone Report 3044-WBS1.2.3.4.1.4.1.** Conca, J.L. (Washington State Univ., Richland, WA (United States)). Los Alamos National Lab., NM (United States). Dec 1993. 28p. Sponsored by USDOE, Washington, DC (United

States). DOE Contract W-7405-ENG-36. Order Number DE94004880. Source: OSTI; NTIS; INIS; GPO Dep.

Hydraulic conductivities, K, were experimentally determined as a function of volumetric water content, θ, in tuff from the Yucca Mountain site. In addition, the retardation factor, R_f, in Yucca Mountain tuff with respect to selenium, as the selenite species, was measured under unsaturated conditions. These data were used to determine the feasibility of applying a new unsaturated flow technology (UFA) to further hydrologic studies at Yucca Mountain. The UFA directly measures $K(\theta)$ rapidly in Yucca Mountain tuff and is shown to agree well with traditional methods. Hysteresis does not appear important during this testing. Hydraulic steady-state is achieved fastest during desaturation from a saturated state. Imbibition into dry tuff requires a long time for steady-state to occur because of slow filling of the diffusion porosity which can take a few weeks. The existing UFA is a prototype, and a new design of the next generation UFA is completed that eliminates some of the earlier problems. These preliminary investigations demonstrates that the UFA is a useful investigate technique that should be used to compliment existing techniques for hydrogeochemical characterization at Yucca Mountain and other arid sites.

266 (LA–12652-MS) **Mineralogy and clinoptilolite K/Ar results from Yucca Mountain, Nevada, USA: A potential high-level radioactive waste repository site.** WoldeGabriel, G.; Broxton, D.E.; Bish, D.L.; Chipera, S.J. Los Alamos National Lab., NM (United States). Nov 1993. 44p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94005018. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project is investigating Yucca Mountain, Nevada, as a potential site for a high-level nuclear waste repository. An important aspect of this evaluation is to understand the geologic history of the site including the diagenetic processes that are largely responsible for the present-day chemical and physical properties of the altered tuffs. This study evaluates the use of K/Ar geochronology in determining the alteration history of the zeolitized portions of Miocene tuffs at Yucca Mountain. Clinoptilolite is not generally regarded as suitable for dating because of its open structure and large ion-exchange capacity. However, it is the most abundant zeolite at Yucca Mountain and was selected for this study to assess the feasibility of dating the zeolitization process and/or subsequent processes that may have affected the zeolites. In this study we examine the ability of this mineral to retain all or part of its K and radiogenic Ar during diagenesis and evaluate the usefulness of the clinoptilolite K/Ar dates for determining the history of alteration.

267 (LA–12703-SR) **Los Alamos National Laboratory Yucca Mountain Site Characterization Project 1992 quality program status report.** Bolivar, S.L. (and others); Burningham, A.; Chavez, P. Los Alamos National Lab., NM (United States). Mar 1994. 126p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94007726. Source: OSTI; NTIS; INIS; GPO Dep.

This status report summarizes the activities and accomplishments of the Los Alamos Yucca Mountain Site Characterization Project's quality assurance program for calendar year 1992. The report includes major sections on Program Activities and Trend Analysis. Program Activities are discussed periodically at quality meetings. The most significant issue addressed in 1992 has been the timely revision of quality administrative procedures. The procedure revision process was streamlined from 55 steps to 7. The number of forms in procedures was reduced by 38%, and the text reduced by 29%. This allowed revision in 1992 of almost half of all implementing procedures. The time necessary to complete the revision process (for a procedure) was reduced from 11 months to 3 months. Other accomplishments include the relaxation of unnecessarily strict training requirements, requiring quality assurance reviews only from affected organizations, and in general simplifying work processes. All members of the YMP received training to the new Orientation class Eleven other training classed were held. Investigators submitted 971 records to the Project and only 37 were rejected. The software program has 115 programs approved for quality-affecting work. The Project Office conducted 3 audits and 1 survey of Los Alamos activities. We conducted 14 audits and 4 surveys. Eight corrective action reports were closed, leaving only one open. Internally, 22 deficiencies were recognized. This is a decrease from 65 in 1991. Since each deficiency requires about 2 man weeks to resolve, the savings are significant. Problems with writing acceptable deficiency reports have essentially disappeared. Trend reports for 1992 were examined and are summarized herein. Three adverse trends have been closed; one remaining adverse trend will be closed when the affected procedures are revised. The number of deficiencies issued to Los Alamos compared to other participants is minimal.

268 (LA–12707-MS) **Transport of synthetic colloids through single saturated fractures: A literature review.** Reimus, P.W. Los Alamos National Lab., NM (United States). Jul 1995. 109p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95016381. Source: OSTI; NTIS; INIS; GPO Dep.

Colloids having the same surface charge sign as the bulk of the geologic media in a groundwater system may be able to travel through the system faster than soluble species because they will follow fluid streamlines more closely and they should have less tendency to diffuse into pores or dead spaces in the media than soluble species. Synthetic colloids with uniform, controlled properties may be ideal for serving as "worst-case" tracers that provide lower-bound estimates of contaminant travel times in hydrologic systems. This report discusses a review of the literature pertaining to colloid transport in single saturated natural fractures. After a brief background discussion to put the literature review in perspective, the phenomenon of colloid transport in saturated fractures is divided into three major topics, each of which is reviewed in detail: (1) saturated fluid flow through fractures; (2) colloid transport by convection, diffusion, and force fields; and (3) colloid interactions with surfaces. It is suggested that these phenomena be accounted for in colloid transport models by using (1) lubrication theory to describe water flow through fractures, (2) particle tracking methods to describe colloid transport in fractures, and (3) a kinetic boundary layer approximation to describe colloid interactions with fracture walls. These methods offer better computational efficiency and better experimental accessibility to model parameters than rigorously solving the complete governing equations.

269 (LA–12720-MS) **Calcite deposits in drill cores USW G-2 and USW GU-3/G-3 at Yucca Mountain, Nevada: Preliminary report.** Vaniman, D.T. Los Alamos National Lab., NM (United States). Apr 1994. 28p. Sponsored by USDOE, Washington, DC (United States). DOE

Contract W-7405-ENG-36. Order Number DE94008780. Source: OSTI; NTIS; INIS; GPO Dep.

Yucca Mountain is being studied as a potential site for deep geologic disposal of high-level radioactive waste. Should a repository be developed at Yucca Mountain, the preferred location is within the upper unsaturated tuffaceous volcanic rocks. In this location, one factor of concern is the amount and rate of aqueous transport through the unsaturated rocks toward the underlying saturated intervals. Calcite, one of the most recently-formed minerals at Yucca Mountain, is of minor abundance in the unsaturated rocks but is widely distributed. Studies of calcite ages, isotopic systematics, chemistry and petrography could lead to a better understanding of transport processes at Yucca Mountain.

270 (LA–12779-MS) **Colloid-facilitated radionuclide transport at Yucca Mountain.** Triay, I. (Los Alamos National Lab., NM (United States)); Levy, S.; Robinson, B.; Simmons, A.; Nelson, S.; Nuttall, H.; Steinkampf, W.; Viani, B. Los Alamos National Lab., NM (United States). Apr 1995. 27p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95010558. Source: OSTI; NTIS; GPO Dep.

The objective of this report is to describe the colloid investigations within the Yucca Mountain Site Characterization Project (YMP) to evaluate whether colloids will significantly increase radionuclide release from a potential high-level nuclear waste repository at Yucca Mountain to the accessible environment. The evidence of the existence of colloids from sampling studies and observation of colloid transport at the field scale are reviewed. The relevance of colloid transport laboratory and field experiments to the conditions at Yucca Mountain are discussed. Research needs are identified in the areas of colloid sampling, colloid generation, colloid stability, colloidal sorption/desorption of radionuclides, and colloid migration. The colloid transport calculations that will allow evaluation of the data to assess the importance of colloid-facilitated radionuclide transport at Yucca Mountain are presented.

271 (LA–12780-MS) **Molecular models for actinide speciation.** Clark, D.L.; Watkin, J.G.; Morris, D.E.; Berg, J.M. Los Alamos National Lab., NM (United States). Jun 1994. 32p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94012370. Source: OSTI; NTIS; INIS; GPO Dep.

Much effort has been devoted to the development of sensitive spectroscopic techniques for the study of actinide speciation based on the sensitivity of f-f electronic absorption bands to oxidation state and ligation of the actinide ions. These efforts assume that data obtained in such studies will be interpretable in terms of changes in complexation of the metal center. However, the current understanding of 5f electronic structure is based on data from solid state doped single crystals. In those studies, the local coordination geometry about the central actinide ion is maintained in an almost perfect high-symmetry environment and will have little relevance for species in solution where deviations from perfect high symmetry tend to be the rule rather than the exception. The authors have developed a vigorous research program in the systematic preparation and spectroscopic characterization of synthetic actinide complexes (Th, U, Np, and Pu) in which they can control nuclearity, oxidation state, and molecular structure. These complexes have been used to determine how observable electronic transitions are perturbed in response to structural changes in the complex in solution. From the spectra obtained for these model complexes, the authors have found that the f-f transitions naturally fall into obvious groupings by coordination number and symmetry by which they can now differentiate between monomeric, dimeric, and trimeric species in solution. The study of radionuclide speciation is fundamentally important to the determination of radionuclide solubility in the groundwater at Yucca Mountain.

272 (LA–12803-MS) **Field guide to fracture-lining minerals at Yucca Mountain, Nevada.** Carlos, B.A. Los Alamos National Lab., NM (United States). Dec 1994. 12p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95010669. Source: OSTI; NTIS; INIS; GPO Dep.

This guide is intended to provide descriptions useful to those researchers who are logging core or mapping fractures with aid of a hand lens or binocular microscope. Many minerals are fine-grained and cannot be distinguished at 10x magnification, but the information contained in this guide should at least allow the possibilities to be constrained. Although some of these minerals are more easily identified using hardness or acid tests, the descriptions do not include information on hardness or response to acid because scratching and use of acid on core are not permitted at the drill site or in the sample management facility. Because these descriptions are intended for use in the field, they are organized by visual properties rather than by mineralogy or chemistry. Five primary groups are used, and individual minerals are discussed within the visual-characteristic groups.

273 (LA–12810-MS) **Mineralogic variation in drill core UE-25 UZ#16, Yucca Mountain, Nevada.** Chipera, S.J.; Vaniman, D.T.; Carlos, B.A.; Bish, D.L. Los Alamos National Lab., NM (United States). Feb 1995. 39p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95008371. Source: OSTI; NTIS; INIS; GPO Dep.

Quantitative X-ray powder diffraction methods have been used to analyze 108 samples from drill core UE-25 UZ#16 at Yucca Mountain, Nevada. This drill hole, located within the imbricate fault zone east of the potential Yucca Mountain repository site, confirms the authors' previous knowledge of gross-scale mineral distributions at Yucca Mountain and provides insight into possible shallow pathways for hydrologic recharge into the potential host rock. Analyses of samples from UE-25 UZ#16 have shown that the distribution of major zeolitized horizons, of silica phases, and of glassy tuffs are similar to those noted in nearby drill cores. However, the continuous core and closer sample spacing in UE-25 UZ#16 provide a more exact determination of mineral stratigraphy, particularly in hydrologically important units such as the Paintbrush bedded tuffs above the Topopah Spring Tuff and in the upper vitrophyre of the Topopah Spring Tuff. The discovery of matrix zeolitization in the devitrified Topopah Spring Tuff of UE25 UZ#16 shows that some unexpected mineralogic features can still be encountered in the exploration of Yucca Mountain and emphasizes the importance of obtaining a more complete three-dimensional model of Yucca Mountain mineralogy.

274 (LA–12820-MS) **Actinide(IV) and actinide(VI) carbonate speciation studies by PAS and NMR spectroscopies: Yucca Mountain Project: Milestone report 3031-WBS 1.2.3.4.1.3.1.** Clark, D.L.; Ekberg, S.A.; Morris, D.E.; Palmer, P.D.; Tait, C.D. Los Alamos National Lab., NM (United States). Sep 1994. 62p. Sponsored by USDOE,

Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94016957. Source: OSTI; NTIS; INIS; GPO Dep.

Pulsed-laser photoacoustic spectroscopy (PAS) and Fourier-transform nuclear magnetic resonance (NMR) spectroscopy were used to study speciation of actinide(IV) and actinide(VI) ions (Np, Pu, Am) in aqueous carbonate solutions vs pH, carbonate content, actinide content, temperature. PAS focused on Pu(IV) speciation. Stability fields on a pH (8.4 to 12.0) versus total carbonate content (0.003 to 1.0 M) plot for dilute Pu(IV) carbonate species ($[Pu]_{tot}$ = 1 mM) were mapped. Four plutonium species, with absorption peaks at 486, 492, 500, and 512 nm were found. Loss of a single carbonate ligand does not account for the difference in speciation for the 486 and 492 nm absorption peaks, nor can any of the observed species be identified as colloidal Pu(IV). NMR data have been obtained for UO_2^{2+}, PuO_2^{2+} and AmO_2^{2+}. This report focuses on results for PuO_2^{2+}. The ligand exchange reaction between free and coordinated carbonate on the $PuO_2(CO_3)_3^{4-}$ systems has been examined by variable temperature ^{13}C NMR spectroscopy. In each of the six different $PuO_2(CO_3)_3^{4-}$ samples, two NMR signals are present, one for the free carbonate ligand and one for the carbonate ligand coordinated to a paramagnetic plutonium metal center. The single ^{13}C resonance line for coordinated carbonate is consistent with expectations of a monomeric $PuO_2(CO_3)_3^{4-}$ species in solution. A modified Carr-Purcell-Meiboom-Gill NMR pulse sequence was used for determining ligand exchange parameters for paramagnetic actinide complexes. Eyring analysis at standard conditions provided activation parameters of ΔH = 38 KJ/M and ΔS = −60 J/K for the plutonyl triscarbonate system, suggesting an associative transition state for the plutonyl(VI) carbonate complex self-exchange reaction.

275 (LA–12824-MS) **Selection of a preferred initial access for the exploratory studies facility.** Boak, D.M. (Woodward Clyde Federal Services, Las Vegas, NV (United States)); Cikanek, E.M.; Elkins, N.Z. Los Alamos National Lab., NM (United States). Jun 1995. 18p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95015063. Source: OSTI; NTIS; INIS; GPO Dep.

An issue of interest to the Yucca Mountain Site Characterization Project Office (YMPO) has been selection of the preferred location for initial access to the Exploratory Studies Facility (ESF) in the event that the U.S. Department of Energy (DOE) elected to proceed with a phased approach to facility development. A task force to conduct an assessment and prepare a recommendation of the preferred initial location (north or south) for starting underground in situ tests at Yucca Mountain was initiated by YMPO to address this issue. The task force addressed geotechnical issues associated with the presence of disqualifying conditions at the site, the inability of the site to meet qualifying conditions, and the potential for unexpected geologic conditions at the site. The task force compared the north and south ramp accesses of the ESF to determine whether either access would be more likely to provide relevant information about potential site unsuitability. The task force did not address issues such as design time or construction costs. Within the aforementioned context, a balanced evaluation of currently available geotechnical information and issues failed to provide a clear mandate for either ramp as the preferred initial ESF access. Neither access was clearly superior in providing geotechnical information to resolve site suitability issues. The task force therefore recommended that other appropriate programmatic factors, such as schedule, be used as a basis in determining the choice of a preferred, initial ESF access in the event of phased construction.

276 (LA–12886-MS) **Plutonium carbonate speciation changes as measured in dilute solutions with photoacoustic spectroscopy: Yucca Mountain Site Characterization Program Milestone report 3350.** Tait, C.D.; Ekberg, S.A.; Palmer, P.D.; Morris, D.E. Los Alamos National Lab., NM (United States). May 1995. 23p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95012118. Source: OSTI; NTIS; INIS; GPO Dep.

The stability fields for dilute Pu-carbonate species versus pH (8.4 to 12.0) and total carbonate concentrations (3 mM to 1.0 M) have been mapped-out using photoacoustic absorption spectroscopy (PAS). At least four different plutonium species, characterized by absorption peaks at 486, 492, 500, and 513 rim, have been found. A redox change to a Pu(VI) complex can not account for the speciation change associated with the first two spectra (486 and 492 nm peaks). Moreover, the data are consistent with what is predicted from a previous YMP milestone. This previous study was performed under very different conditions of plutonium concentration and carbonate/pH changes, and extension of these conditions to much lower Pu concentrations and to more neutral pHs was made possible with PAS spectroscopy. These new results reinforce the previous results by extending the range of direct observation and by eliminating other possibilities such as dimerization/polymerization reactions. As bicarbonate concentration is increased from .01 M to 1.0 M at pH=8.4 to 8.9, predominately $[Pu(OH)_{x+1}(CO_3)_y]^{4-(x+2y)}$ (492 nm peak) is converted to $[Pu(OH)_x(CO_3)_{y+1}]^{4-(x+2y+2)}$ (486 nm peak). The starting stoichiometry (x and y values) remain undetermined, but the effect of ionic strength and temperature indicate that the 486 nm species is highly charged, and therefore $x+2y \geq 3$. The temperature effect on the equilibrium between these two species was also investigated, with the species giving rise to the 486 nm peak reversibly losing importance at elevated (50 and 75°C temperatures).

277 (LA–12894-MS) **Ion exchange and dehydration experimental studies of clinoptilolite: Implications to zeolite dating.** WoldeGabriel, G. Los Alamos National Lab., NM (United States). Feb 1995. 20p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95007726. Source: OSTI; NTIS; INIS; GPO Dep.

Variable effects were noted on the argon (Ar) and potassium (K) contents of clinoptilolite fractions used in ion-exchange and dehydration experiments. The K contents of clinoptilolite fractions were differently affected during cation exchange with Ca-, Cs-, K-, and Na-chloride solutions. Ar was generally less affected during these experiments, except for a Na-clinoptitolite fraction exchanged for five days. Loss of Ar during organic heavy-liquid treatment and cleaning using acetone and deionized water does occur, as indicated by comparing the amounts of radiogenic Ar of treated and untreated fractions. Moreover, a regular decrease in radiogenic Ar contents was noted in clinoptilolite fractions during dehydration experiments at different temperatures for 16 hours. Comparable losses do not occur from saturated samples that were heated in 100 C for more than five months. Water appears to play a vital role in stabilizing the clinoptilolite framework structure and in the retention of

Ar. The radiogenic Ar depletion pattern noted in clinoptilolite fractions dehydrated in unsaturated environment at different temperatures is similar to variations in the amount of radiogenic Ar observed in clinoptilolite samples from the unsaturated zone of an altered tuff. These results can be used to evaluate the extent of zeolitic water (and hence Ar) retention in unsaturated geologic settings. The utility of alkali zeolites (e.g., phillipsite, clinoptilolite, and mordenite) from low-temperature, open-hydrologic alteration as potential dateable minerals was evaluated using the K/Ar method as part of the Yucca Mountain Site Characterization Project, which is evaluating Yucca Mountain, Nevada, as a potential high-level radioactive waste repository site.

278 (LA–12897-MS) **^{13}C and ^{17}O NMR binding constant studies of uranyl carbonate complexes in near-neutral aqueous solution. Yucca Mountain Project Milestone Report 3351.** Clark, D.L.; Newton, T.W.; Palmer, P.D.; Zwick, B.D. Los Alamos National Lab., NM (United States). Jan 1995. 56p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95008109. Source: OSTI; NTIS; INIS; GPO Dep.

Valuable structural information, much of it unavailable by other methods, can be obtained about complexes in solution through NMR spectroscopy. From chemical shift and intensity measurements of complexed species, NMR can serve as a species-specific structural probe for molecules in solution and can be used to validate thermodynamic constants used in geochemical modeling. Fourier-transform nuclear magnetic resonance (FT-NMR) spectroscopy has been employed to study the speciation of uranium(VI) ions in aqueous carbonate solutions as a function of pH, ionic strength, carbonate concentration, uranium concentration, and temperature. Carbon-13 and oxygen-17 NMR spectroscopy were used to monitor the fractions, and hence thermodynamic binding constants of two different uranyl species $U0_2(CO_3)_3^{4-}$ and $(UO_2)_3(CO_3)_6^{6-}$ in aqueous solution. Synthetic buffer solutions were prepared under the ionic strength conditions used in the NMR studies in order to obtain an accurate measure of the hydrogen ion concentration, and a discussion of $pH = -\log(a_{H^+})$ versus $p[H] = -\log[H+]$ is provided. It is shown that for quantitative studies, the quantity p[H] needs to be used. Fourteen uranium(VI) binding constants recommended by the OECD NEA literature review were corrected to the ionic strengths employed in the NMR study using specific ion interaction theory (SIT), and the predicted species distributions were compared with the actual species observed by multinuclear NMR. Agreement between observed and predicted stability fields is excellent. This establishes the utility of multinuclear NMR as a species-specific tool for the study of the actinide carbonate complexation constants, and serves as a means for validating the recommendations provided by the OECD NEA.

279 (LA–12905-SR) **Los Alamos National Laboratory Yucca Mountain Site Characterization Project 1993 Quality Program status report.** Bolivar, S.L. Los Alamos National Lab., NM (United States). May 1995. 131p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95015021. Source: OSTI; NTIS; INIS; GPO Dep.

This status report is for calendar year 1993. It summarizes the annual activities and accomplishments of the Los Alamos National Laboratory (Los Alamos) Yucca Mountain Site Characterization Project (YMP or Project) quality assurance program. By identifying the accomplishments of the quality program, we establish a baseline that will assist in decision making, improve administrative controls and predictability, and allow us to annually identify long term trends and to evaluate improvements. This is the third annual status report (Bolivar, 1992; Bolivar, 1994). This report is divided into two primary sections: Program Activities and Trend Analysis. Under Program Activities, programmatic issues occurring in 1993 are discussed. The goals for 1993 are also listed, followed by a discussion of their status. Lastly, goals for 1994 are identified. The Trend Analysis section is a summary of 1993 quarterly trend reports and provides a good overview of the quality assurance issues of the Los Alamos YMP.

280 (LA–12908-MS) **Status of volcanism studies for the Yucca Mountain Site Characterization Project.** Crowe, B. (Los Alamos National Lab., NM (United States)); Perry, F.; Murrell, M.; Poths, J.; Valentine, G.A.; Wells, S.; Bowker, L.; Finnegan, K.; Geissman, J.; McFadden, L. Los Alamos National Lab., NM (United States). Feb 1995. 396p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95009090. Source: OSTI; NTIS; INIS; GPO Dep.

Chapter 1 introduces the volcanism issue for the Yucca Mountain site and provides the reader with an overview of the organization, content, and significant conclusions of this report. The risk of future basaltic volcanism is the primary topic of concern including both events that intersect a potential repository and events that occur near or within the waste isolation system of a repository. Chapter 2 describes the volcanic history of the Yucca Mountain region (YMR) and emphasizes the Pliocene and Quaternary volcanic record, the interval of primary concern for volcanic risk assessment. The Lathrop Wells volcanic center is described in detail because it is the youngest basalt center in the YMR. Chapter 3 describes the tectonic setting of the YMR and presents and assesses the significance of multiple alternative tectonic models. Geophysical data are described for the YMR and are used as an aid to understand the distribution of basaltic volcanic centers. Chapter 4 discusses the petrologic and geochemical features of basaltic volcanism in the YMR, the southern Great Basin and the Basin and Range province. The long time of activity and characteristic small volume of the Postcaldera basalt of the YMR result in one of the lowest eruptive rates in a volcanic field in the southwest United States. Chapter 5 summarizes current concepts of the segregation, ascent, and eruption of basalt magma. Chapter 6 summarizes the history of volcanism studies (1979 through early 1994), including work for the Yucca Mountain Site Characterization Project and overview studies by the state of Nevada and the Nuclear Regulatory Commission. Chapter 7 summarizes probabilistic volcanic hazard assessment using a three-part conditional probability model. Chapter 8 describes remaining volcanism work judged to be needed to complete characterization studies for the YMR. Chapter 9 summarizes the conclusions of this volcanism status report.

281 (LA–12917-PR) **Laboratory and field studies related to the Hydrologic Resources Management Program. Progress report, October 1, 1993–September 30, 1994.** Thompson, J.L. (ed.). Los Alamos National Lab., NM (United States). Mar 1995. 24p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95007675. Source: OSTI; NTIS; INIS; GPO Dep.

This report describes the work done at Los Alamos in FY 1994 for the Hydrologic Resources Management Program, a multi-organization project funded by the US Department of

Energy/Nevada Operations Office. The authors participated in cooperative collaborations with University of California (UC), Berkeley, the Yucca Mountain Project, the Underground Test Area Operable Unit, and other participating organizations within the Hydrologic Resources Management Program (HRMP). They provided operational support to the Nevada Test Site (NTS) organizations by testing a water-evaporation system, championing the use of high-sensitivity logging equipment during drillbacks, and participating in the planning and execution of drilling operations at two nuclear test sites. Los Alamos personnel cooperated in preparing a proposal to drill beside and under a nuclear test located in unsaturated media. The authors gave assistance in laboratory work related to colloid migration and actinide sorption. In conjunction with personnel from the Lawrence Livermore Laboratory, they collected water samples from 10 wells at the NTS that are known to contain radionuclides. Their analyses of these samples suggest that radionuclides may not be moving away from cavity zones at appreciable rates. Recent field sampling shows clearly the need to purge wells of materials introduced during drilling and illustrates the inconsistency between water samples taken by bailing and those taken by pumping. 36 refs.

282 (LA–13004-T) **The use of synthetic colloids in tracer transport experiments in saturated rock fractures.** Reimus, P.W. Los Alamos National Lab., NM (United States). Aug 1995. 252p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95016706. Source: OSTI; NTIS; INIS; GPO Dep.

NM.

Studies of groundwater flow and contaminant transport in saturated, fractured geologic media are of great interest to researchers studying the potential long-term storage of hazardous wastes in or near such media. A popular technique for conducting such studies is to introduce tracers having different chemical and physical properties into a system and then observe the tracers at one or more downstream locations, inferring flow and transport mechanisms from the breakthrough characteristics of the different tracers. Many tracer studies have been conducted in saturated, fractured media to help develop and/or refine models capable of predicting contaminant transport over large scales in such media.

283 (LA–13036-MS) **Joint orientation and characteristics as observed in a trench excavated near TA-3 and a basement excavated at TA-55.** Purtymun, W.D.; Koenig, E.; Morgan, T.; Sagon, E. Los Alamos National Lab., NM (United States). Oct 1995. 42p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE96000885. Source: OSTI; NTIS; GPO Dep.

Walls of excavations in the Bandelier Tuff for pipelines and foundations for structures provide excellent areas to determine the orientation (strike and dip) and characteristics of the joints (frequency, width, and type of material filling the joint). Joints or fractures are commonly associated with structural adjustments such as faulting; however, joints formed in the tuff mainly result from the shrinkage of the ash-flow tuff as it cools. The presence of faults can restrict the siting of buildings or structures. In waste disposal operations, open joints can be pathways for the transport of contaminants.

284 (LA-SUB–94-34) **Preparation for kinetic measurements on the silicates of the Yucca Mountain potential repository. [Final report], June 15, 1993–September 30, 1993.** Los Alamos National Lab., NM (United States); Pennsylvania State Univ., University Park, PA (United States). Ore Deposits Research Section. [1993]. 37p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94017049. Source: OSTI; NTIS; INIS; GPO Dep.

Part 1, "The Preparation of Clinoptilolite, Mordenite and Analcime," summarized progress made during the contract period on preparing Na-end member clinoptilolite, mordenite, and analcime. The objective is to use the prepared zeolites to determine rates of dissolution and precipitation in laboratory flow-through systems in both this lab to 350 C and by the geochemists at Yale University to about 80 C. Because clinoptilolite represents the most complicated phase of these three zeolites and it is most abundant at Yucca Mountain, the authors have concentrated most of their efforts on its preparation. They have collected, high-concentration natural clinoptilolite samples. A hindered settling technique that takes advantage of the relatively low specific gravity of clinoptilolite coupled with ultrasonic cleaning in deionized water has been employed. This material is now a mixed Na-K zeolite which must then be converted to the pure Na-end member composition. In Part 2, "Draft Manuscript on the Heterogeneous Kinetics of Cristobalite," experiments on the rates of reactions of dissolution and precipitation of cristobalite were carried at 150–300 C. Results show that cristobalite may precipitate from hydrothermal solution if the concentration of $Si(OH)_4$ exceeds that at quartz saturation and is less than that of amorphous silica saturation and if there are cristobalite nuclei present. Such nuclei may occur where there has been devitrification of volcanic glasses, for example. Cristobalite has refused to crystallize in the absence of such nuclei. Steady state concentrations were reached experimentally after starting at 150 ° with initially supersaturated solutions and at 200 C starting with either supersaturated or undersaturated solutions. From the steady state conditions, equilibrium constants can be derived.

285 (LA-SUB–94-92) **Yucca Mountain Project Integrated Data System (IDS): Final report, October 1, 1989–December 31, 1990.** Los Alamos National Lab., NM (United States); Computer Applications Group, Inc., Carlton, OR (United States). 23 May 1991. 166p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94017052. Source: OSTI; NTIS; INIS; GPO Dep.

This final report for LANL Subcontract 9-XS8-2604-1 includes copies of all formal letters, memorandums, and reports provided by CAG to support the IDS effort in the LANL Test Managers Office, Las Vegas, Nevada from October 1, 1989 through the end of the contract on December 31, 1990. The material is divided into two sections; the Functional Requirements Document (FRD) and other reports, letters, and memorandums. All documents are arranged in chronological order with most recent last. Numerous draft copies of the FRD were prepared and cover sheets for all drafts are included. The complete text of only the last version supplied (July 27, 1990) is included in this document.

286 (LA-SUB–94-109) **1992-93 Results of geomorphological and field studies Volcanic Studies Program, Yucca Mountain Project.** Wells, S.G. Los Alamos National Lab., NM (United States). Oct 1993. 51p. Sponsored by

USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94017065. Source: OSTI; NTIS; INIS; GPO Dep.

Field mapping and stratigraphic studies were completed of the Black Tank volcanic center, which represents the southwestern most eruptive center in the Cima volcanic field of California. The results of this mapping are presented. Contacts between volcanic units and geomorphic features were field checked, incorporating data from eight field trenches as well as several exposures along Black Tank Wash. Within each of the eight trenches, logs were measured and stratigraphic sections were described. These data indicate that three, temporally separate volcanic eruptions occurred at the Black Tank center. The field evidence for significant time breaks between each stratigraphic unit is the presence of soil and pavement-bounded unconformities.

287 (LA-SUB-94-111) **[Characterization of historical infiltration in the unsaturated zone at the Nevada Test Site using chloride, bromide, and chlorine-36 as environmental tracers]: [Final subcontract report].** Los Alamos National Lab., NM (United States); Hydro Geo Chem., Inc., Tucson, AZ (United States). 17 May 1991. 111p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94016570. Source: OSTI; NTIS; INIS; GPO Dep.

This document is an end-of-contract report, prepared by Hydro Geo Chem for Los Alamos National Laboratory under contract number 9-XDD-6329F-1. The ultimate goal of this work is to characterize historical infiltration and unsaturated flow in the Yucca Mountain area of the Nevada Test Site. Work on this contract has focused on using chloride, bromide, stable chlorine isotopes, and chlorine-36 distributions to evaluate the depth of infiltration in the unsaturated zone. Effort in support of this work has included developing analytical procedures, exploring ways in which to separate the meteoric component from the rock component, and meeting quality assurance requirements.

288 (LA-SUB-94-159) **Progress report on the kinetic measurements of the reactions of the silicates at the Yucca Mountain potential repository site: [Final] report, June 15, 1993-September 30, 1993.** Lasaga, A.C. (Yale Univ., New Haven, CT (United States). Dept. of Geology and Geophysics); Ganor, J. Los Alamos National Lab., NM (United States); Yale Univ., New Haven, CT (United States). Dept. of Geology and Geophysics. [1994]. 28p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95001752. Source: OSTI; NTIS; INIS; GPO Dep.

Preliminary results are provided on: Synthesis and characterization of analcime and Na-clinoptilolite (Penn State), batch solubility experiments on analcime and clinoptilolite, thermodynamic modelling of solubility data, and kinetic flow-through experiments on analcime and clinoptilolite.

289 (LA-SUB-95-36-Vol.2) **FY94 CAG trip reports, CAG memos and other products: Volume 2. Final report.** Los Alamos National Lab., NM (United States); Computer Applications Group, Inc., Carlton, OR (United States). 15 Dec 1994. 290p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95013477. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project (YMP) of the US DOE is tasked with designing, constructing, and operating an Exploratory Studies Facility (ESF) at Yucca Mountain, Nevada. The purpose of the YMP is to provide detailed characterization of the Yucca Mountain site for the potential mined geologic repository for permanent disposal of high-level radioactive waste. Detailed characterization of properties of the site are to be conducted through a wide variety of short-term and long-term in-situ tests. Testing methods require the installation of a large number of test instruments and sensors with a variety of functions. These instruments produce analog and digital data that must be collected, processed, stored, and evaluated in an attempt to predict performance of the repository. The Integrated Data and Control System (IDCS) is envisioned as a distributed data acquisition that electronically acquires and stores data from these test instruments. IDCS designers are responsible for designing and overseeing the procurement of the system, IDCS Operation and Maintenance operates and maintains the installed system, and the IDCS Data Manager is responsible for distribution of IDCS data to participants. This report is a compilation of trip reports, interoffice memos, and other memos relevant to Computer Applications Group, Inc., work on this project.

290 (LA-SUB-95-41) **Kinetic measurements on the silicates of the Yucca Mountain potential repository. [Final report], January-September 1994.** Barnes, H.L. (Los Alamos National Lab., NM (United States)); Wilkin, R.T. Los Alamos National Lab., NM (United States); Pennsylvania State Univ., University Park, PA (United States). 25 Aug 1994. 22p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95012085. Source: OSTI; NTIS; INIS; GPO Dep.

The principal effort has been concentrated on the preparation of clean clinoptilolite, quartz, and boehmite and then reaction of the natural clinoptilolite solid solution to the Naendmember, plus measurements of the endmember solubility to derive an accurate equilibrium constant for the clinoptilolite dissolution reaction, correctly speciated. We are very pleased with the consistency between the best calorimetrically measured and modeled equilibrium constants and those we have determined from 125°C to 265°C. These results now provide a basis for relating measurements of reaction rates to departures from equilibrium.

291 (LA-SUB-95-73) **Determination of water movement in the unsaturated zone at Yucca Mountain using chloride, bromide, and chlorine isotopes as environmental tracers. Final report.** Los Alamos National Lab., NM (United States); Hydro Geo Chem., Inc., Tucson, AZ (United States). 31 Jul 1994. 24p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95014568. Source: OSTI; NTIS; INIS; GPO Dep.

This report, prepared by Hydro Geo Chem staff for Los Alamos National Laboratory, summarizes work conducted by the company under Subcontract 9-XG1-N3993-1. The ultimate objective of this work is to characterize the movement of subsurface water in the vicinity of Yucca Mountain, Nevada. Data produced under this contract is to be used by the US Department of Energy in its Yucca Mountain Site Characterization Project (YMP) to help determine hydrologic flows that may affect the performance of a potential nuclear waste repository. The data may be used in the licensing proceedings, and certain quality assurance procedures have thus been required. The work has focussed on measuring the distribution of environmental tracers-chlorine-36, chlorine, and bromine-and on evaluating the depth to which these conservative solutes have percolated in the unsaturated zone at Yucca Mountain. The following discussion

summarizes progress made on the tasks outlined in the original Scope of Work. Details of this work and all data acquired by Hydro Geo Chem for this subcontract have been systematically organized in logbooks and laboratory notebooks. These documents have been structured to make it easy to trace the analytical history of a sample, from time of receipt to the final analytical results.

292 (LA-UR–93-3691) **Natural alteration in the cooling Topopah Spring tuff, Yucca Mountain, Nevada, as an analog to a waste-repository hydrothermal regime.** Levy, S.; Valentine, G. Los Alamos National Lab., NM (United States). [1993]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-9309228–5: Focus 93: site characterization and model validation, Las Vegas, NV (United States), 26-29 Sep 1993). Order Number DE94002699. Source: OSTI; NTIS; INIS; GPO Dep.

Studies of natural hydrothermal alteration in the cooling Topopah Spring tuff suggest a useful "self-analog" predictor of fluid-rock interactions within the thermal regime imposed by a potential nuclear waste repository at Yucca Mountain. This tuff has the advantages of representative rock types and appropriate spatial distribution of lithologic features. The cooling history of the tuff spanned the temperature range for any proposed repository thermal load, and the unsaturated-zone hydrologic conditions of the natural alteration would have been similar to existing conditions. A site at northeastern Yucca Mountain, with a prominent vertical fracture zone, has been selected for natural analog studies. The cooling of the tuff and the movement of water in the fracture zone and adjacent matrix will be modeled with the finite element code FEHNM, capable of simulating flow through porous and fractured media using a dual porosity-dual permeability continuum model, with heat transfer and two-phase (vapor and liquid) processes fully accounted for.

293 (LA-UR–93-3699) **Role of magma-water interaction in very large explosive eruptions.** Valentine, G.A. Los Alamos National Lab., NM (United States). [1993]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-9310222–1: Seminar on physics of vapor explosion, Tomakomai (Japan), 25-29 Oct 1993). Order Number DE94002698. Source: OSTI; NTIS; GPO Dep.

An important class of explosive eruptions, involving large-scale magma-water interaction during the discharge of hundreds to thousands of cubic kilometers of magma, is discussed. Geologic evidence for such eruptions is summarized. Case studies from New Zealand, Australia, England, and the western United States are described, focusing on inferred eruption dynamics. Several critical problems that need theoretical and experimental research are identified. These include rates at which water can flow into a volcanic vent or plumbing system, entrainment of water by explosive eruptions through lakes and seas, effects of magma properties and gas bubbles on magma-water interaction, and hazards associated with the eruptions.

294 (LA-UR–93-3992) **The Nevada Test Site: An analog for a nuclear repository.** Thompson, J.L. Los Alamos National Lab., NM (United States). [1993]. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-931201–3: 4. international conference on chemistry and migration behavior of actinides and fission products in the geosphere, Charleston, SC (United States), 12-17 Dec 1993). Order Number DE94003956. Source: OSTI; NTIS; INIS; GPO Dep.

The United States proposes to store high level nuclear wastes underground; a site at Yucca Mountain in southern Nevada is currently under evaluation. A major concern is that radioactive materials may dissolve in the groundwater and be transported to the accessible environment. At the Nevada Test Site (NTS) adjacent to Yucca Mountain underground nuclear tests have been conducted for over 30 years. Radionuclides (unreacted fissile material, activation products, fission products) from these tests remain underground with no confinement by engineered barriers. The US Department of Energy has supported studies since 1973 designed to measure the distribution of these radionuclides and to evaluate the processes by which they might be transported by groundwater. The authors describe here some of what they have learned about how radionuclides are distributed around nuclear test cavities and how they interact with groundwater.

295 (LA-UR–94-640) **Inferences of paleoenvironment from petrographic, chemical and stable-isotope studies of calcretes and fracture calcites.** Vaniman, D.T. (Los Alamos National Lab., NM (United States)); Whelan, J.F. Los Alamos National Lab., NM (United States). [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-940553–13: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94007559. Source: OSTI; NTIS; INIS; GPO Dep.

Past research has indicated a genetic connection between calcite formed in calcretes at the surface of Yucca Mountain, Nevada, and calcites deposited in underlying fractures of the unsaturated zone. This common genesis suggests that paleoenvironmental information, as well as the timing and pathways of past recharge episodes, might be obtained from studies of the deposits in both the calcretes and the unsaturated fractures. Chemical and isotopic modification of calcite-precipitating fluids appears to begin at the surface, largely under the influence of plant roots and their decay products. Chemical characteristics of the deeper calcites are either initiated or largely defined within the first few meters of fluid migration into the unsaturated tuffs beneath the calcretes. However, petrographic and isotopic data indicate a very unique low-$\delta^{13}C$ microenvironment that is localized at the upper surfaces of the calcretes. These surfaces form an interface in the soil horizon where infiltration may pond above the underlying carbonate "plug." In order to decipher the chemistry and petrology of past recharge events, it is important to first understand microenvironments such as this that contribute to mineral precipitation/dissolution events in the pedogenic environment.

296 (LA-UR–94-921) **The Quality Council in the scientific arena.** Day, J.L. (Los Alamos Technical Associates, Inc., NM (United States)); Gillespie, P.F.; Bolivar, S.L. Los Alamos National Lab., NM (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-940538–3: 48. annual quality congress, Las Vegas, NV (United States), 24-26 May 1994). Order Number DE94009358. Source: OSTI; NTIS; GPO Dep.

Communication between 12 separate Los Alamos National Laboratory (Los Alamos) research-and-development organizations (9 located in Los Alamos, NM, and 3 located in different areas of the United States) performing work on

Los Alamos Yucca Mountain Site Characterization Project (YW or the Project) have improved significantly since the Los Alamos YNT Quality. Council was tonned in 1991. The Quality Council has also been instrumental in improving communications between Los Alamos scientists and the Los Alamos quality assurance (QA) organization and between Los Alamos YNT and the US Department of Energy (DOE) management. This paper describes the evolution of Los Alamos YNT's Quality Council and the resulting benefits.

297 (LA-UR–94-925) **Selenite transport in unsaturated tuff from Yucca Mountain.** Conca, J.L. (Washington State Univ., Richland, WA (United States)); Triay, I.R. Los Alamos National Lab., NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-940553–31: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94009360. Source: OSTI; NTIS; INIS; GPO Dep.

Direct measurements of unsaturated selenite retardation coefficients and unsaturated hydraulic conductivity were obtained on two tuff samples from Yucca Mountain using the UFA™ technology. The retardation factor for the selenite species was only 2.5 in both Yucca Mountain vitric member at 62.6% saturation and zeolitized nonwelded tuff from G-tunnel at 52.8% saturation with respect to J-13 well water from the Nevada Test Site contaminated with selenium at 1.31 mg/l (ppm). In batch tests on the same material using 1.2 mg/l (ppm), the average K_d was determined to be 13, giving retardation factors higher than the UFA column breakthrough tests by an order of magnitude. The difference could result from preferential flow paths in the UFA column as might occur in the field or differences in residence times between the two types of test. The unsaturated hydraulic conductivities during the experiments were 2.49×10^{-8} cm/s for the Yucca Mountain vitric member and 1.16×10^{-8} cm/s for the zeolitized nonwelded tuff.

298 (LA-UR–94-1038) **The transition to a revised quality assurance standard: The Los Alamos experience.** Bolivar, S.L. (Los Alamos National Lab., NM (United States)); Clevenger, M.J.; Gillespie, P.F.; Day, J.L. Los Alamos National Lab., NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-940985–1: American Society for Quality Control Energy and Environmental Quality Division conference, Tucson, AZ (United States), 18-21 Sep 1994). Order Number DE94009337. Source: OSTI; NTIS; GPO Dep.

On January 6, 1993 the Los Alamos Yucca Mountain Site Characterization Project (YMP) office received a directive to implement DOE/RW-0333P, Quality Assurance Requirements and Description. This document is a revised quality assurance standard containing the quality assurance requirements for the YMP. Forty-two Los Alamos quality assurance documents were affected by this directive. Our goal was to transition to the revised standard with minimal impact on research activities yet maintain maximum flexibility and efficiency. The process of transitioning to a revised quality assurance standard, in essence replacing an existing quality assurance program with a new program, was a unique learning experience. Although some problems were anticipated, the magnitude and complexity of problems was, at times, almost overwhelming. The problems encountered include the review process being more complex than anticipated; inconsistencies of much larger magnitude than originally believed; difficulties with electronic data base connections; quality processes being more complex than originally perceived, and administrative bottlenecks. The transition was very stressful and this was in part caused by the magnitude of the change. However, the transition process was enhanced by both a flexible schedule (provided by the customer) and flexibility in being able to revise procedures and modify processes. This allowed for minimal disruption to research activities. The new quality assurance program is better documented, therefore should be better understood by YMP personnel, is tracked electronically, and should provide a better product for the customer.

299 (LA-UR–94-1071) **Late cenozoic evolution of Fortymile Wash: Major change in drainage pattern in the Yucca Mountain, Nevada region during late miocene volcanism.** Lundstrom, S.C. (Geological Survey, Las Vegas, NV (United States)); Warren, R.G. Los Alamos National Lab., NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36 ; AI08-78ET44802. (CONF-940553–27: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94009332. Source: OSTI; NTIS; INIS; GPO Dep.

The site characterization of Yucca Mountain, NV as a potential high level nuclear waste repository includes study of the surficial deposits as a record of the paleoenvironmental history of the Yucca Mountain region. An important aspect of this history is an understanding of the evolution of paleogeography leading to establishment of the present drainage pattern. Establishment of drainage basin evolution is needed before geomorphic response to paleoclimate and tectonics can be assessed, because a major change in drainage basin geometry can predominantly affect the sedimentary record. Because alluvial aquifers are significant to regional hydrology, a major change in surface drainage resulting in buried alluvium could have hydrogeologic significance. In this paper, we report on geologic evidence for a major modification in surface drainage pattern in the Yucca Mountain region, resulting in the probable establishment of the Fortymile Wash drainage basin by latest Miocene time.

300 (LA-UR–94-1613) **Iron oxide mineral-water interface reactions studied by AFM.** Hawley, M.E.; Rogers, P.S.Z. Los Alamos National Lab., NM (United States). [1994]. 30p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-9405191–1: Scanning microscopy conference, Toronto (Canada), 7-19 May 1994). Order Number DE94014807. Source: OSTI; NTIS; GPO Dep.

Natural iron mineral surfaces have been examined in air by atomic force (AFM) and scanning tunneling (STM) microscopies. A number of different surface features were found to be characteristic of the native surface. Even surfaces freshly exposed by crushing larger crystals were found to have a pebbly surface texture caused by the presence of thin coatings of what might be surface precipitates. This finding is interpreted as evidence for previous exposure to water, probably through an extensive network of microfractures. Surface reactions on the goethite crystals were studied by AFM at size resolutions ranging from microns to atomic resolution before, during, and after reaction with distilled water and 0.IN HCl. Immediate and extensive surface reconfiguration occurred on contact with water. In one case, after equilibration with water for 3 days, surface reprecipitation, etching and pitting were observed. Atomic resolution

images taken under water were found to be disordered. The result of surface reaction was generally to increase the surface area substantially through the extension of surface platelet arrays, present prior to reaction. This work is being done in support of the site characterization project at Yucca Mountain.

301 (LA-UR–94-2891) **Simultaneous transport of synthetic colloids and a nonsorbing solute through single saturated natural fractures.** Reimus, P.W. (Los Alamos National Lab., NM (United States)); Robinson, B.A.; Nuttall, H.E.; Kale, R. Los Alamos National Lab., NM (United States). [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-941075–1: 18. international symposium on the scientific basis for nuclear waste management, Kyoto (Japan), 23-27 Oct 1994). Order Number DE94018318. Source: OSTI; NTIS; INIS; GPO Dep.

Tracer transport experiments involving colloids that showed little tendency to attach to rock surfaces and a nonsorbing solute (iodide) -were conducted in three different well-characterized natural fractures in tuff. The colloids always arrived earlier in the effluent than the iodide, which we believe is evidence of (1) hydrodynamic chromatography and/or (2) the fact that the colloids experience a smaller effective volume in the fracture because they diffuse too slowly to enter low-velocity regions (dead zones) along the rough fracture walls. The iodide also approached the inlet concentration in the effluent more slowly than the colloids, with the concentration at a given elution volume being greater at higher flow rates. By contrast, the rate of approach of the colloid concentration to the inlet concentration did not vary with flow rate. We attribute this behavior to matrix diffusion of the iodide, with the colloids being too large/nondiffusive to experience this phenomenon. Dispersion of all tracers was greatest in the fracture of widest average aperture and least in the fracture of narrowest aperture, which is consistent with Taylor dispersion theory. The tracer experiments were modeled/interpreted using a three-step approach that involved (1) estimating the aperture distribution in each fracture using surface profiling techniques, (2) predicting the flow field in the fractures using a localized parallel-plate approximation, and (3) predicting tracer transport in the fractures using particle-tracking techniques. Although considered preliminary at this time, the model results were in qualitative agreement with the experiments.

302 (LA-UR–94-3303) **Effect of natural organic materials on cadmium and neptunium sorption.** Kung, K.S.; Triay, I.R. Los Alamos National Lab., NM (United States). [1994]. 13p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-9409231–1: NEA workshop on binding models concerning natural organic substances in performance assessment, Bad Zurach (Switzerland), 14-16 Sep 1994). Order Number DE95000843. Source: OSTI; NTIS; INIS; GPO Dep.

In a batch sorption study of the effect of naturally occurring organic materials on the sorption of cadmium and neptunium on oxides and tuff surfaces, the model sorbents were synthetic goethite, boehmite, amorphous silicon oxides, and a crushed tuff material from Yucca Mountain, Nevada. An amino acid, 3-(3,4-dihydroxypheny)-DL-alanine (DOPA), and an aquatic-originated fulvic material, Nordic aquatic fulvic acid (NAFA), were used as model organic chemicals. Sorption isotherm results showed that DOPA sorption followed the order aluminum oxide > iron oxide > silicon oxide and that the amount of DOAP sorption for a given sorbent increased as the solution pH was raised. The sorption of cadmium and neptunium on the iron oxide was about ten times higher than that on the aluminum oxide. The sorption of cadmium and neptunium on natural tuff material was much lower than that on aluminum and iron oxides. The sorption of cadmium on iron and aluminum oxides was found to be influenced by the presence of DOPA, and increasing the amount of DOPA coating resulted in higher cadmium sorption on aluminum oxide. However, for iron oxide, cadmium sorption decreased with increasing DOPA concentration. The presence of the model organic materials DOPA and NAFA did not affect the sorption of neptunium on tuff material or on the iron and aluminum oxides. Spectroscopic results indicate that cadmium complexes strongly with DOPA. Therefore, the effect of the organic material, DOPA, on the cadmium sorption is readily observed. However, neptunium is possibly complexed weakly with organic material. Thus, DOPA and NAFA have little effect on neptunium sorption on all sorbents selected for study.

303 (LA-UR–94-3820) **Fracture coatings in Topopah Spring Tuff along drill hole wash.** Carlos, B.A.; Chipera, S.J.; Bish, D.L. Los Alamos National Lab., NM (United States). [1994]. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-950570–1: International high-level radioactive waste management conference: progress toward understanding, Las Vegas, NV (United States), 1-5 May 1995). Order Number DE95003692. Source: OSTI; NTIS; INIS; GPO Dep.

Fracture-lining minerals are being studied as part of site characterization to determine the suitability of Yucca Mountain, Nevada as a potential high level nuclear waste repository. Fracture coatings in the Paintbrush Group provide information on potential flow paths above the water table both toward and away from the potential repository and provide information on the distribution of fracture-lining minerals needed to model thermal effects of waste emplacement. Fracture coatings within the predominantly non-zeolitic Paintbrush Group vary both with depth and laterally across Yucca Mountain, whereas fracture coatings in tuffs below the Paintbrush Group are related to the mineralogy of the tuffs and follow a consistent pattern of distribution with predominantly quartz, calcite, and manganese oxides in the devitrified intervals and mordenite and clinoptilolite in the zeolitic intervals. The zeolites stellerite and heulandite are more abundant in fractures in the Topopah Spring Tuff in drill holes USW G-1 and UE-25 a#l, located along Drill Hole Wash (at the northern end of Yucca Mountain) than in core from other parts of Yucca Mountain. Buesch et al. (2) present evidence for a complex fault system along Drill Hole Wash. To investigate the possibility that the abundant fracture-lining zeolites in USW G-1 and UE-25 a# 1 are related to the Drill Hole Wash fault, the Topopah Spring Tuff was examined in drill cores from USW UZ-14, USW G-1, USW NRG-7/7a, and UE-25 a#l.

304 (LA-UR–95-572) **Significance of apparent discrepanices in water ages derived from atmospheric radionuclides at Yucca Mountain, Nevada.** Liu, B. (Los Alamos National Lab., NM (United States)); Fabryka-Martin, J.; Wolfsberg, A.; Robinson, B.; Sharma, P. Los Alamos National Lab., NM (United States). 23 Feb 1995. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-9505188–1: 1995 American Institute of Hydrology annual meeting, Denver, CO (United States), 14-18 May 1995). Order Number DE95007886. Source: OSTI; NTIS; INIS; GPO Dep.

Cosmogenic ^{36}Cl and ^{14}C produced in the atmosphere are being used to estimate water residence times in the unsaturated zone at Yucca Mountain. Results thus far show a systematic discordance in that ^{14}C-based ages are generally one to two orders of magnitude younger than ^{36}Cl-based ages. This lack of concordance probably arises from one or more of the following reasons: (1) different transport mechanisms, e.g., vapor transport for ^{14}C; (2) different magnitudes and timing of bomb-pulse signals; (3) mixing of waters from different flow paths; and (4) possibly inadequate methods for correcting for the effect of sample contamination by carbon or chlorine from sources other than the infiltrating water. Preliminary numerical simulation results using the FEHMN code suggest that spatial variation in infiltration rates can enhance lateral flow and mixing that leads to discordance in apparent ages depending on the dating technique. Examples are presented to show that disparate radiometric ages are inevitable and to be expected where mixing of waters of markedly different ages occurs.

305 (LA-UR–95-871) **Multiple episodes of zeolite deposition in fractured silicic tuff.** Carlos, B.A.; Chipera, S.J.; Snow, M.G. Los Alamos National Lab., NM (United States). [1995]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-950888–1: International symposium on water-rock interaction, Vladivostok (Russian Federation), 13-28 Aug 1995). Order Number DE95009430. Source: OSTI; NTIS; INIS; GPO Dep.

Fractures in silicic tuffs above the water table at Yucca Mountain, Nevada, USA contain two morphologies of heulandite with different compositions. Tabular heulandite is zoned, with Sr-rich cores and Mg-rich rims. Later prismatic heulandite is nearly the same composition as the more magnesian rims. Heulandite and stellerite may occur between layers of calcite, and calcite occurs locally between generations of heulandite. Thermodynamic modeling, using estimated thermodynamic data and observed chemical compositions for heulandite and stellerite, shows that stellerite is the favored zeolite unless Ca concentrations are reduced or Mg and/or Sr concentrations are significantly elevated above current Yucca Mountain waters.

306 (LA-UR–95-1286) **Construction of the exploratory studies facility at Yucca Mountain - North Ramp.** Kalia, H.N. (Los Alamos National Lab., NM (United States)); Repogle, J.M.; McNeely, J.E. Los Alamos National Lab., NM (United States). [1995]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-9504148–1: Institute of shaft drilling technology annual technical conference, Las Vegas, NV (United States), 24-27 Apr 1995). Order Number DE95010890. Source: OSTI; NTIS; INIS; GPO Dep.

Yucca Mountain Site Characterization Office of the US Department of Energy is constructing an Exploratory Studies Facility, approximately 160 km (100 miles) northwest of Las Vegas, Nevada. This facility will be used to gather geological, hydrological, geomechanical, thermomechanical, and geochemical information to characterize Yucca Mountain as a potential site to isolate High-Level Radioactive Waste from the accessible environment. The Exploratory Studies Facility, when completed shall consist of two ramps from the surface, a connecting drift, underground test areas and below ground operational support facilities. The ramps and connecting drift are being mined by a 7.62 m (25 ft) diameter Tunnel Boring Machine. This machine was fabricated for the Department of Energy by Construction Tunneling Services, Inc; of Kent, Washington. This paper describes the current status of the concentration of the North Ramp at Yucca Mountain. At the time of this writing, the North Ramp had advanced to a distance of about 517 m (1700 ft). With the exception of some minor problems through Bow Ridge fault, the excavation has progressed as expected.

307 (UCRL-CR–120464) **Survey of the degradation modes of candidate materials for high-level radioactive waste disposal containers.** Vinson, D.W. (Iowa State Univ. of Science and Technology, Ames, IA (United States)); Nutt, W.M.; Bullen, D.B. Lawrence Livermore National Lab., CA (United States); Iowa State Univ. of Science and Technology, Ames, IA (United States). Jun 1995. 148p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE95015979. Source: OSTI; NTIS; INIS; GPO Dep.

Oxidation and atmospheric corrosion data suggest that addition of Cr provides the greatest improvement in oxidation resistance. Cr-bearing cast irons are resistant to chloride environments and solutions containing strongly oxidizing constituents. Weathering steels, including high content and at least 0.04% Cu, appear to provide adequate resistance to oxidation under temperate conditions. However, data from long-term, high-temperature oxidation studies on weathering steels were not available. From the literature, it appears that the low alloy steels, plain carbon steels, cast steels, and cast irons con-ode at similar rates in an aqueous environment. Alloys containing more than 12% Cr or 36% Ni corrode at a lower rate than plain carbon steels, but pitting may be worse. Short term tests indicate that an alloy of 9Cr-1Mo may result in increased corrosion resistance, however long term data are not available. Austenitic cast irons show the best corrosion resistance. A ranking of total corrosion performance of the materials from most corrosion resistant to least corrosion resistant is: Austenitic Cast Iron; 12% Cr = 36% Ni = 9Cr-1Mo; Carbon Steel = Low Alloy Steels; and Cast Iron. Since the materials to be employed in the Advanced Conceptual Design (ACD) waste package are considered to be corrosion allowance materials, the austenitic cast irons, high Cr steels, high Ni steels and the high Cr-Mo steels should not be considered as candidates for the outer containment barrier. Based upon the oxidation and corrosion data available for carbon steels, low alloy steels, and cast irons, a suitable list of candidate materials for a corrosion allowance outer barrier for an ACD waste package could include, A516, 2.25%Cr – 1%Mo Steel, and A27.

308 **Complexation of carbonate species at the goethite surface: Implications for adsorption of metal ions in natural waters.** Van Geen, A. (Stanford Univ., CA (United States)); Robertson, A.P.; Leckie, J.O. *Geochimica et Cosmochimica Acta;* 58(9): 2073-2086 (May 1994).

Headspace P_{CO_2} was measured with an infrared gas analyzer over an equilibrated goethite suspension to determine adsorption of carbonate species in the pH range 3 to 8. For a 2 g/L goethite suspension in 0.1 N $NaClO_4$ ($\sim 3\ 10^{-4}$ M surface sites), the fraction of carbonate species adsorbed increased from 0.15 at pH 3 to a maximum of 0.56 at pH 6. In 0.01 N $NaClO_4$, the fraction of carbonate species adsorbed at pH 6 increased to 0.67. The total concentration of CO_2 in the suspension increased from about 0.4 to 0.6 10^{-4} M in the pH range of these experiments. The development of surface charge at the goethite surface was determined in the pH range 4 to 11 by potentiometric titration under controlled

low CO_2 conditions. No hysteresis was observed between the acid and base legs of titrations in 0.10, 0.03, and 0.01 N $NaClO_4$ resulting in a pH_{pzc} of 8.9. The carbonate species adsorption data were modelled using the least squares optimization program FITEQL for the diffuse double-layer model and the triple-layer model using stoichiometries of the type Fe-OCOOH and Fe-$OCOO^-$ for surface bound carbonate species. The model results are consistent with separate experiments showing a significant reduction in chromate adsorption on goethite as the partial pressure of CO_2 was increased from <5 to 450 and 40,000 μatm. The data suggest that mineral oxide surface sites which control solid/solute partitioning of metal ions in natural systems may be largely bound to adsorbed carbonate species.

309 A strategy for validating a concept model for radionuclide migration in the saturated zone beneath Yucca Mountain. Robinson, B.A. (Los Alamos National Laboratory, Earth and Environmental Sciences Div., Los Alamos (United States)). *Radioactive Waste Management and Environmental Restoration;* 19(1-3): 73-96 (1994).

Special issue Yucca Mountain.

A conceptual model for radionuclide migration in the saturated zone beneath Yucca Mountain is presented. The available hydrologic data from the site is compiled to present a qualitative picture of transport of radionuclides horizontally within the first 100-200 m of the saturated zone. The transport model consists of flow within fractures and interchange of dissolved species between the fractures and surrounding matrix blocks via molecular diffusion. A parametric study illustrates that at the groundwater conditions expected to exist in the saturated zone, radionuclide will have ample time to diffuse fully within the matrix blocks. The result is a predicted solute transport time several orders of magnitude greater than the groundwater travel time (GWTT). To validate this model, a suite of interwell tracer tests are proposed at various flow rates and with conservative and sorbing species. Numerical simulations show that these tests will allow us to discriminate between a matrix diffusion model and a more conventional continuum transport model. (author) 8 figs., tabs., 35 refs.

310 The use of selectivity coefficients to estimate modified Langmuir isotherm parameters as a function of experimental conditions. Polzer, W.L. (Los Alamos National Laboratory, Earth and Environmental Sciences Div., Los Alamos (United States)); Essington, E.H.; Fellenz, K.M.; McLeod, J.R. *Radioactive Waste Management and Environmental Restoration;* 19(1-3): 107-128 (1994).

Special issue Yucca Mountain.

Modified Langmuir isotherm parameters (K_D and β) were fitted to experimentally determined selectivity coefficients to test relationship between them. Reasonable estimates of K_D and β values were obtained for a wide range of assumed solid-liquid ratios (W/V) and initial concentrations of competing solute (C_{B0}). The results indicate that at low initial concentrations K_D decreases and β increases as C_{B0} increases. A more pronounced effect is observed at lower W/V values for K_D and at higher W/V values for β. At low C_{B0} values, both K_D and β decrease as W/V increases. At higher C_{B0} values, K_D and β are not affected by W/V. Results also indicate that a linear K_D can be strongly affected by W/V and C_{B0}. The effect of both parameters have been documented in the literature. The relationship between the modified Langmuir isotherm parameters and experimentally determined selectivity coefficients provides a method that optimizes the information obtained from the adsorption modeling of experimental data. (author) 11 figs., 2 tabs., 21 refs.

311 Three-dimensional simulations of radionuclide transport at Yucca Mountain. Birdsell, K.H. (Los Alamos National Lab., NM (United States)); Eggert, K.G.; Travis, B.J. *Radioactive Waste Management and Environmental Restoration;* 19(1-3): 165-192 (1994).

Special issue Yucca Mountain.

This paper presents preliminary transport calculations for radionuclide movement at Yucca Mountain. The simulations were run with TRACRN using approximately 30 000 finite-difference zones to represent the unsaturated and saturated zones underlying the potential repository in three dimensions. The results are used to study the sensitivity of radionuclide migration to uncertainties in several factors that affect transport through porous media. These factors include recharge rate, dispersivity length scale, radionuclide species, and source term. The calculations show that the transport of weakly sorbing species like ^{99}Tc and ^{129}I is highly sensitive to all of these factors. The transport of strongly sorbing species like ^{135}Cs is limited by retardation and is therefore fairly insensitive to these factors. In addition to showing the sensitivity of transport to physical processes, the results show that the calculations themselves are sensitive to problem dimensionality. The calculations indicate that modeling in three dimensions provides faster breakthrough than modeling in one or two dimensions. (author) 30 figs., 2 tabs., 13 refs.

312 Effect of natural organics on Cd and Np sorption. Kung, K.S. (Isotope and Environmental Geochemistry Group, Chemical Science and Technology Div., Los Alamos National Lab., NM (United States)); Triay, I.R. *Radiochimica Acta;* 66-67: 421-426 (1994). (CONF-931201—: 4. international conference on chemistry and migration behavior of actinides and fission products in the geosphere, Charleston, SC (United States), 12-17 Dec 1993).

A batch sorption study was performed to investigate the effect of naturally occurring organic materials on the sorption of Cd and Np on oxides and tuff surfaces. Synthetic goethite, boehmite, amorphous Si oxides and a crushed tuff material from Yucca Montain, NV, were used as model sorbents. An amino acid, 3-(3,4-dihydroxyphenyl)-DL-alanine (DOPA), and an aquatic originated fulvic material, nordic aquatic fulvic acid (NAFA), were used as model organic chemicals. Sorption isotherm results showed that DOPA sorption followed the order: Al oxide > Fe oxide > Si oxide. The amount of DOPA sorption for a given sorbent increased as the solution pH was raised. The sorption of Cd and Np on Fe oxide was about ten times higher than that on Al oxide. The sorption of Cd and Np on natural tuff materials was much lower than that on Al and Fe oxides. The sorption of Cd on Fe and Al oxides was found to be influenced by the presence of DOPA. Incrasing DOPA coating resulted in higher Cd sorption on Al oxide. However, for Fe oxide, Cd sorption decreased with increasing DOPA concentration. The presence of model organic materials, DOPA and NAFA, did not affect the sorption of Np on tuff material or on Fe and Al oxides. (orig.)

313 Hydration swelling effects on time-dependent deformation of zeolitized tuff. Blacic, J.D. (Los Alamos National Lab., NM (United States)). *Journal of Geophysical Research;* 98(B9): 15909-15917 (10 Sep 1993).

Long-duration creep deformation experiments were performed on zeolitized tuffs from Yucca Mountain, Nevada, at

temperatures of 35°-75°C, confining pressure of 5 MPa, and water pore pressure of 0.1 MPa. The test samples were initially loaded to a relatively small fraction of the uniaxial compressive failure stress, and allowed to creep; then the stress was increased periodically until creep failure occurred. The strain versus time creep curves exhibit the classical phenomenological phases of primary, secondary, and tertiary creep analogous to those for ductile metals, although the tuffs deform by dilational microcracking and fail by brittle fracture. Mechanical "steady state" or secondary creep strain rates as low as 1×10^{-10} s^{-1} were observed in the tests. Tertiary creep axial failure strains averaged about 6×10^{-3}. The early, water saturation phases of the tests are characterized by large hydration swelling strains associated with water absorption by the zeolite minerals in the tuffs. The hydration was often incomplete after one month of immersion, and slow, continued hydration affected the creep curves so that the samples appeared to lengthen against axial differential stresses as high as 55 MPa. This strong chemical-mechanical coupling suggests that in situ hydration state changes could generate stresses of similar magnitude. 18 refs., 10 figs., 3 tabs.

LAWRENCE LIVERMORE NATIONAL LABORATORY

314 (ANL–92/48) **Test plan for reactions between spent fuel and J-13 well water under unsaturated conditions.** Finn, P.A.; Wronkiewicz, D.J.; Hoh, J.C.; Emery, J.W.; Hafenrichter, L.D.; Bates, J.K. Argonne National Lab., IL (United States). Jan 1993. 41p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94008702. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project is evaluating the long-term performance of a high-level nuclear waste form, spent fuel from commercial reactors. Permanent disposal of the spent fuel is possible in a potential repository to be located in the volcanic tuff beds near Yucca Mountain, Nevada. During the post-containment period the spent fuel could be exposed to water condensation since of the cladding is assumed to fail during this time. Spent fuel leach (SFL) tests are designed to simulate and monitor the release of radionuclides from the spent fuel under this condition. This Test Plan addresses the anticipated conditions whereby spent fuel is contacted by small amounts of water that trickle through the spent fuel container. Two complentary test plans are presented, one to examine the reaction of spent fuel and J-13 well water under unsaturated conditions and the second to examine the reaction of unirradiated UO_2 pellets and J-13 well water under unsaturated conditions. The former test plan examines the importance of the water content, the oxygen content as affected by radiolysis, the fuel burnup, fuel surface area, and temperature. The latter test plant examines the effect of the non-presence of Teflon in the test vessel.

315 (ANL–93/37) **Nuclear waste programs: Semiannual progress report, October 1991–March 1992.** Bates, J.K. (and others); Bradley, C.R.; Buck, E.C.; Dietz, N.L.; Ebert, W.L.; Emery, J.W.; Feng, X.; Finn, P.A.; Gerding, T.J.; Hoh, J.C. Argonne National Lab., IL (United States). Nov 1993. 33p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94011227. Source: OSTI; NTIS; INIS; GPO Dep.

This document reports on the work done by the Nuclear Waste Programs of the Chemical Technology Division (CMT), Argonne National Laboratory, in the period October 1991-March 1992. In these programs, studies are underway on the performance of waste glass and spent fuel in projected nuclear repository conditions to provide input to the licensing of the nation's high-level waste repositories

316 (ANL–94/42) **Yucca Mountain Project - Argonne National Laboratory annual progress report, FY 1994.** Bates, J.K.; Fortner, J.A.; Finn, P.A.; Wronkiewicz, D.J.; Hoh, J.C.; Emery, J.W.; Buck, E.C.; Wolf, S.F. Argonne National Lab., IL (United States). Feb 1995. 59p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE95010431. Source: OSTI; NTIS; INIS; GPO Dep.

This document reports on the work done by the Nuclear Waste Management Section of the Chemical Technology Division (CMT), Argonne National Laboratory, in the period October 1993-September 1994. Studies have been performed to evaluate the performance of nuclear waste glass and spent fuel samples under unsaturated conditions (low volume water contact) that are likely to exist in the Yucca Mountain environment being considered as a potential site for a high-level waste repository. Tests with simulated waste glasses have been in progress for over eight years and demonstrate that actinides from initially fresh glass surfaces will be released as a result of the spallation of reacted glass layers from the surface, as the small volume of water passes over the waste form. Studies are also underway to evaluate the performance of spent fuel samples and unirradiated UO_2 in projected repository conditions. Tests with UO_2 have been ongoing for nine years and show that the oxidation of UO_2 occurs rapidly, and the resulting paragenetic sequence of secondary phases that form on the sample surface is similar to that observed in natural analogues. The reaction of spent fuel samples under conditions similar to those used with UO_2 have been in progress for nearly two years, and the results suggest that spent fuel follows the same reaction progress as UO_2. The release of individual fission products and transuranic elements was not congruent, with the release being controlled by the formation of small particles or colloids that are suspended in solution and transported away from the waste form. The reaction progress depends on the composition of the spent fuel samples used and, likely, on the composition of the groundwater that contacts the waste form.

317 (ANL–95/20) **ANL technical support program for DOE environmental restoration and waste management. Annual report, October 1993–September 1994.** Bates, J.K. (and others); Brown, N.R.; Buck, E.C. Argonne National Lab., IL (United States). Jun 1995. 124p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE95016554. Source: OSTI; NTIS; INIS; GPO Dep.

A program was established for DOE Environmental Restoration and Waste Management (EM) to evaluate factors that are anticipated to affect waste glass reaction during repository disposal, especially in an unsaturated environment typical of what may be expected for the proposed Yucca Mountain repository site. This report covers progress in FY 1994 on the following tasks: (1) Critical Reviews of important parameters that affect the reactivity of glass in an unsaturated environment are being prepared. (2) A series of tests is ongoing to evaluate the reactivity of fully radioactive glasses in a high-level waste repository environment and

compare it to the reactivity of synthetic, nonradioactive glasses of similar composition. (3) The effect of radiation upon the durability of waste glasses at a high SA/V ratio and a high gas-to-liquid volume ratio has been assessed. (4) A series of tests is being performed to compare the extent of reaction of nuclear waste glasses at various SA/V ratios. Such differences in the SA/V ratio may significantly affect glass durability. At long-term periods and high SA/V ratios, acceleration in glass reaction has been observed. (5) Tests were initiated on West Valley Reference 6 (WV6) glass and on the Environmental Assessment (EA) glass. (6) Tests with the actinide-doped West Valley glass ATM-10 have been in progress for over seven years as a part of work for the Yucca Mountain Site Characterization Project (YMP). (7) Analytical electron microscopy (AEM) is being used to assess the glass/water reaction pathway by identifying intermediate phases that appear on the reacting glass. Also, colloids from the leach solutions are being studied using AEM.

318 (ANL/CMT/CP–81047) **Disposition of actinides released from high-level waste glass.** Ebert, W.L.; Bates, J.K.; Buck, E.C.; Gong, M.; Wolf, S.F. Argonne National Lab., IL (United States). [1994]. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. (CONF-940416–7: 96. annual meeting of the American Ceramic Society (ACS), Indianapolis, IN (United States), 25-28 Apr 1994). Order Number DE94011474. Source: OSTI; NTIS; INIS; GPO Dep.

A series of static leach tests was conducted using glasses developed for vitrifying tank wastes at the Savannah River Site to monitor the disposition of actinide elements upon corrosion of the glasses. In these tests, glasses produced from SRL 131 and SRL 202 frits were corroded at 90°C in a tuff groundwater. Tests were conducted using crushed glass at different glass surface area-to-solution volume (S/V) ratios to assess the effect of the S/V on the solution chemistry, the corrosion of the glass, and the disposition of actinide elements. Observations regarding the effects of the S/V on the solution chemistry and the corrosion of the glass matrix have been reported previously. This paper highlights the solution analyses performed to assess how the S/V used in a static leach test affects the disposition of actinide elements between fractions that are suspended or dissolved in the solution, and retained by the altered glass or other materials.

319 (ANL/CMT/CP–81910) **Results of drip tests on sludge-based and actinide-doped glasses.** Bates, J.K.; Buck, E.C. Argonne National Lab., IL (United States). [1994]. 19p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. (CONF-940553–33: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94009687. Source: OSTI; NTIS; INIS; GPO Dep.

The reaction of three differs simulated nuclear waste glasses is being evaluated using a test method that slowly drips water onto a glass/metal assembly. The tests have been in progress for up to eight years and are being performed with as-cast and glass aged by reaction with water vapor. Results are presented for the cumulative release of Np, Pu, and Am as a function of time; also reported are the particulate species that have been detected suspended in solution. A significant difference is noted in the suspended species depending on the glass composition, and on whether the glass is aged. With as-cast glass, the radioactivity is associated with the suspended particles, while with the aged glass, the solution has a high initial anion content, and the transuranic elements appear to be dissolved in solution, since they pass through filters with small pore sizes. Examples are given of possible tests to evaluate the interaction between these test solutions and potential engineered barrier components.

320 (ANL/CMT/CP–83895) **Behavior of spent fuel under unsaturated conditions.** Finn, P.A. (Argonne National Lab., IL (United States). Chemical Technology Div.); Hoh, J.C.; Bates, J.K.; Wolf, S.F. Argonne National Lab., IL (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. (CONF-941207–33: Spent nuclear fuel meeting: challenges and initiatives, Salt Lake City, UT (United States), 14-16 Dec 1994). Order Number DE95009899. Source: OSTI; NTIS; INIS; GPO Dep.

To evaluate the performance of spent fuel in the potential repository at Yucca Mountain, Nevada, spent fuel fragments are being exposed to small and intermittent amounts of simulated groundwater under unsaturated conditions. Both the leachate and the visual appearance of the spent fuel have been characterized for 581 days of testing. The amount of Am and Cm measured in the leachates was one to two orders of magnitude greater than that released from spent fuel under saturated conditions. The cause of this difference has not been firmly identified but may be attributable to the presence of large amounts of actinide-containing colloids in the leachate of the unsaturated tests.

321 (ANL/CMT/CP–84524) **Laboratory testing of West Valley reference 6 glass.** Ebert, W.L. Argonne National Lab., IL (United States). [1995]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. (CONF-950401–13: 97. annual meeting of the American Ceramic Society, Cincinnati, OH (United States), 30 Apr - 1 may 1995). Order Number DE95014235. Source: OSTI; NTIS; INIS; GPO Dep.

A series of laboratory tests is being conducted to characterize the corrosion of West Valley reference 6 glass (WV6) and to provide parametric values for modeling its long-term durability. Models require measurement of the corrosion rate in the absence of corrosion products and in fluids that are "saturated" with corrosion products, and the identification of alteration phases. Corrosion rates in dilute and saturated conditions were measured using MCC-1 and PCT tests, respectively. Vapor hydration tests were performed to generate secondary phases. The PCT tests show the WV6 glass to be more durable than SRL EA, SRL 202, and HW-39-1 glasses. Vapor hydration tests show weeksite (a uranyl silicate), a potassium-bearing zeolite, analcime, potassium feldspar, a calcium silicate phase, and lithium phosphate to form as WV6 glass corrodes. Test results are presented and their relevance to long-term performance discussed.

322 (ANL/CMT/CP–84591) **Long-term test results from a West Valley actinide-doped reference glass.** Fortner, J.A.; Gerding, T.J.; Bates, J.K. Argonne National Lab., IL (United States). [1995]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. (CONF-950401–20: 97. annual meeting of the American Ceramic Society, Cincinnati, OH (United States), 30 Apr - 1 may 1995). Order Number DE95013693. Source: OSTI; NTIS; INIS; GPO Dep.

Results from drip tests designed to simulate unsaturated conditions in the proposed Yucca Mountain Repository are reported for an actinide-doped glass (reference glass ATM-10) used as a model waste form. These tests have been

ongoing for nearly 7 years, with data collected on solution composition (including transuranics), colloid formation and disposition, glass corrosion layers, and solid secondary phases. This test is unique because of its long elapsed time, high content of thorium and transuranics, use of actual groundwater from the proposed site area, use of contact between the glass and sensitized stainless steel in the test, and the variety of analytical procedures applied to the components. Some tests have been terminated, and scanning electron microscopy (SEM) and analytical transmission electron microscopy (AEM) were used to directly measure glass corrosion and identify secondary phases. Other tests remain ongoing, with periodic sampling of the water that had contacted the glass. The importance of integrated testing has been demonstrated, as complex interactions between the glass, the groundwater, and the sensitized stainless steel have been observed. Secondary phases include smectite clay, iron silicates, and brockite. Actinides, except neptunium, concentrate into stable secondary phases. The release of actinides is then controlled by the behavior of these phases.

323 (ANL/CMT/CP–84720) **Alteration of spent fuel matrix under unsaturated water conditions.** Finn, P.A.; Bates, J.K.; Buck, E.C.; Wronkiewicz, D.J.; Hoh, J.C.; Wolf, S.F. Argonne National Lab., IL (United States). [1995]. 4p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31-109-ENG-38. (CONF-950570–28: International high-level radioactive waste management conference: progress toward understanding, Las Vegas, NV (United States), 1-5 May 1995). Order Number DE95013433. Source: OSTI; NTIS; INIS; GPO Dep.

Drip tests which simulate the unsaturated conditions expected in the potential repository at Yucca Mountain are in progress to evaluate the long-term performance of spent fuel. This paper examines the corrosion behavior of the spent fuel matrix under conditions in which water is introduced at a rate of 1.5 mL every 7 days. Our recent results suggest a rapid reaction rate of the spent fuel matrix, the formation of alteration products that are similar to the sequence found in ore deposits in uranium mines, and the presence of colloidal species in the leachate. These results are compared to results from two models developed for a potential repository in an unsaturated zone.

324 (ANL/CMT/PP–71628) **Repository relevant testing applied to the Yucca Mountain Project.** Bates, J.K.; Woodland, A.B.; Wronkiewicz, D.J.; Cunnane, J.C. Argonne National Lab., IL (United States). Oct 1990. 25p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94008476. Source: OSTI; NTIS; INIS; GPO Dep.

The tuff beds of Yucca Mountain, Nevada, are currently being investigated as a site for the disposal of high-level nuclear waste in an underground repository. If this site is found suitable, the repository would be located in the unsaturated zone above the water table, and a description of the site and the methodology of assessing the performance of the repository are described in the Site Characterization Plan (SCP). While many factors are accounted for during performance assessment, an important input parameter is the degradation behavior of the waste forms, which may be either spent fuel or reprocessed waste contained in a borosilicate glass matrix. To develop the necessary waste form degradation input, the waste package environment needs to be identified. This environment will change as the waste decays and also is a function of the repository design which has not yet been finalized. At the present time, an exact description of the waste package environment is not available. The SCP does provide an initial description of conditions that can be used to guide waste form evaluation. However, considerable uncertainty exists concerning the conditions under which waste form degradation and radionuclide release may occur after the waste package containment barriers are finally breached. The release conditions that are considered to be plausible include (1) a "bathtub" condition in which the waste becomes fully or partially submerged in water that enters the breached container and accumulates to fill the container up to the level of the breach opening, (2) a "wet drip" or "trickle through" condition in which the waste form is exposed to dripping water that enters through the top and exits the bottom of a container with multiple holes, and (3) a "dry" condition in which the waste form is exposed to a humid air environment.

325 (ANL/CMT/PP–71738) **Leaching patterns and secondary phase formation during unsaturated leaching of UO_2 at 90°C.** Wronkiewicz, D.J.; Bates, J.K.; Gerding, T.J.; Veleckis, E.; Tani, B.S. Argonne National Lab., IL (United States). Nov 1991. 56p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94008483. Source: OSTI; NTIS; INIS; GPO Dep.

Experiments are being conducted that examine the reaction of UO_2 with dripping oxygenated ground water at 90°C. The experiments are designed to identify secondary phases formed during UO_2 alteration, evaluate parameters controlling U release, and act as scoping tests for studies with spent fuel. This study is the first of its kind that examines the alteration of UO_2 under unsaturated conditions expected to exist at the proposed Yucca Mountain repository site. Results suggest the UO_2 matrix will readily react within a few months after being exposed to simulated Yucca Mountain conditions. A pulse of rapid U release, combined with the formation of dehydrated schoepite on the UO_2 surface, characterizes the reaction between one to two years. Rapid dissolution of intergrain boundaries and spallation of UO_2 granules appears to be responsible for much of the U released. Differential release of the UO_2 granules may be responsible for much of the variation observed between duplicate experiments. Less than 5 wt % of the released U remains in solution or in a suspended form, while the remaining settles out of solution as fine particles or is reprecipitated as secondary phases. Subsequent to the pulse period, U release rates decline and a more stable assemblage of uranyl silicate phases are formed by incorporating cations from the ground water leachant. Uranophane, boltwoodite, and sklodowskite appear as the final solubility limiting phases that form in these tests. This observed paragenetic sequence (from uraninite to schoepite-type phases to uranyl silicates) is identical to those observed in weathered zones of natural uraninite occurrences. The combined results indicate that the release of radionuclides from spent fuel may not be limited by U solubility constraints, but that spallation of particulate matter may be an important, if not the dominant release mechanism affecting release.

326 (ANL/DIS/TM–17) **Stigma models: Testing hypotheses of how images of Nevada are acquired and values are attached to them.** Jenkins-Smith, H.C. (New Mexico Univ., Albuquerque, NM (United States)). Argonne National Lab., IL (United States). Decision and Information Sciences Div.; New Mexico Univ., Albuquerque, NM (United States). Dec 1994. 72p. Sponsored by USDOE, Washington,

DC (United States). DOE Contract W-31109-ENG-38. Order Number DE95004985. Source: OSTI; NTIS; INIS; GPO Dep.

This report analyzes data from surveys on the effects that images associated with nuclear power and waste (i.e., nuclear images) have on people's preference to vacation in Nevada. The analysis was stimulated by a model of imagery and stigma which assumes that information about a potentially hazardous facility generates signals that elicit negative images about the place in which it is located. Individuals give these images negative values (valences) that lessen their desire to vacation, relocate, or retire in that place. The model has been used to argue that the proposed Yucca Mountain high-level nuclear waste repository could elicit images of nuclear waste that would stigmatize Nevada and thus impose substantial economic losses there. This report proposes a revised model that assumes that the acquisition and valuation of images depend on individuals' ideological and cultural predispositions and that the ways in which new images will affect their preferences and behavior partly depend on these predispositions. The report tests these hypotheses: (1) individuals with distinct cultural and ideological predispositions have different propensities for acquiring nuclear images, (2) these people attach different valences to these images, (3) the variations in these valences are important, and (4) the valences of the different categories of images within an individual's image sets for a place correlate very well. The analysis largely confirms these hypotheses, indicating that the stigma model should be revised to (1) consider the relevant ideological and cultural predispositions of the people who will potentially acquire and attach value to the image, (2) specify the kinds of images that previously attracted people to the host state, and (3) consider interactions between the old and potential new images of the place. 37 refs., 18 figs., 17 tabs.

327 (ANL/RA/SUMM–85653) **Performance assessment modeling of high level nuclear wasteforms from the pyroprocess fuel cycle.** Nutt, W.M. (Argonne National Lab., IL (United States)); Hill, R.N.; Bullen, D.B. Argonne National Lab., IL (United States). [1995]. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31-109-ENG-38. (CONF-950570–30: International high-level radioactive waste management conference: progress toward understanding, Las Vegas, NV (United States), 1-5 May 1995). Order Number DE95013470. Source: OSTI; NTIS; INIS; GPO Dep.

Several performance assessment (PA) analyses have been completed to estimate the release to the accessible environment of radionuclides from spent light water reactor (LWR) fuel emplaced in the proposed Yucca Mountain repository. Probabilistic methods were utilized based on the complexity of the repository system. Recent investigations have been conducted to identify the merits of a pyroprocess fuel cycle. This cycle utilizes high temperature molten salts and metals to partially separate actinides and fission products. In a closed liquid metal reactor (LMR) fuel cycle, this allows recycling of nearly all of the actinides. In a once-through cycle, this isolates the actinides for storage into a wasteform which can be specifically tailored for their retention. With appropriate front-end treatment, this Process can also be used to treat LWR spent fuel.

328 **Spent fuel waste form characteristics: Grain and fragment size statistical dependence for oxidation response.** Stout, R.B. (Lawrence Livermore National Lab., CA (United States)); Kansa, E.; Buchanan, H.C.; Einziger, R.E.; Thomas, L.E. pp. 103-111 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Yucca Mountain Project of the US DOE is investigating the suitability of a site in the unsaturated zone at Yucca Mountain, NV, for a high level nuclear waste repository. All of the nuclear waste will be enclosed in a container package. Most of the waste form will consist of fragmented UO_2 spent fuel pellets in Zircaloy-clad rods from nuclear reactors. If failure of both the waste containers and the cladding occurs, then the UO_2 fragments will be exposed to oxygen in the air and higher oxides of uranium may form. Some existing microscopic data from low temperature testing indicate that UO_2 oxidizes to U_4O_9 by a phase transformation front that propagates into the fragments. The oxidation state and its extend into the spent fuel fragments may affect the dissolution behavior of spent fuel if it is contacted by water. Thus, a model for this oxidation response of UO_2 spent fuel fragments is necessary to predict the behavior of the exposed waste form in order to assess the performance of any repository with respect to containment of radionuclides. A preliminary model of phase transformation oxidation response of spent fuel is developed that incorporates a statistical dependence on the size distribution of pellet fragments.

329 **Spent fuel waste form characteristics: Grain and fragment size statistical dependence for dissolution response.** Stout, R.B. (Univ. of California, Livermore, CA (United States)); Leider, H.; Weed, H.; Nguyen, S.; McKenzie, W.; Prussin, S.; Wilson, C.N.; Gray, W.J. pp. 112-120 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Yucca Mountain Project of the US DOE is investigating the suitability of the unsaturated zone at Yucca Mountain, NV, for a high-level nuclear waste repository. All of the nuclear waste will be enclosed in a container package. Most of the nuclear waste will be in the form of fractured UO_2 spent fuel pellets in its Zircaloy-clad from electric power reactors. If failure of both the container and its enclosed clad rods occurs, then the fragments of the fractured UO_2 spent fuel will be exposed to their surroundings. Even though the surroundings are an unsaturated zone, a possibility of water transport exists, and consequently, UO_2 spent fuel dissolution may occur. A repository requirement imposes a limit on the nuclide release per year during a 10,000 year period; thus the short term dissolution response from fragmented fuel pellet surfaces in any given year must be understood. This requirement necessitates that both experimental and analytical activities be directed toward predicting the relatively short term dissolution response of UO_2 spent fuel. The short term dissolution response involves gap nuclides, grain boundary nuclides, and grain volume nuclides. Analytical expressions are developed that describe the combined geometrical influences of grain boundary nuclides and grain volume nuclides on the dissolution rate of spent fuel.

330 **Flow and transport around a noncontinuous horizontal layer at Yucca Mountain.** McGraw, M.A. (Pacific Northwest Lab., Richland, WA (United States)); Miley, T.B.; Langford, D.W. pp. 513-519 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC06-76RL01830. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Computer simulations were used to examine the effect of a noncontinuous horizontal layer on the flow field and contaminant transport of a simplified conceptual model. The domain consisted of four different material types, where the pinched-out layer had a hydraulic conductivity one order of magnitude less than the other three zones. The boundary conditions were modified for three different simulations. The model results indicate that the boundary conditions used affect the results and are an important consideration in modeling. This implies that one-dimensional modeling is not adequate to represent the system.

331 **Unsaturated flow through a variable aperture fracture in Topopah Spring welded tuff.** Smoot, J.L. (Pacific Northwest Lab., Richland, WA (United States)); Wurstner, S.K.; Freshley, M.D. pp. 542-546 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC06-76RL01830. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The role of fractures in unsaturated flow through welded and nonwelded tuffaceous rocks is a fundamental question being addressed in performance assessment activities for the Yucca Mountain Project. A computer simulation test case was devised to investigate fracture-matrix interactions for a meter-scale block of Topopah Spring welded tuff. A data set produced by a laser scan of an actual fracture was used to generate the fracture geometry of a three-dimensional model. Simulation results indicate that pulses of water input to the top of the fracture produce gradients of flow down the fracture and into the matrix. The rate and extent of the advance appear to be influenced by the ambient saturation into the matrix. At 90% matrix saturation, an infiltration pulse of 1 cm of water in 1 h increased the pressure head by 250 cm. The wetting front penetrated approximately 8 cm vertically and 2 cm laterally in either direction from the fracture. At 50% matrix saturation, an identical infiltration pulse increased the pressure head by 400 cm. The wetting front penetrated approximately 3 cm vertically and less than 0.5 cm horizontally.

332 **Laboratory determined suction potential of Topopah Spring tuff at high temperatures.** Daily, W. (Lawrence Livermore National Lab., CA (United States)); Lin, W. pp. 583-588 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The purpose of this work is to experimentally determine the capillary suction potential of Topopah Spring tuff from Yucca Mountain, Nye County, Nevada. This data can be used to help characterize the unsaturated hydraulic properties of the densely welded tuff at this site.

333 **Degradation mode surveys of high performance candidate container materials.** Gdowski, G.E. (KMI Energy, Livermore; CA (United States)); McCright, R.D. pp. 932-939 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Corrosion resistant materials are being considered for the metallic barrier of the Yucca Mountain Project's high-level radioactive waste disposal containers. Nickel-chromium-molybdenum alloys and titanium alloys have good corrosion resistance properties and are considered good candidates for the metallic barrier. The localized corrosion phenomena, pitting and crevice corrosion, are considered as potentially limiting for the barrier lifetime. An understanding of the mechanisms of localized corrosion and of how various parameters affect it will be necessary for adequate performance assessment of candidate container materials. Examples of some of the concerns involving localized corrosion are discussed. The effects of various parameters, such as temperature and concentration of halide species, on localized corrosion are given. In addition, concerns about aging of the protective oxide layer in the expected service temperature range (50 to 250°C) are presented. Also some mechanistic considerations of localized corrosion are given.

334 **An electrochemical approach to predicting corrosion performance of container materials.** McCright, R.D. (Lawrence Livermore National Lab., CA (United States)); Farmer, J.C.; Fleming, D.L. pp. 940-944 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The pitting potentials of nickel-rich Alloy 825 are measured in chloride-containing solutions at different temperatures and adjusted to different pH values. The pitting potentials were determined by potentiodynamic polarization of Alloy 825 test specimens from the corrosion potential until a sharp increase in the electrochemical current indicated a breakdown of the protective passive film on the metal surface. Results show that Alloy 825 is susceptible to pitting attach in aggressive electrolytes containing more than 10,000 ppm chloride at 90°C and acicified to a pH value less than 2.5.

335 **Variation of permeability with temperature in fractured Topopah Spring tuff samples.** Lin, W. (Lawrence Livermore National Lab., CA (United States)). pp. 988-993 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Fractures will play an important role in the near-field hydrology of a nuclear-waste package in a mined repository. Our previous studies showed that the water permeability of fractured Topopah Springs tuff samples decreased by more than three orders of magnitude when the sample's temperature (in the case of a sample under a thermal gradient, the temperature in the hottest zone) increased to 150°C at a constant confining pressure of 5 MPa. When the fractured tuff samples were returned to room temperature the water permeability did not recover. We attributed the permeability decrease to smoothing of the asperities on the fracture surfaces, which has caused by the dissolution and redeposition of silica minerals as water flowed through the sample. Water permeability of an intact tuff sample did not change significantly under similar experimental conditions.

336 **Preliminary calculations of release rates from spent fuel in a tuff repository.** Apted, M.J. (Battelle Pacific Northwest Labs., Richland, WA (United States)); Pigford, T.H.; Lee, W.W.L.; O'Connell, W.J.; Lee, K.H.; MacIntyre, A.T.; Ueng, T.S. pp. 1080-1090 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC06-76RL01830 ; W-7405-ENG-48 ; AC03-76SF00098. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Time-dependent release rates of Tc-99, I-129, Cs-135, and Np-237 have been calculated for wet-drip and moist-continuous release modes from the engineered barrier system of a potential nuclear waste repository in unsaturated tuff. We describe the modes of water contact and of release of dissolved radionuclides to be surrounding intact rock, and the corresponding calculational models. We list the parameter values adopted, and then present numerical results, conclusions, and recommendations.

337 **Effects of spent fuel aging on repository disposal requirements.** McKee, R.W. (Pacific Northwest Lab., Richland, WA (United States)); Johnson, K.I.; Huber, H.D.; Bierschbach, M.C. pp. 1132-1142 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

A study has been carried out to analyze the effects of extended spent fuel aging on spent fuel disposal requirements. The analysis considers additional spent fuel aging up to a maximum of 50 years relative to the currently planned 2010 repository startup. As part of the analysis, an equal energy deposition (EED) methodology was developed for determining allowable waste emplacement densities in a tuff geologic repository as a function of spent fuel age and exposure. The method yields virtually identical results to those obtained by a more indirect method referred to as the "equivalent peak temperature rise concept" that has been used by the Yucca Mountain Project. This study demonstrates how this methodology can be used to design both the waste package and the waste emplacement layout to meet more than one thermal goal simultaneously.

338 **Yucca Mountain near field environment considerations for engineered barrier system design and performance.** Wilder, D.G. (Lawrence Livermore National Lab., CA (United States)). pp. 1366-1374 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The United States DOE is investigating the suitability of Yucca Mountain (YM) as a potential site for the nation's first High-level Nuclear Waste Repository. The focus of this paper is to discuss what is currently known about the Near-Field (NF) environment, particularly those aspects whose interaction with the Engineered Barrier System (EBS) components have significant impacts on the performance of the EBS and its ability to contribute to the isolation of radioactive waste.

339 **Effect of ionizing radiation on the waste package environment.** Reed, D.T. (Argonne National Lab., IL (United States)); Van Konynenburg, R.A. pp. 1396-1403 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract W-31109-ENG-38 ; W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The radiolytic production of nitrogen oxides, nitrogen acids and ammonia are discussed in relation to the expected environment in a high-level waste repository that may be constructed at the Yucca Mountain site if it is found to be suitable. Both literature data and repository-relevant data are summarized for air-water vapor systems. The limiting cases of a dry air and a pure water vapor gas phase are also discussed. Design guidelines and recommendations, based solely on the potential consequence of radiation enhancement of corrosion, are given.

340 **The constructive use of heat in an unsaturated tuff repository.** Ramspott, L.D. (Lawrence Livermore National Lab., CA (United States)). pp. 1602-1607 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

By designing the engineered barrier system in an unsaturated tuff repository to constructively use heat, the waste containers can be kept dry for hundreds of years. Without water, the aqueous processes that release and transport radionuclides do not operate. In the plans of most international programs, waste is cooled prior to disposal in granite or salt. For these rocks there are technical issues favoring reduced heat. Recently, it has been suggested that the US Program adopt a strategy of cooling nuclear waste prior to disposal. This paper reviews technical issues associated with the role of heat in an unsaturated tuff repository and concludes that the overall effect of heat in such a setting appears to be beneficial to waste isolation.

341 **Modeling ion exchange in clinoptilolite using the EQ3/6 geochemical modeling code.** Viani, B.E. (Lawrence Livermore National Lab., CA (United States)); Bruton, C.J. pp. 73-77 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka,

Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

Potential disposal of high-level nuclear waste at Yucca Mtn., Nevada requires the means to simulate ion-exchange behavior of clays and zeolites. Vanselow and Gapon convention cation-exchange models have been added to geochemical modeling codes EQ3NR/EQ6, allowing exchange to be modeled for up to three exchangers or a single exchanger with three independent sites. Solid-solution models that are numerically equivalent to the ion-exchange models were derived and also implemented in the code. The Gapon model is inconsistent with experimental adsorption isotherms of trace components in clinoptilolite. A one-site Vanselow model can describe adsorption of Cs and Sr on clinoptilolite, but a two-site Vanselow exchange model is necessary to describe K contents of natural clinoptilolites. 15 refs., 5 figs., 1 tab.

342 **Geochemical modeling of water-rock interactions in the unsaturated zone.** Bruton, C.J. (Lawrence Livermore National Lab., CA (United States)); Viani, B.E. pp. 705-708 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

If nuclear waste is buried in unsaturated tuffaceous rocks at Yucca Mountain, nevada, the surrounding environment may be subjected to elevated temperatures and complex patterns of fluid boiling, condensation and flow. Prediction of water-rock interactions is such environments requires evaluating the activity of water and describing activity coefficients of aqueous species in the unsaturated zone, where water is subjected to the effects of capillarity. The activity of water, or relative humidity, can be calculated from soil-moisture characteristic curves. Experimental results from the literature suggest that the Debye-Hueckel activity coefficient model, though developed for saturated systems, is adequate for thermodynamic calculations under ambient conditions in potential repository horizon tuffs. Dynamic geochemical simulations of water-tuff interactions demonstrate the impact of fluid saturation on mineral reaction and fluid chemistry in the unsaturated zone, relative to reaction in the saturated zone. 10 refs., 2 figs.

343 **Drift emplaced waste package thermal response.** Ruffner, D.J. (Lawrence Livermore National Lab., CA (United States)); Johnson, G.L.; Platt, E.A.; Blink, J.A.; Doering, T.W. pp. 538-543 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract W-7405-ENG-48. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Thermal calculations of the effects of radioactive waste decay heat on the potential repository at Yucca Mountain, Nevada, have been conducted by the Yucca Mountain Site Characterization Project (YMP) at Lawrence Livermore National Lab. (LLNL) in conjunction with the B&W Fuel Co. For a number of waste package spacings, these 3D transient calculations use the TOPAZ3D code to predict drift wall temperatures to 10,000 years following emplacement. Systematic temperature variation occurs as a function of fuel age at emplacement and Areal Mass Loading (AML) during the first few centuries after emplacement. After about 1000 years, emplacement age is not a strong driver on rock temperature; AML has a larger impact. High AMLs occur when large waste packages are emplaced end-to-end in drifts. Drift emplacement of equivalent packages results in lower rock temperatures than borehole emplacement. For an emplacement scheme with 50% of the drift length occupied by packages, an AML of 138 MTU/acre is about three times higher than the Site Characterization Plan-Conceptual Design (SCP-CD) value. With this higher AML (requiring only 1/3 of the SCP-CD repository footprint), peak drift wall temperatures do not exceed 160°C, but rock temperatures exceed the boiling point of water for about 3000 years. These TOPAZ3D results have been compared with reasonable agreement with two other computer codes.

344 **The analysis of repository-heat-driven hydrothermal flow at Yucca Mountain.** Buscheck, T.A. (Lawrence Livermore National Lab., CA (United States)); Nitao, J.J. pp. 847-867 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract W-7405-ENG-48. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

To safely and permanently store high-level nuclear waste, the potential Yucca Mountain repository site must mitigate the release and transport of radionuclides for tens of thousands of years. In the failure scenario of greatest concern, water would contact the waste package (WP), accelerate its failure rate, and eventually transport radionuclides to the water table. In a concept called the "extended-dry repository," decay heat arising from radioactive waste extends the time before liquid water can contact a WP. Recent modeling and theoretical advances in nonisothermal, multiphase fracture-matrix flow have demonstrated (1) the critical importance of capillary pressure disequilibrium between fracture and matrix flow, and (2) that radioactive decay heat plays a dominant role in the ability of the engineered and natural barriers to contain and isolate radionuclides. Our analyses indicate that the thermo-hydrological performance of both the unsaturated zone (UZ) and saturated zone (SZ) will be dominated by repository-heat-driven hydrothermal flow for tens of thousands of years. For thermal loads resulting in extended-dry repository conditions, UZ performance is primarily sensitive to the thermal properties and thermal loading conditions and much less sensitive to the thermal properties and thermal loading conditions and much less sensitive to the highly spatially and temporally variable ambient hydrologic properties and conditions. The magnitude of repository-heat-driven buoyancy flow in the SZ is far more dependent on the total mass of emplaced spent nuclear fuel (SNF) than on the details of SNF emplacement, such as the Areal Power Density [(APD) expressed in kW/acre] or SNF age.

345 **Alternative strategies - a means for saving money and time on the Yucca Mountain Project.** Wilder, D.G. (Lawrence Livermore National Laboratory, CA (United States)). pp. 1263-1270 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The United States Department of Energy (DOE) is undertaking studies to determine the suitability of Yucca Mountain (YM) as a potential site for disposal of high-level nuclear waste. Yucca Mountain is located approximately 120 miles

northwest of Las Vegas in an arid environment. Many processes that could contribute to mobilization of radionuclides are either absent or minimized in a dry site. Therefore, Yucca Mountain should have the potential of being a very favorable site for disposal of waste. However, the determination of suitability has no precedence, and the characterization of an arid site is complex, requiring intensive studies to determine suitability. The studies undertaken by the Yucca Mountain Site Characterization Project (YMP) are very costly. Unfortunately many people have concluded that the costs are so excessive that the project should not proceed, but rather should be curtailed. The author feels this is unfortunate for two reasons. First, the solution of what to do with nuclear waste is a clear and urgent national need if we are to have a balanced US energy strategy. Second, the excessive cost and lengthy schedule are in part artifacts of the strategy that has been developed for satisfying regulations and providing for isolation of the waste. It is this latter point that will be addressed in this paper.

346 **Large-scale in situ heater tests for hydrothermal characterization at Yucca Mountain.** Buscheck, T.A. (Lawrence Livermore National Laboratory, CA (United States)); Wilder, D.G.; Nitao, J.J. pp. 1854-1872 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

To safely and permanently store high-level nuclear-waste, the potential Yucca Mountain repository site must mitigate the release and transport of radionuclides for tens of thousands of years. In the failure scenario of greatest concern, water would contact a waste package, accelerate its failure rate, and eventually transport radionuclides to the water table. Our analysis indicate that the ambient hydrological system will be dominated by repository-heat-driven hydrothermal flow for tens of thousands of years. In situ heater tests are required to provide an understanding of coupled geomechanical-hydrothermal-geochemical behavior in the engineered and natural barriers under repository thermal loading conditions. In situ heater tests have been included in the Site Characterization Plan in response to regulatory requirements for site characterization and to support the validation of process models required to assess the total systems performance at the site. The success of the License Application (LA) hinges largely on how effectively we validate the process models that provide the basis for performance assessment. Because of limited time, some of the in situ tests will have to be accelerated relative to actual thermal loading conditions. We examine the trade-offs between the limited test duration and generating hydrothermal conditions applicable to repository performance during the entire thermal loading cycle, including heating (boiling and dry-out) and cooldown (re-wetting). For in situ heater tests duration of 6-7 yr (including 4 yr of full-power heating) is required. The parallel use of highly accelerated, shorter-duration tests may provide timely information for the LA, provided that the applicability of the test results can be validated against ongoing nominal-rate heater tests.

347 (CONF-9310102–Vol.2, pp. 822-827) **Seismic design & analysis considerations for high level nuclear waste repositories.** Hossain, Q.A. (Lawrence Livermore National Lab., CA (United States)). Lawrence Livermore National Lab., CA (United States). [1993]. From 4. energy natural phenomena hazards mitigation conference; Atlanta, GA (United States); 19-22 Oct 1993. In *Fourth DOE Natural Phenomena Hazards Mitigation Conference: Proceedings: Volume 2.* 437p. Order Number DE94009267. Source: OSTI; NTIS; INIS.

A high level nuclear waste repository, like the one at Nevada's Yucca Mountain that is being investigated for site suitability, will have some unique seismic design and analysis considerations. These are discussed, and a design philosophy that can rationally account for the unique performance objectives of such facilities is presented. A case is made for the use of DOE's performance goal-based seismic design and evaluation methodology that is based on a hybrid "deterministic" and "probabilistic" concept. How and to what extent this methodology should be modified to adopt it for a potential site like Yucca Mountain is also outlined. Finally, the issue of designing for seismic fault rupture is discussed briefly, and the desirability of using the proposed seismic design philosophy in fault rupture evaluation is described.

348 **Initial results from dissolution testing of various air-oxidized spent fuels.** Gray, W.J. (Pacific Northwest Labs., Richland, WA (United States)); Thomas, L.E. pp. 391-398 of Scientific basis for nuclear waste management XVII. Barkatt, A. (ed.); Van Konynenburg, R.A. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1994). pp. 964 DOE Contract AC06-76RL01830. From Fall meeting of the Materials Research Society (MRS); Boston, MA (United States); 29 Nov - 3 dec 1993.

Flowthrough dissolution tests have been conducted on two different light-water-reactor spent fuels oxidized to U_4O_{9+x} or U_3O_8. Oxidation had a bigger impact on the dissolution of U and a smaller impact on the dissolution of T_c from the fuel with higher burnup and higher fission gas release. Possible reasons for the observed differences in test results are discussed, but clarification awaits results from tests on other fuels, which are in progress.

349 **Testing long-term predictions from hydrogeochemical models.** Glassley, W.E. (Lawrence Livermore National Lab., CA (United States)); Bruton, C.J.; Bourcier, W.L. pp. 805-810 of Scientific basis for nuclear waste management XVII. Barkatt, A. (ed.); Van Konynenburg, R.A. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1994). pp. 964 DOE Contract W-7405-ENG-48. From Fall meeting of the Materials Research Society (MRS); Boston, MA (United States); 29 Nov - 3 dec 1993.

Thermally induced flow of liquid water and water vapor at the potential repository site at Yucca Mountain, Nevada, will extend hundreds of meters away from the repository edge. The resultant transfer of heat and mass will sufficiently perturb the ambient conditions such that a variety of mineralogical and chemical reactions will occur that may modify hydrological properties. The consequences of this "coupling" of geochemical and hydrological processes will vary through time, and will occur to different degrees in four regimes ($T < T_{boiling}$; $T = T_{boiling}$; $T > T_{boiling}$; cooling) that will develop within the repository block. The dominant processes in the regimes differ, and reflect the local balance between: (1) kinetics and equilibrium; (2) dissolution and precipitation; (3) evaporation and boiling; and (4) fluid flow in matrix and fractures. Simulations were conducted of the evolution of these regimes, using laboratory derived kinetics and thermodynamic data, and site specific mineralogical and hydrological properties. These simulations identify regions where chemical and mineralogical equilibrium is likely to be achieved, and where net changes in hydrological properties will be concentrated. Tests of the results of these simulations have been initiated

using field data from the Taupo Volcanic Zone, New Zealand. A preliminary series of calculations suggest that relative changes in porosity of as much as ± 20% to 30% may be possible for rocks with an initial porosity of 10%.

350 Experimental investigation of hydrous pyrolysis of diesel fuel and the effect of pyrolysis products on performance of the candidate nuclear waste repository at Yucca Mountain. Jackson, K.J. (Lawrence Livermore National Lab., CA (United States)); Carroll, S.A. pp. 841-847 of Scientific basis for nuclear waste management XVII. Barkatt, A. (ed.); Van Konynenburg, R.A. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1994). pp. 964 DOE Contract W-7405-ENG-48. From Fall meeting of the Materials Research Society (MRS); Boston, MA (United States); 29 Nov - 3 dec 1993.

It is thought that a significant amount of diesel fuel and other hydrocarbon-rich phases may remain inside the candidate nuclear waste repository at Yucca Mountain after construction and subsequent emplacement of radioactive waste. Although the proposed repository horizon is above the water table, the remnant hydrocarbon phases may react with hydrothermal solutions generated by high temperature conditions that will prevail for a period of time in the repository. The preliminary experimental results of this study show that diesel fuel hydrous pyrolysis is minimal at 200°C and 70 bars. The composition of the diesel fuel remained constant throughout the experiment and the concentration of carboxylic acids in the aqueous phases was only slightly above the detection limit (1-2 ppm) of the analytical technique.

351 On the benefits of an integrated nuclear complex for Nevada. Blink, J.A. (Lawrence Livermore National Lab., NM (United States)); Halsey, W.G. pp. 18-25 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 373 DOE Contract W-7405-ENG-48. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

An integrated nuclear complex is proposed for location at the Nevada Test Site. In addition to solving the nuclear waste disposal problem, this complex would tremendously enhance the southern Nevada economy, and it would provide low cost electricity to each resident and business in the affected counties. Nuclear industry and the national economy would benefit because the complex would demonstrate the new generation of safer nuclear power plants and revitalize the industry. Many spin-offs of the complex would be possible, including research into nuclear fusion and a world class medical facility for southern Nevada. For such a complex to become a reality, the cycle of distrust between the federal government and the State of Nevada must be broken. The paper concludes with a discussion of implementation through a public process led by state officials and culminating in a voter referendum.

352 Evaluation of thermo-hydrological performance in support of the thermal loading systems study. Buscheck, T.A. (Lawrence Livermore National Lab., CA (United States)); Nitao, J.J.; Saterlie, S.F. pp. 592-610 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 DOE Contract W-7405-ENG-48. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Heat generated as a result of emplacing spent nuclear fuel will significantly affect the pre- and post-closure performance of the Mined Geological Disposal System (MGDS) at the potential repository site in Yucca Mountain. Understanding thermo-hydrological behavior under repository thermal loads is essential in (a) planning and conducting the site characterization and testing program, (b) designing the repository and engineered barrier system, and (c) assessing performance. The greatest concern for hydrological performance is sources of water that would contact a waste package, accelerate its failure rate, and eventually transport radionuclides to the water table. The primary sources of liquid water are: (1) natural infiltration, (2) condensate generated under boiling conditions, and (3) condensate generated under sub-boiling conditions. Buoyant vapor flow, occurring either on a sub-repository scale or on a mountain scale, may affect the generation of the second and third sources of liquid water. A system of connected fractures facilitates repository-heat-driven gas and liquid flow as well as natural infiltration. With the use of repository-scale and sub-repository-scale models, we analyze thermo-hydrological behavior for Areal Mass Loadings (AMLs) of 24.2, 35.9, 55.3, 83.4, and 110.5 MTU/acre for a wide range of bulk permeability. We examine the temporal and spatial extent of the temperature and saturation changes during the first 100,000 yr. We also examine the sensitivity of mountain scale moisture redistribution to a range of AMLs and bulk permeabilities. In addition, we investigate how boiling and buoyant, gas-phase convection influence thermo-hydrological behavior in the vicinity of emplacement drifts containing spent nuclear fuel. The effort was done in support of a thermal loading systems study being performed to evaluate the impact of various thermal loads on the MGDS.

353 Rationale for determining spent fuel acquisitions for repository testing. Marschman, S.C. (Pacific Northwest Lab., Richland, WA (United States)); Einziger, R.E.; Stout, R.B. pp. 1074-1079 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 DOE Contract AC06-76RL01830. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A rationale for selecting commercial spent nuclear fuels for use as testing materials for the Yucca Mountain Project was developed. A review of experimental data from fuel performance testing was conducted and performance-affecting attributes pertinent to storage and disposal conditions were identified. These were used to form the basis for a fuel-selection strategy designed to ensure adequate and representative samples are available for storage- and disposal-relevant testing.

354 Engineered barrier environment, Yucca Mountain. Wilder, D.G. (Lawrence Livermore National Lab., CA (United States)). pp. 1179-1187 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 DOE Contract W-7405-ENG-48. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The suitability of Yucca Mountain (YM) as a potential nuclear waste repository site will ultimately depend on how well it provides for isolation of the waste. Analysis of isolation capabilities of YM must consider interactions between

natural and engineered systems. In addition, environmental conditions are important to EBS design, materials testing, selection, design criteria, and waste-form characterization. Studies of environmental interactions with the EBS, have emphasized processes and changed (not ambient) conditions resulting from interaction with waste, since these are the pertinent conditions for the EBS. The results of these studies indicate that the radioactive heat-of-decay from spent nuclear fuel will play a dominant role in the performance of a potential repository at Yucca Mountain. In addition, coupled hydrothermal-geochemical phenomena may significantly affect the performance of natural barriers surrounding the repository. Depending on the thermal-loading management strategy, as well as site conditions, repository heat may either substantially increase the likelihood of water contacting waste packages, with an associated potential increased magnitude of release and transport of radionuclides, or preclude, or at least minimize, these effects for extended periods of time, perhaps as much as hundreds of thousand years.

355 **Integrated modelling of near field and engineered barrier system processes.** Lamont, A. (Lawrence Livermore National Lab., CA (United States)); Gansemer, J. pp. 1195-1201 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 DOE Contract W-7405-ENG-48. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The Yucca Mountain Integrating Model (YMIM) is an integrated model of the Engineered Barrier System. It has been developed to assist project managers at LLNL in identifying areas where research emphasis should be placed. The model was designed to be highly modular so that a model of an individual process could be easily modified or replaced without interfering with the models of other processes. The modules modelling container failure and the dissolution of nuclides include particularly detailed, temperature dependent models of their corresponding processes.

356 **The testing of thermal-mechanical-hydrological-chemical processes using a large block.** Lin, W. (Lawrence Livermore National Lab., CA (United States)); Wilder, D.G.; Blink, J.A.; Blair, S.C.; Buscheck, T.A.; Chestnut, D.A.; Glassley, W.E.; Lee, K.; Roberts, J.J. pp. 1938-1945 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract W-7405-ENG-48. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The radioactive decay heat from nuclear waste packages may, depending on the thermal load, create coupled thermal-mechanical-hydrological-chemical (TMHC) processes in the near-field environment of a repository. A group of tests on a large block (LBT) are planned to provide a timely opportunity to test and calibrate some of the TMHC model concepts. The LBT is advantageous for testing and verifying model concepts because the boundary conditions are controlled, and the block can be characterized before and after the experiment. A block of Topopah Spring tuff of about 3 x 3 x 4.5 m will be sawed and isolated at Fran Ridge, Nevada Test Site. Small blocks of the rock adjacent to the large block will be collected for laboratory testing of some individual thermal-mechanical, hydrological, and chemical processes. A constant load of about 4 MPAa will be applied to the top and sides of the large block. The sides will be sealed with moisture and thermal barriers. The large block will be heated with heater in boreholes and guard heaters on the sides so that a dry-out zone and a condensate zone will exist simultaneously. Temperature, moisture content, pore pressure, chemical composition, stress and displacement will be measured through out the block during the heating and cool-down phases. The results from the experiments on small blocks and the tests on the large block will provide a better understanding of some concepts of the coupled TMHC processes. The progress of the project is also presented in this paper.

357 **Electrical properties of Topopah Spring tuff as a function of saturation.** Roberts, J.J. (Lawrence Livermore National Lab., CA (United States)); Lin, Wunan. pp. 2112-2120 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Estimates of water content in unsaturated regions based on electrical properties such as resistivity and dielectric permittivity depend on reliable laboratory measurements. We report measurements on three tuffs from Yucca Mountain, Nevada as a function of water saturation at 23°C. Hysteresis is observed between the wetting and drying phases. Measurements made over a range of frequency verify measurements made at a single frequency and provide additional information about conduction mechanisms and microstructural parameters.

358 **What do we mean by a "Cold Repository"?.** Halsey, W.G. (Lawrence Livermore National Lab., CA (United States)). pp. 2183-2188 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract W-7405-ENG-48. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The topic of thermal loading of a potential repository at Yucca Mountain in Nevada has been the subject of intense discussion within the project technical community. While terms such as "Hot Repository" and "Cold Repository" are frequently used, they have not been clearly defined. In particular, the definition of a cold repository has remained the opinion of each individual. This has led to confusion and misunderstanding. In this paper, a number of observed definitions for a cold repository are discussed along with the technical implications, assumptions and inconsistencies. Finally, a common language is suggested.

359 **Identifying significant uncertainties in thermally dependent processes for repository performance analysis.** Gansemer, J.D. (Lawrence Livermore National Lab., CA (United States)); Lamont, A. pp. 2197-2206 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract W-7405-ENG-48. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

In order to study the performance of the potential Yucca Mountain Nuclear Waste Repository, scientific investigations are being conducted to reduce the uncertainty about process models and system parameters. This paper is intended to demonstrate a method for determining a strategy for the cost effective management of these investigations. It is not meant to be a complete study of all processes and interactions, but does outline a method which can be applied to more in-depth investigations.

360 **A performance goal-based seismic design philosophy for waste repository facilities.** Hossain, Q.A. (Lawrence Livermore National Lab., CA (United States)). pp. 2266-2271 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract W-7405-ENG-48. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A performance goal-based seismic design philosophy, compatible with DOE's present natural phenomena hazards mitigation and "graded approach" philosophy, has been proposed for high level nuclear waste repository facilities. The rationale, evolution, and the desirable features of this method have been described. Why and how the method should and can be applied to the design of a repository facility are also discussed.

361 **The impact of buoyant, gas-phase flow and heterogeneity on thermo-hydrological behavior at Yucca Mountain.** Buscheck, T.A. (Lawrence Livermore National Lab., CA (United States)); Nitao, J.J. pp. 2450-2474 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract W-7405-ENG-48. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

To safely and permanently store high-level nuclear waste, the potential Yucca Mountain repository system must mitigate the release and transport of radionuclides for tens of thousands of years. In the failure scenario of greatest concern, water would contact a waste package, accelerate its failure rate, and eventually transport radionuclides to the water table. Our analyses have demonstrated that the only significant source of liquid water is fracture flow from: (1) natural infiltration, (2) condensate drainage generated under boiling conditions, and (3) condensate drainage generated under sub-boiling conditions. The first source of liquid water arises from the ambient system; the second and third sources are generated by repository heat. Buoyant, gas-phase flow, occurring either on a sub-repository scale or on a mountain scale, may play an important role in generating the second and third sources of liquid water. By considering a wide range in bulk permeability of the fractured rock, we identify a threshold bulk permeability at which buoyant, gas-phase convection begins to dominate hydrological behavior. At 10 times this threshold, convection begins to dominate thermal behavior. These effects can dominate moisture movement in the unsaturated zone on the order of 100,000 yr. We find that the development of a large above-boiling zone suppresses the effects of buoyant vapor flow. Zones of sharply contrasting bulk permeability also influence condensate generation and drainage. Of particular concern are conditions that focus vapor flow and condensate drainage, which could result in persistent refluxing at the repository, causing water to drip onto waste packages. These effects can occur under both sub-boiling and boiling conditions. Long-term in situ heater tests are required to diagnose the potential for major repository-heat-driven sources of fracture flow.

362 **Performance assessment modeling of high-level nuclear waste containers.** Nutt, W.M. (Argonne National Lab., IL (United States)); Bullen, D.B. pp. 568-570 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

A model has been developed to predict the time dependent failure distribution of containers to be used to isolate high level nuclear waste. This model uses the Weibull distribution as the statistical tool for the prediction of barrier lifetimes. Sequential failure of each barrier is explicitly modelled. The model was utilized to estimate the failure properties of a container design proposed for use at the Yucca Mountain Repository. Two proposed container designs were analyzed: a small, single barrier container and a large multi-barrier container isolates the waste for a longer period of time.

363 **Seismic design methodology for a geologic repository at Yucca Mountain.** Stepp, J.C. (WCFS, Austin, TX (United States)); Hardy, M.P.; Hossain, Q.A. pp. 691-693 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This paper is a summary of the topical report which describes the methodology that the Department of Energy (DOE) plans to use for the preclosure seismic design of the potential geologic repository at Yucca Mountain. The topical report summarized is the second of three topical reports on seismic assessment and design for Yucca Mountain. Four seismic safety performance categories for seismic design of Yucca Mountain are identified and linked to accepted seismic codes and practices. The methodology and criteria that DOE is proposing to use to design the Yucca Mountain systems, structures, and components for fault displacement is also summarized.

364 (ESTSC-000324SUN0003) **EQ3/6 V7.2A: Geochemical Modeling of Aqueous Systems.** Wolery, T.J. (Lawrence Livermore National Lab., CA (United States)). Lawrence Livermore National Lab., CA (United States). 14 Sep 1992. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Source: ESTSC; Lawrence Livermore National Lab.

Description: SUN; UNIX; ANSI FORTRAN 77; UNIX interface software, C-shell UNIX; 2 3.5 Diskettes. EQ3NR input files end in .3i, EQ6 input files end in .6i. This is a recommended convention, and it is required in order to run these codes using the UNIX interface software. The data file names have the form exemplified by data0.comR22. Here com is one of the five data file descriptors and R22 is a stage number (a configuration control identifier). The main code FORTRAN source files end in .fsc. The EQLIB library package supports the EQPT, EQ3NR, and EQ6 codes. This library is included with the package.

EQ3/6 is a software package for geochemical modeling of aqueous systems. This description pertains to version 7.2A. It addresses aqueous speciation, thermodynamic equilibrium, disequilibrium, and chemical kinetics. The major components of the package are EQ3NR a speciation-solubility code and EQ6, a reaction path code. EQ3NR is useful for analyzing groundwater chemistry data, calculating solubility limits, and determining whether certain reactions are in states of equilibrium or disequilibrium. It also initializes EQ6 calculations. EQ6 models the consequences of reacting an aqueous solution with a specified set of reactants (e.g. minerals or waste forms). It can also model fluid mixing and the effects of changes in temperature. Each of five supporting data files contains both standard state and activity coefficient-related data. Three support the use of the Davies or B-dot equations for the activity coefficients; the other two support the use of Pitzer's equations. The temperature range of the thermodynamic data on the data files varies from only 25 degrees C to 0-300 degrees C.

365 (LBL–35186) **Phenomenological studies of two-phase flow processes for nuclear waste isolation.** Pruess, K.; Finsterle, S.; Persoff, P.; Oldenburg, C. Lawrence Berkeley Lab., CA (United States). Jan 1994. 9p. Sponsored by USDOE, Washington, DC (United States);Swiss National Cooperative for the Storage of Nuclear Waste, Baden (Switzerland). DOE Contract AC03-76SF00098. (CONF-940553–47: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94011350. Source: OSTI; NTIS; INIS; GPO Dep.

The US civilian radioactive waste management program is unique in its focus on a site in the unsaturated zone, at Yucca Mountain, Nevada. Two-phase flow phenomena can also play an important role in repositories beneath the water table where gas is generated by corrosion, hydrolysis, and biological degradation of the waste packages. An integrated program has been initiated to enhance our understanding of two-phase flow behavior in fractured rock masses. The studies include two-phase (gas-liquid) flow experiments in laboratory specimens of natural rock fractures, analysis and modeling of heterogeneity and instability effects in two-phase flow, and design and interpretation of field experiments by means of numerical simulation. We present results that identify important aspects of two-phase flow behavior on different space and time scales which are relevant to nuclear waste disposal in both unsaturated and saturated formations.

366 (LLNL–95012992) **Bibliography of Yucca Mountain Project (YMP) publications at Lawrence Livermore National Laboratory, September 1977–December 1994.** Lawrence Livermore National Lab., CA (United States). Jan 1995. 66p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE95012992. Source: OSTI; NTIS; INIS; GPO Dep.

This report consists of a listing of research projects pertaining to the Yucca Mountain project.

367 (PNL–9414) **Global ice sheet modeling.** Hughes, T.J. (Univ. of Maine, Orono, ME (United States). Institute for Quaternary Studies); Fastook, J.L. Pacific Northwest Lab., Richland, WA (United States). May 1994. 165p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94013744. Source: OSTI; NTIS; INIS; GPO Dep.

The University of Maine conducted this study for Pacific Northwest Laboratory (PNL) as part of a global climate modeling task for site characterization of the potential nuclear waste respository site at Yucca Mountain, NV. The purpose of the study was to develop a global ice sheet dynamics model that will forecast the three-dimensional configuration of global ice sheets for specific climate change scenarios. The objective of the third (final) year of the work was to produce ice sheet data for glaciation scenarios covering the next 100,000 years. This was accomplished using both the map-plane and flowband solutions of our time-dependent, finite-element gridpoint model. The theory and equations used to develop the ice sheet models are presented. Three future scenarios were simulated by the model and results are discussed.

368 (PNL–9416) **Regional forecasting with global atmospheric models: Third year report.** Crowley, T.J. (Applied Research Corp., College Station, TX (United States)); North, G.R.; Smith, N.R. Pacific Northwest Lab., Richland, WA (United States); Applied Research Corp., College Station, TX (United States). May 1994. 328p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94013863. Source: OSTI; NTIS; INIS; GPO Dep.

This report was prepared by the Applied Research Corporation (ARC), College Station, Texas, under subcontract to Pacific Northwest Laboratory (PNL) as part of a global climate studies task. The task supports site characterization work required for the selection of a potential high-level nuclear waste repository and is part of the Performance Assessment Scientific Support (PASS) Program at PNL. The work is under the overall direction of the Office of Civilian Radioactive Waste Management (OCRWM), US Department of Energy Headquarters, Washington, DC. The scope of the report is to present the results of the third year's work on the atmospheric modeling part of the global climate studies task. The development testing of computer models and initial results are discussed. The appendices contain several studies that provide supporting information and guidance to the modeling work and further details on computer model development. Complete documentation of the models, including user information, will be prepared under separate reports and manuals.

369 (PNL–9418) **Global climate change model natural climate variation: Paleoclimate data base, probabilities and astronomic predictors.** Kukla, G. (Columbia Univ., Palisades, NY (United States). Lamont-Doherty Geological Observatory); Gavin, J. Pacific Northwest Lab., Richland, WA (United States); Columbia Univ., Palisades, NY (United States). Lamont-Doherty Geological Observatory. May 1994. 592p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94013956. Source: OSTI; NTIS; INIS; GPO Dep.

This report was prepared at the Lamont-Doherty Geological Observatory of Columbia University at Palisades, New York, under subcontract to Pacific Northwest Laboratory it is a part of a larger project of global climate studies which supports site characterization work required for the selection of a potential high-level nuclear waste repository and forms part of the Performance Assessment Scientific Support (PASS) Program at PNL. The work under the PASS Program is currently focusing on the proposed site at Yucca Mountain, Nevada, and is under the overall direction of the Yucca Mountain Project Office US Department of Energy, Las Vegas, Nevada. The final results of the PNL project will

provide input to global atmospheric models designed to test specific climate scenarios which will be used in the site specific modeling work of others. The primary purpose of the data bases compiled and of the astronomic predictive models is to aid in the estimation of the probabilities of future climate states. The results will be used by two other teams working on the global climate study under contract to PNL. They are located at and the University of Maine in Orono, Maine, and the Applied Research Corporation in College Station, Texas. This report presents the results of the third year's work on the global climate change models and the data bases describing past climates.

370 (PNL–9788) **Regional forecasting with global atmospheric models: Final report.** Crowley, T.J. (Applied Research Corp., College Station, TX (United States)); Smith, N.R. Pacific Northwest Lab., Richland, WA (United States). May 1994. 138p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94014218. Source: OSTI; NTIS; GPO Dep.

The purpose of the project was to conduct model simulations for past and future climate change with respect to the proposed Yucca Mtn. repository. The authors report on three main topics, one of which is boundary conditions for paleo-hindcast studies. These conditions are necessary for the conduction of three to four model simulations. The boundary conditions have been prepared for future runs. The second topic is (a) comparing the atmospheric general circulation model (GCM) with observations and other GCMs; and (b) development of a better precipitation data base for the Yucca Mtn. region for comparisons with models. These tasks have been completed. The third topic is preliminary assessments of future climate change. Energy balance model (EBM) simulations suggest that the greenhouse effect will likely dominate climate change at Yucca Mtn. for the next 10,000 years. The EBM study should improve rational choice of GCM CO_2 scenarios for future climate change.

371 (PNL-SA–23748) **Interlaboratory comparison of UO_2 dissolution rates.** Gray, W.J. (Pacific Northwest Lab., Richland, WA (United States)); Steward, S.A.; Trait, J.C.; Shoesmith, D.W. Pacific Northwest Lab., Richland, WA (United States). May 1994. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830 ; W-7405-ENG-48. (UCRL-JC–115356; CONF-940553–71: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014413. Source: OSTI; NTIS; INIS; GPO Dep.

Direct disposal of spent nuclear fuel in deep underground geologic repositories (vaults) is being pursued by several countries. Isolation relies on multiple barriers consisting of the site geology, engineered barriers including containers to surround the fuel, and the spent fuel itself. These barriers are intended to inhibit dissolution and transport of radionuclides by groundwater, which is virtually the only mechanism available to release radionuclides from the repository. Performance assessment studies are needed to demonstrate the adequacy of the various repository designs. Essential to this performance assessment is an understanding of the dissolution behavior of the spent fuel. Since the dissolution behavior of spent fuel in an actual repository cannot be adequately approximated in a laboratory, laboratory tests and data must be used to develop a mechanistic model that can predict long-term behavior in a repository. Three different laboratories have performed flowthrough dissolution tests at room temperature on portions of the same batch of unirradiated UO_2 powder, and good agreement was achieved between the different test results. Dissolution rates obtained from electrochemical studies conducted with UO_2 electrodes at Whiteshell Laboratories are compared with the flowthrough test results.

372 (PNL-SA–23965) **Development and feasibility of a waste package coupled reactive transport model (AREST-CT).** Engel, D.W.; McGrail, B.P.; Fort, J.A.; Roberts, J.S. Pacific Northwest Lab., Richland, WA (United States). May 1994. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. (CONF-940553–83: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE95007260. Source: OSTI; NTIS; INIS; GPO Dep.

Most models that analyze the waste package and engineered barrier system (near-field) of an underground geologic repository assume constant boundary conditions at the waste form surface and constant chemical properties of the groundwater. These models are useful for preliminary modeling, iterative modeling to estimate uncertainties, and as a source for a total systems analysis. However, the chemical behavior of the system is a very important factor in the containment and release of radionuclides, and one needs to understand the underlying processes involved. Therefore, the authors are developing a model to couple the calculation of the chemical properties with the reactive transport which can be used to assess the near-field. This report describes the models being implemented and presents some simple analyses demonstrating the feasibility of the chemical and coupled transport models.

373 (PNL-SA–26209) **The development and usage of a new chemical transport code: AREST-CT.** Engel, D.W.; Chen, Yueting; Fort, J.A.; McGrail, B.P.; Steefel, C.I. Pacific Northwest Lab., Richland, WA (United States). Apr 1995. 4p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. (CONF-9504179–2: 6. annual international conference on high level radioactive waste management, Las Vegas, NV (United States), 30 Apr - 5 may 1995). Order Number DE95014620. Source: OSTI; NTIS; INIS; GPO Dep.

We are developing a computer code for DOE, called the Analyzer for REpository Source Term with Chemical Transport (AREST-CT), as a waste package computer model to analyze the performance of the potential site for the repository at Yucca Mountain, Nevada. This report briefly describes the AREST-CT development and an example showing the use of the coupled chemical-transport model.

374 (UCRL-CR–122068) **Assessment of the effects of microbially influenced degradation on a massive concrete structure. Final report, Report 5.** Rogers, R.D. (Biodegradation Systems, Inc., Idaho Falls, ID (United States)). Lawrence Livermore National Lab., CA (United States); Biodegradation Systems, Inc., Idaho Falls, ID (United States). 8 Jul 1995. 96p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE96000372. Source: OSTI; NTIS; INIS; GPO Dep.

There is a need to estimate the effect of environmental conditions on construction materials to be used in the repository at Yucca Mountain. Previous reports from this project have demonstrated that it is important to develop an understanding of microbially influenced degradation (MID)

development and its influence on massive concrete structures. Further, it has been shown that the most effective way to obtain quantitative data on the effects of MID on the structural integrity of repository concrete is to study man-made, analog structures known to be susceptible to MID. The cooling tower shell located at the Ohaaki Power Station near Wairakei, New Zealand is such a structure.

375 (UCRL-ID–108314-Rev.1) **Preliminary waste form characteristics report Version 1.0. Revision 1.** Stout, R.B.; Leider, H.R. (eds.). Lawrence Livermore National Lab., CA (United States). 11 Oct 1991. 499p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE95006371. Source: OSTI; NTIS; INIS; GPO Dep.

This report focuses on radioactive waste form characteristics that will be used to design a waste package and an engineered barrier system (EBS) for a suitable repository as part of the Yucca Mountain Project. The term waste form refers to irradiated reactor fuel, other high-level waste (HLW) in various physical forms, and other radioactive materials (other than HLW) which are received for emplacement in a geologic repository. Any encapsulating of stabilizing matrix is also referred to as a waste form.

376 (UCRL-ID–114739) **The role of multiple barriers in assuring waste package reliability: Yucca Mountain Project.** Bradford, R.M. Lawrence Livermore National Lab., CA (United States). Aug 1993. 16p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE94007845. Source: OSTI; NTIS; INIS; GPO Dep.

Yucca Mountain in southwestern Nevada is being studied as a potential repository site for the permanent storage of high-level nuclear waste. Regulators have set performance standards that the potential repository must meet in order to obtain regulatory approval. Nuclear Regulatory Commission (NRC) regulations state that containment of radioactivity must be "substantially complete" for the first 1000 years after closure of the facility. Thereafter, the acceptable annual limit on releases is 1/100,000 of each radionuclide remaining in the inventory after 1000 years. To demonstrate that the potential facility is in compliance with the regulations, it is necessary to obtain some understanding of the probability distribution of the cumulative quantity of releases by certain time points. This paper will discuss the probability distribution of waste container lifetimes and how the understanding of this distribution will play a role in finding the distribution of the release quantities over time. It will be shown that, for reasonable assumptions about the process of barrier failure, the reliability of a multiple-barrier container can be achieved and demonstrated much more readily than a container consisting of a single barrier. The discussion will focus primarily on the requirement of substantially complete containment for the first 1000 years.

377 (UCRL-ID–116129) **New observations of infiltration through fractured alluvium in Yucca Flat, Nevada Test Site: A preliminary field investigation.** Kao, C.S. (California Univ., Berkeley, CA (United States). Dept. of Civil Engineering); Smith, D.K.; McKinnis, W.B. Lawrence Livermore National Lab., CA (United States). Feb 1994. 41p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE94012589. Source: OSTI; NTIS; GPO Dep.

Regional tectonics coupled with the subsurface detonation of nuclear explosives has caused widespread fracturing of the alluvium of Yucca Flat. Fractures deeper than 30 meters have been observed in boreholes. Some of these fractures are large enough to capture significant amounts of runoff during storm events. Evidence of stream capture by fractures and observations of runoff flowing into open fractures give qualitative evidence of infiltration to depths greater than several meters and possibly to the saturated zone. Our field observations contradict the assumption that little infiltration occurs on Yucca Flat. The larger, hydrologically important fractures are associated with geologic faults or the regional stress field. Additional field studies are needed to investigate the impact of fractures on the transport of contaminants.

378 (UCRL-ID–118009) **Field-based tests of geochemical modeling codes using New Zealand hydrothermal systems.** Bruton, C.J.; Glassley, W.E.; Bourcier, W.L. Lawrence Livermore National Lab., CA (United States). Jun 1994. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE95005658. Source: OSTI; NTIS; INIS; GPO Dep.

Hydrothermal systems in the Taupo Volcanic Zone, North Island, New Zealand are being used as field-based modeling exercises for the EQ3/6 geochemical modeling code package. Comparisons of the observed state and evolution of the hydrothermal systems with predictions of fluid-solid equilibria made using geochemical modeling codes will determine how the codes can be used to predict the chemical and mineralogical response of the environment to nuclear waste emplacement. Field-based exercises allow us to test the models on time scales unattainable in the laboratory. Preliminary predictions of mineral assemblages in equilibrium with fluids sampled from wells in the Wairakei and Kawerau geothermal field suggest that affinity-temperature diagrams must be used in conjunction with EQ6 to minimize the effect of uncertainties in thermodynamic and kinetic data on code predictions.

379 (UCRL-ID–118660) **Ceramic package fabrication for YMP nuclear waste disposal.** Wilfinger, K. Lawrence Livermore National Lab., CA (United States). Aug 1994. 30p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE95011522. Source: OSTI; NTIS; INIS; GPO Dep.

The purpose of this work is to develop alternate materials/design concepts to metal barriers for the Nevada Nuclear Waste Storage Investigations Project. There is some potential that site conditions may prove to be too aggressive for successful employment of the metal alloys under current consideration or that performance assessment models will predict metal container degradation rates that are inconsistent with the goal of substantially complete containment included in the NRC regulations. In the event that the anticipated lifetimes of metal containers are considered inadequate, alternate materials (i.e. ceramics or ceramic/metal composites) will be chosen due to superior corrosion resistance. This document was prepared using information taken from the open literature, conversations and correspondence with vendors, news releases and data presented at conferences to determine what form such a package might take. This discussion presents some ceramic material selection criteria, alternatives for the materials which might be used and alternatives for potential fabrication routes. This includes "stand alone" ceramic components and ceramic coatings/linings for metallic structures. A list of companies providing verbal or written information concerning the

production of ceramic or ceramic lined waste containers appears at the end of this discussion.

380 (UCRL-ID–118699) **Progress report on pre-test calculations for the large block test.** Lee, K.H. Lawrence Livermore National Lab., CA (United States). 20 Jan 1995. 27p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE95011433. Source: OSTI; NTIS; INIS; GPO Dep.

The U.S. Department of Energy's (DOE) Yucca Mountain Site Characterization Project (YMP) is investigating the suitability of the Topopah Spring tuff in the thick vadose zone at Yucca Mountain, Nevada, as a host rock for permanent disposal of high-level radioactive waste. As part of the YMP, a group of field tests, referred to as the Large Block Test (LBT), will be conducted on a large electrically heated block of Topopah Spring tuff, isolated at Fran Ridge, Nevada Test Site. The block, which will be 3 x 3 m in horizontal dimensions and 4.5 m in height, will be heated by electrical heaters. The goals of the LBT axe to gain information on the coupled thermal-mechanical-hydrological-chemical processes active in the near-field environment of a repository; to provide field data for testing and calibrating models; and to help the development of measurement systems and techniques. This progress report presents results of on-going numerical modeling calculations carried out in support of the LBT design. An equivalent continuum model with an upper boundary temperature of 60°C was used to simulate the hydrothermal response of the block to heating over a one-year period. The total heating power was started at 1500 W and later reduced to maintain an approximately uniform temperature of 138-140°C. For a homogeneous bulk permeability case, the results show the formation of a distinct dry-out zone in and around the heater plane, and well-developed condensation zones above and below the heater plane. For a heterogeneous permeability distribution, the condensation zone above the heater plane was not well developed. This difference in results suggests that water saturation changes might be sensitive to changes in bulk permeability distribution. Rock temperatures were almost unaffected by permeability distribution. Heat flow was dominated by conduction. No liquid flow through the top of the block was predicted.

381 (UCRL-ID–119033) **Hydrological property measurements of Topopah Spring Tuff.** Roberts, J.J.; Lin, W. Lawrence Livermore National Lab., CA (United States). Apr 1995. 30p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE95011434. Source: OSTI; NTIS; INIS; GPO Dep.

This report documents the progress made during FY 1994 on hydrological property measurements of samples from Topopah Spring tuff at Yucca Mountain, Nevada. These measurements were performed in the laboratory at Lawrence Livermore National Laboratory. This report contains descriptions of experimental designs and procedures, data, observations, and preliminary analyses, and also describes planned future work. The report is organized into three sections: (1) permeability of fractured Topopah Spring tuff as a function of temperature and confining pressure; (2) electrical properties of Topopah Spring tuff as a function of temperature and of saturation; and (3) moisture retention measurements of Topopah Spring tuff as a function of temperature.

382 (UCRL-ID–119101) **A progress report for the large block test of the coupled thermal-mechanical-hydrological-chemical processes.** Lin, W. (and others); Wilder, D.G.; Blink, J. Lawrence Livermore National Lab., CA (United States). Oct 1994. 32p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE95011432. Source: OSTI; NTIS; INIS; GPO Dep.

This is a progress report on the Large Block Test (LBT) project. The purpose of the LBT is to study some of the coupled thermal-mechanical-hydrological-chemical (TMHC) processes in the near field of a nuclear waste repository under controlled boundary conditions. To do so, a large block of Topopah Spring tuff will be heated from within for about 4 to 6 months, then cooled down for about the same duration. Instruments to measure temperature, moisture content, stress, displacement, and chemical changes will be installed in three directions in the block. Meanwhile, laboratory tests will be conducted on small blocks to investigate individual thermal-mechanical, thermal-hydrological, and thermal-chemical processes. The fractures in the large block will be characterized from five exposed surfaces. The minerals on fracture surfaces will be studied before and after the test. The results from the LBT will be useful for testing and building confidence in models that will be used to predict TMHC processes in a repository. The boundary conditions to be controlled on the block include zero moisture flux and zero heat flux on the sides, constant temperature on the top, and constant stress on the outside surfaces of the block. To control these boundary conditions, a load-retaining frame is required. A 3 x 3 x 4.5 m block of Topopah Spring tuff has been isolated on the outcrop at Fran Ridge, Nevada Test Site. Pre-test model calculations indicate that a permeability of at least 10^{-15} m^2 is required so that a dryout zone can be created within a practical time frame when the block is heated from within. Neutron logging was conducted in some of the vertical holes to estimate the initial moisture content of the block. It was found that about 60 to 80% of the pore volume of the block is saturated with water. Cores from the vertical holes have been used to map the fractures and to determine the properties of the rock. A current schedule is included in the report.

383 (UCRL-ID–119442) **Updated candidate list for engineered barrier materials.** McCright, R.D. Lawrence Livermore National Lab., CA (United States). Oct 1995. 12p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE96002181. Source: OSTI; NTIS; INIS; GPO Dep.

This report describes candidate materials to be evaluated over the next several years during advanced design phases for the waste package to be used for the underground disposal of high-level radioactive wastes at the Yucca Mountain facility.

384 (UCRL-ID–119564-Vol.1) **Engineered materials characterization report for the Yucca Mountain Site Characterization Project. Volume 1, Introduction, history, and current candidates.** Van Konynenburg, R.A.; McCright, R.D.; Roy, A.K.; Jones, D.A. Lawrence Livermore National Lab., CA (United States). Aug 1995. 58p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48 ; AC01-91RW00134. Order Number DE96000369. Source: OSTI; NTIS; INIS; GPO Dep.

The purpose of the Yucca Mountain Site Characterization Project is to evaluate Yucca Mountain for its suitability as a potential site for the nation's first high-level nuclear waste

repository. As part of this effort, Lawrence Livermore National Laboratory (LLNL) has been occupied for a number of years with developing and evaluating the performance of waste packages for the potential repository. In recent years this work has been carried out under the guidance of and in collaboration with the Management and Operating contractor for the Civilian Radioactive Waste Management System, TRW Environmental Safety Systems, Inc., which in turn reports to the Office of Civilian Radioactive Waste Management of the US Department of Energy. This report summarizes the history of the selection and characterization of materials to be used in the engineered barrier system for the potential repository at Yucca Mountain, describes the current candidate materials, presents a compilation of their properties, and summarizes available corrosion data and modeling. The term "engineered materials" is intended to distinguish those materials that are used as part of the engineered barrier system from the natural, geologic materials of the site.

385 (UCRL-ID–119564-Vol.2) **Engineered materials characterization report for the Yucca Mountain Site Characterization Project. Volume 2, Design data.** Konynenburg, R.A. (Lawrence Livermore National Lab., CA (United States)); McCright, R.D.; Roy, A.K.; Jones, D.A. Lawrence Livermore National Lab., CA (United States). Aug 1995. 50p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48 ; AC01-91RW00134. Order Number DE96000370. Source: OSTI; NTIS; INIS; GPO Dep.

This is Volume 2 of the Engineered Materials Characterization Report which presents the design data for candidate materials needed in fabricating different components for both large and medium multi-purpose canister (MPC) disposal containers, waste packages for containing uncanistered spent fuel (UCF), and defense high-level waste (HLW) glass disposal containers. The UCF waste package consists of a disposal container with a basket therein. It is assumed that the waste packages will incorporate all-metallic multi-barrier disposal containers to accommodate medium and large MPCs, ULCF, and HLW glass canisters. Unless otherwise specified, the disposal container designs incorporate an outer corrosion-allowance metal barrier over an inner corrosion-resistant metal barrier. The corrosion-allowance barrier, which will be thicker than the inner corrosion-resistant barrier, is designed to undergo corrosion-induced degradation at a very low rate, thus providing the inner barrier protection from the near-field environment for a prolonged service period.

386 (UCRL-ID–119564-vol.3) **Engineered materials characterization report for the Yucca Mountain Site Characterization Project. Volume 3: Corrosion and data modeling.** Van Konynenburg, R.A. (Lawrence Livermore National Lab., CA (United States)); McCright, R.D.; Roy, A.K.; Jones, D.A. Lawrence Livermore National Lab., CA (United States). Aug 1995. 14p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48 ; AC01-91RW00134. Order Number DE96000371. Source: OSTI; NTIS; INIS; GPO Dep.

This three-volume report serves several purposes. The first volume provides an introduction to the engineered materials effort for the Yucca Mountain Site Characterization Project. It defines terms and outlines the history of selection and characterization of these materials. A summary of the recent engineered barrier materials characterization workshop is presented, and the current candidate materials are listed. The second volume tabulates design data for engineered materials, and the third volume is devoted to corrosion data, radiation effects on corrosion, and corrosion modeling. The second and third volumes are intended to be evolving documents, to which new data will be added as they become available from additional studies. The initial version of Volume 3 is devoted to information currently available for environments most similar to those expected in the potential Yucca Mountain repository. This is volume three.

387 (UCRL-ID–119832) **Corrosion of candidate materials in Lake Rotokawa geothermal exposure.** Estill, J.C.; McCright, R.D. Lawrence Livermore National Lab., CA (United States). May 1995. 24p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE95015128. Source: OSTI; NTIS; GPO Dep.

Corrosion rates were determined for CDA 613, CDA 715, A-36 carbon steel, 1020 carbon steel, and Alloy 825 flat coupons which were exposed to geothermal spring water at Paraiki site number 9 near Lake Rotokawa, New Zealand. Qualitative observations of the corrosion performance of Type 304L stainless steel and CDA 102 exposed to the same environment were noted. CDA 715, Alloy 825, 1020 carbon steel, and other alloys are being considered for the materials of construction for high-level radioactive waste containers for the United States civilian radioactive waste disposal program. Alloys CDA 613 and CDA 102 were tested to provide copper-based materials for corrosion performance comparison purposes. A36 was tested to provide a carbon steel baseline material for comparison purposes, and alloy 304L stainless steel was tested to provide an austenitic stainless steel baseline material for comparison purposes. In an effort to gather corrosion data from an environment that is rooted in natural sources of water and rock, samples of some of the proposed container materials were exposed to a geothermal spring environment. At the proposed site at Yucca Mountain, Nevada, currently under consideration for high-level nuclear waste disposal, transient groundwater may come in contact with waste containers over the course of a 10,000-year disposal period. The geothermal springs environment, while extremely more aggressive than the anticipated general environment at Yucca Mountain, Nevada, could have similarities to the environment that arises at selected local sites on a container as a result of crevice corrosion, pitting corrosion, microbiologically influenced corrosion (MIC), or the concentration of the ionic species due to repetitive evaporation or boiling of the groundwater near the containers. The corrosion rates were based on weight loss data obtained after six weeks exposure in a 90°C, low-pH spring with relatively high concentrations of SO_4^{2-} and Cl^-.

388 (UCRL-ID–119842) **Geothermal areas as analogues to chemical processes in the near-field and altered zone of the potential Yucca Mountain, Nevada repository.** Bruton, C.J.; Glassley, W.E.; Meike, A. Lawrence Livermore National Lab., CA (United States). Feb 1995. 24p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE95017857. Source: OSTI; NTIS; INIS; GPO Dep.

The need to bound system performance of the potential Yucca Mountain repository for thousands of years after emplacement of high-level nuclear waste requires the use of computer codes. The use of such codes to produce reliable bounds over such long time periods must be tested using long-lived natural and historical systems as analogues. The

geothermal systems of the Taupo Volcanic Zone (TVZ) in New Zealand were selected as the site most amenable to study. The rocks of the TVZ are silicic volcanics that are similar in composition to Yucca Mountain. The area has been subjected to temperatures of 25 to 300 C which have produced a variety of secondary minerals similar to those anticipated at Yucca Mountain. The availability of rocks, fluids and fabricated materials for sampling is excellent because of widespread exploitation of the systems for geothermal power. Current work has focused on testing the ability of the EQ3/6 code and thermodynamic data base to describe mineral-fluid relations at elevated temperatures. Welfare starting long-term dissolution/corrosion tests of rocks, minerals and manufactured materials in natural thermal features in order to compare laboratory rates with field-derived rates. Available field data on rates of silica precipitation from heated fluids have been analyzed and compared to laboratory rates. New sets of precipitation experiments are being planned. The microbially influenced degradation of concrete in the Broadlands-Ohaaki geothermal field is being characterized. The authors will continue to work on these projects in FY 1996 and expand to include the study of naturally occurring uranium and thorium series radionuclides, as a prelude to studying radionuclide migration in heated silicic volcanic rocks. 32 refs.

389 (UCRL-ID-121191) **Degradation mode survey of titanium-base alloys.** Gdowski, G.E. (Lawrence Livermore National Lab., CA (United States)); Ahluwalia, H.S. Lawrence Livermore National Lab., CA (United States). 30 Jan 1995. 62p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE95017044. Source: OSTI; NTIS; INIS; GPO Dep.

Of the materials reviewed, commercially pure titanium, Ti Gr 2, is the most susceptible to crevice corrosion. Ti Gr 7, 12, and 16 are likely to be resistant to crevice corrosion under the current expected Yucca Mountain repository conditions. Although Grade 7 has the greatest resistance to crevice corrosion it is also the most expensive. Although the possibility of sustained loads cracking exists, it has not yet been observed in a Ti alloys. For hydride precipitation to occur 100°C, the hydrogen concentration would need to be relatively high, much higher than the maximum amount of hydrogen allowed during the manufacture of (α Ti alloys (0.0 15 wt%). A large amount of (SCC) stress corrosion cracking data accumulated at SNL and BNL for the WIPP program and by the Canadian Waste Management Program on titanium grades 2 and 12 indicates that there is no SCC at naturally occurring potentials in various brines. Hydride-induced cracking of titanium is a possibility and therefore, further investigation of this phenomenon under credible repository conditions is warranted. One disadvantage of titanium and its alloys is that their strengths decrease rather rapidly with temperature. This is due to the strong temperature dependence of interstitial solute strengthening mechanisms. Ti Gr 12 and 16 are recommended for further consideration as candidate materials for high level nuclear waste containers.

390 (UCRL-JC-114686-Rev.1) **Technical changes that would contribute to success in the civilian radioactive waste management program: Revision 1.** Ramspott, L.D. Lawrence Livermore National Lab., CA (United States). 1 Oct 1993. 35p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-9309295-3-Rev.1: Nuclear as a large-scale global option conference, Oak Ridge, TN (United States), 28-30 Sep 1993). Order Number DE94014059. Source: OSTI; NTIS; INIS; GPO Dep.

This paper briefly reviews the history of the United States program for high-level waste disposal. It then describes the current DOE strategy for licensing and safety for a repository at Yucca Mountain, Nevada. Changes that have occurred since the origin of the program and since publication of the Site Characterization Plan are reviewed. These include changes in external circumstances, changes in technology and new understanding of Yucca Mountain. An alternative approach is then described, based on four key concepts: a simple safety case, reversibility, demonstrability, and decompling operation of a repository from the operation of reactors.

391 (UCRL-JC-114776) **The testing of thermal-mechanical-hydrological-chemical processes using a large block.** Lin, W.; Wilder, D.G.; Blink, J.A.; Blair, S.C.; Buscheck, T.A.; Chesnut, D.A.; Glassley, W.E.; Lee, K.; Roberts, J.J. Lawrence Livermore National Lab., CA (United States). Jan 1994. 13p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553-22: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94008966. Source: OSTI; NTIS; INIS; GPO Dep.

The radioactive decay heat from nuclear waste packages may, depending on the thermal load, create coupled thermal-mechanical-hydrological-chemical (TMHC) processes in the near-field environment of a repository. A group of tests on a large block (LBT) are planned to provide a timely opportunity to test and calibrate some of the TMHC model concepts. The LBT is advantageous for testing and verifying model concepts because the boundary conditions are controlled, and the block can be characterized before and after the experiment. A block of Topopah Spring tuff of about 3 × 3 × 4.5 m will be sawed and isolated at Fran Ridge, Nevada Test Site. Small blocks of the rock adjacent to the large block will be collected for laboratory testing of some individual thermal-mechanical, hydrological, and chemical processes. A constant load of about 4 MPa will be applied to the top and sides of the large block. The sides will be sealed with moisture and thermal barriers. The large block will be heated with one heater in each borehole and guard heaters on the sides so that a dry-out zone and a condensate zone will exist simultaneously. Temperature, moisture content, pore pressure, chemical composition, stress and displacement will be measured throughout the block during the heating and cool-down phases. The results from the experiments on small blocks and the tests on the large block will provide a better understanding of some concepts of the coupled TMHC processes.

392 (UCRL-JC-114784) **Electrical properties of Topopah Spring tuff as a function of saturation.** Roberts, J.J.; Lin, Wunan. Lawrence Livermore National Lab., CA (United States). Jan 1994. 22p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553-76: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014786. Source: OSTI; NTIS; INIS; GPO Dep.

Much attention has been focused on the hydrologic properties of tuff from the potential nuclear waste repository at Yucca Mountain, Nevada. The successful characterization of the near-field environment of the potential repository

depends on the ability to understand and predict the movement of water within the matrix and fractures when the rock mass is heated by nuclear waste. This understanding will come only after many combined laboratory experiments, field tests, and model calculations have been performed. Electrical properties, including electrical resistivity and dielectric permittivity, have been utilized in past studies to infer water content in partially saturated rocks. In this study we determine the electrical properties of Topopah Spring tuff from Yucca Mountain (Area 25), and Area 3, Nevada Test Site (NTS), NV, as a function of water content. These results will be used to (1) study the electrical properties of ted rocks as functions of saturation and water chemistry; (2) relate the observed electrical properties to the distribution of water and to the microgeometry of the rock; and (3) to create a database of electrical resistivity (ρ) and relative dielectric permittivity (κ') versus water content (Sw) and temperature for rocks within the potential repository horizon. The database will be used both in laboratory experiments and field tests to determine the moisture content in rocks based on measured electrical properties.

393 (UCRL-JC–114786) **On the benefits of an integrated nuclear complex for Nevada.** Blink, J.A. (Lawrence Livermore National Laboratory, Las Vegas, NV (United States)); Halsey, W.G. Lawrence Livermore National Lab., CA (United States). Jan 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–73: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014753. Source: OSTI; NTIS; INIS; GPO Dep.

An integrated nuclear complex is proposed for location at the Nevada Test Site. In addition to solving the nuclear waste disposal problem, this complex would tremendously enhance the southern Nevada economy, and it would provide low cost electricity to each resident and business in the affected counties. Nuclear industry and the national economy would benefit because the complex would demonstrate the new generation of safer nuclear power plants and revitalize the industry. Many spin-offs of the complex would be possible, including research into nuclear fusion and a world class medical facility for southern Nevada. For such a complex to become a reality, the cycle of distrust between the federal government and the State of Nevada must be broken. The paper concludes with a discussion of implementation through a public process led by state officials and culminating in a voter referendum.

394 (UCRL-JC–114790) **Dispersivity in heterogeneous permeable media.** Chesnut, D.A. Lawrence Livermore National Lab., CA (United States). Jan 1994. 22p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–15: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94007870. Source: OSTI; NTIS; INIS; GPO Dep.

When one fluid displaces another through a one-dimensional porous medium, the composition changes from pure displacing fluid at the inlet to pure displaced fluid some distance downstream. The distance over which an arbitrary percentage of this change occurs is defined as the mixing zone length, which increases with increasing average distance traveled by the displacement front. For continuous injection, the mixing zone size can be determined from a breakthrough curve as the time required for the effluent displacing fluid concentration to change from, say, 10% to 90%. In classical dispersion theory, the mixing zone grows in proportion to the square root of the mean distance traveled, or, equivalently, to the square root of the mean breakthrough time. In a multi-dimensional heterogeneous medium, especially at field scales, the size of the mixing zone grows almost linearly with mean distance or travel time. If an observed breakthrough curve is forced to fit the, clinical theory, the resulting effective dispersivity, instead of being constant, also increases almost linearly with the spatial or temporal scale of the problem. This occurs because the heterogeneity in flow properties creates a corresponding velocity distribution along the different flow pathways from the inlet to the outlet of the system. Mixing occurs mostly at the outlet, or wherever the fluid is sampled, rather than within the medium. In this paper, we consider the effects. of this behavior on radionuclide or other contaminant migration.

395 (UCRL-JC–114791) **The impact of repository heat on thermo-hydrological performance at Yucca Mountain.** Buscheck, T.A.; Nitao, J.J. Lawrence Livermore National Lab., CA (United States). Sep 1993. 20p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-9309228–7: Focus 93: site characterization and model validation, Las Vegas, NV (United States), 26-29 Sep 1993). Order Number DE94004349. Source: OSTI; NTIS; INIS; GPO Dep.

To safely and permanently store high-level nuclear waste, the potential Yucca Mountain repository site must mitigate the release and transport of radionuclides for tens of thousands of years. In the failure scenario of greatest concern, water would contact a waste package (WP), accelerate its failure rate, and eventually transport radionuclides to the water table. These analyses have demonstrated that the only significant source of liquid water is nonequilibrium fracture flow from: (1) meteoric sources, (2) condensate drainage generated under boiling conditions, and (3) condensate drainage generated under sub-boiling conditions. The first source of liquid water arises from the ambient system; the second and third sources are generated by repository heat. Buoyant vapor flow, occurring either on a sub-repository scale or on a mountain scale, may play an important role in the generation of the second and third sources of liquid water. By considering a wide range in bulk permeability, k_b, the authors identify the threshold k_b (called k_b^{hyd}) at which buoyant, vapor convection begins to dominate hydrological behavior, and the threshold k_b (called k_b^{th}) at which this convection begins to dominate thermal behavior. They find that k_b^{th} is generally an order of magnitude larger than k_b^{hyd} and that the development of a large above-boiling zone suppresses the effects of buoyant vapor flow. Of particular concern are conditions that promote the focusing of vapor flow and condensate drainage, which could result in persistent two-phase conditions (often referred to as the heat-pipe effect) in the vicinity of WPs. The results of this study underscore the need for in situ heater tests to help diagnose the potential for the major repository-heat-driven sources of fracture flow.

396 (UCRL-JC–115230) **Integrated modelling of near field and engineered barrier system processes.** Lamont, A.; Gansemer, J. Lawrence Livermore National Lab., CA (United States). Jan 1994. 7p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–35: International high-level radioactive waste management conference, Las Vegas, NV

(United States), 22-26 May 1994). Order Number DE94009909. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Integrating Model (YMIM) is an integrated model of the Engineered barrier System has been developed to assist project managers at LLNL in identifying areas where research emphasis should be placed. The model was designed to be highly modular so that a model of an individual process could be easily modified or replaced without interfering with the models of other processes. The modules modelling container failure and the dissolution of nuclides include particularly detailed, temperature dependent models of their corresponding processes.

397 (UCRL-JC-115341) **Geomechanics investigations in support of the large block test at Fran Ridge, Nye County, Nevada.** Blair, S.C.; Berge, P.; Kansa, E.; Lin, Wunan; Roberts, J. Lawrence Livermore National Lab., CA (United States). 21 Jul 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-950435-1: 2. international conference on mechanics of jointed and faulted rock, Vienna (Austria), 10-14 Apr 1995). Order Number DE94017413. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project is investigating the Topopah Spring Tuff at Yucca Mountain, Nevada for its suitability as a host rock for the disposal of high level nuclear wastes. The Lawrence Livermore National Laboratory is planning a large block test (LBT) to investigate coupled thermal-mechanical-hydrological and geochemical processes that may occur in the repository near-field environment.

398 (UCRL-JC-115351) **The impact of buoyant gas-phase flow and heterogeneity on thermo-hydrological behavior at Yucca Mountain.** Buscheck, T.A.; Nitao, J.J. Lawrence Livermore National Lab., CA (United States). Jan 1994. 25p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553-81: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94019050. Source: OSTI; NTIS; INIS; GPO Dep.

To safety and permanently store high-level nuclear waste, the potential Yucca Mountain repository system must mitigate the release and transport of radionuclides for tens of thousands of years. In the failure scenario of greatest concern, water would contact a waste package, accelerate its failure rate, and eventually transport radionuclides to the water table. Our analyses have demonstrated that the only significant source of liquid water is fracture flow from: (1) natural infiltration, (2) condensate drainage generated under boiling conditions, and (3) condensate drainage generated under sub-boiling conditions. The first source of liquid water arises from the ambient system; the second and third sources are generated by repository heat. Buoyant, gas-phase flow, occurring either on a sub-repository scale or on a mountain scale, may play an important role in generating the second and third sources of liquid water. By considering a wide range in bulk permeability of the fractured rock, we identify a threshold bulk permeability at which buoyant, gas-phase convection begins to dominate hydrological behavior. At 10 times this threshold, convection begins to dominate thermal behavior. These effects can dominate moisture movement in the unsaturated zone on the order of 100,000 yr. We find that the development of a large above-boiling zone suppresses the effects of buoyant vapor flow. Zones of sharply contrasting bulk permeability also influence condensate generation and drainage. Of particular concern are conditions that focus vapor flow and condensate drainage, which could result in persistent refluxing at the repository, causing water to drip onto waste packages. These effects can occur under both sub-boiling and boiling conditions Long-term in situ heater tests are required to diagnose the potential for major repository-heat- driven sources of fractures flow.

399 (UCRL-JC-115352) **Evaluation of thermo-hydrological performance in support of the thermal loading systems study.** Buscheck, T.A. (Lawrence Livermore National Lab., CA (United States). Earth Sciences Dept.); Nitao, J.J.; Saterlie, S.F. Lawrence Livermore National Lab., CA (United States). Jan 1994. 19p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553-82: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE95002404. Source: OSTI; NTIS; INIS; GPO Dep.

Heat generated as a result of emplacing spent nuclear fuel will significantly affect the pre- and post-closure performance of the Mined Geological Disposal System (MGDS) at the potential repository site in Yucca Mountain. Understanding thermo-hydrological behavior under repository thermal loads is essential in (a) planning and conducting the site characterization and testing program, (b) designing the repository and engineered barrier system, and (c) assessing performance. The greatest concern for hydrological performance is source of water that would contact a waste package, accelerate its failure rate, and eventually transport radionuclides to the water table. The primary sources of liquid water are: (1) natural infiltration, (2) condensate generated under boiling conditions, and (3) condensate generated under sub-boiling conditions. Buoyant vapor flow, occurring either on a sub-repository scale or on a mountain scale, any affect the generation of the second and third sources of liquid water. A system of connected fractures facilitates repository-heat-driven gas and liquid flow as well as natural infiltration. With the use of repository-scale and sub-repository-scale models, the authors analyze thermo-hydrological behavior for Areal Mass Loadings (AMLs) of 24.2, 35.9, 55.3, 83.4, and 110.5 MTU/acre for a wide range of bulk permeability. They examine the temporal and spatial extent of the temperature and saturation changes during the first 100,000 yr. They also examine the sensitivity of mountain scale moisture redistribution to a range of AMLs and bulk permeabilities. In addition, they investigate how boiling and buoyant, gas-phase convection influence thermo-hydrological behavior in the vicinity of emplacement drifts containing spent nuclear fuel.

400 (UCRL-JC-115613) **On integrating modeling software for application to total-system performance assessment.** Lewis, L.C. (Lawrence Livermore National Lab., CA (United States)); Wilson, M.L. Lawrence Livermore National Lab., CA (United States). May 1994. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940815-75: SPECTRUM '94: international nuclear and hazardous waste management conference, Atlanta, GA (United States), 14-18 Aug 1994). Order Number DE94016361. Source: OSTI; NTIS; INIS; GPO Dep.

We examine the processes and methods used to facilitate collaboration in software development between two organizations at separate locations – Lawrence Livermore National

Laboratory (LLNL) in California and Sandia National Laboratories (SNL) in New Mexico. Our software development process integrated the efforts of these two laboratories. Software developed at LLNL to model corrosion and failure of waste packages and subsequent releases of radionuclides was incorporated as a source term into SNLs computer models for fluid flow and radionuclide transport through the geosphere.

401 (UCRL-JC-115734) **Science and licensing: Let's get off the collision course.** Van Konynenburg, R.A. Lawrence Livermore National Lab., CA (United States). Oct 1993. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-931108-94: Fall meeting of the Materials Research Society (MRS), Boston, MA (United States), 29 Nov - 3 dec 1993). Order Number DE94008688. Source: OSTI; NTIS; INIS; GPO Dep.

Our best possibility for gaining an understanding of the likely future behavior of a high level nuclear waste disposal system is use of the scientific method. However, science has inherent limitations when it comes to making long-term predictions with confidence. This paper examines these limiting factors as well as the criteria for admissibility of scientific evidence in the legal arena, and concludes that the prospects are doubtful for successful licensing of a potential repository under the regulations that were binding until recently. Suggestions are made for remedying this situation.

402 (UCRL-JC-115798) **The impact of repository heat on hydrological behavior at Yucca Mountain.** Buscheck, T.A.; Nitao, J.J. Lawrence Livermore National Lab., CA (United States). Jan 1994. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553-9: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94006658. Source: OSTI; NTIS; INIS; GPO Dep.

This report describes the role of radioactive heat-of-decay in the the performance of the Yucca Mountain Facility. Waste package and waste form degradation due to water contact is described.

403 (UCRL-JC-116147) **What do we mean by a cold repository?.** Halsey, W.G. Lawrence Livermore National Lab., CA (United States). Jan 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553-77: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014790. Source: OSTI; NTIS; INIS; GPO Dep.

The topic of thermal loading of a potential repository at Yucca Mountain in Nevada has been the subject of intense discussion within the project technical community. While terms such as "Hot Repository" and "Cold Repository" are frequently used, they have not been clearly defined. In particular, the definition of a cold repository has remained the opinion of each individual. This has led to confusion and misunderstanding. In this paper, a number of observed definitions for a cold repository are discussed along with the technical implications, assumptions and inconsistencies. Finally, a common language is suggested.

404 (UCRL-JC-116315) **Identifying significant uncertainties in thermally dependent processes for repository performance analysis.** Gansemer, J.D.; Lamont, A. Lawrence Livermore National Lab., CA (United States). Jan 1994. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553-39: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94010061. Source: OSTI; NTIS; INIS; GPO Dep.

In order to study the performance of the potential Yucca Mountain Nuclear Waste Repository, scientific investigations are being conducted to reduce the uncertainty about process models and system parameters. This paper is intended to demonstrate a method for determining a strategy for the cost effective management of these investigations. It is not meant to be a complete study of all processes and interactions, but does outline a method which can be applied to more in-depth investigations.

405 (UCRL-JC-116350) **Limitations on scientific prediction and how they could affect repository licensing.** Van Konynenburg, R.A. Lawrence Livermore National Lab., CA (United States). Jan 1994. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553-74: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014788. Source: OSTI; NTIS; INIS; GPO Dep.

The best possibility for gaining an understanding of the likely future behavior of a high level nuclear waste disposal system is to use the scientific method. However, the scientific approach has inherent limitations when it comes to making long-term predictions with confidence. This paper examines some of these limiting factors as well as the criteria for admissibility of scientific evidence in the legal arena, and concludes that the prospects are doubtful for successful licensing of a potential repository under the regulations that are now being reconsidered. Suggestions am made for remedying this situation.

406 (UCRL-JC-116357) **Rationale for determining spent fuel acquisitions for repository testing.** Marschman, S.C. (Pacific Northwest Lab., Richland, WA (United States)); Einziger, R.E.; Stout, R.B. Lawrence Livermore National Lab., CA (United States); Pacific Northwest Lab., Richland, WA (United States). Jan 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48 ; AC06-76RL01830. (CONF-940553-48: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94011742. Source: OSTI; NTIS; INIS; GPO Dep.

A rationale for selecting commercial spent nuclear fuels for use as testing materials for the Yucca Mountain Project was developed. A review of experimental data from fuel performance testing was conducted and performance-affecting attributes pertinent to storage and disposal conditions were identified. These were used to form the basis for a fuel-selection strategy designed to ensure adequate and representative samples are available for storage- and disposal-relevant testing.

407 (UCRL-JC-116418) **A heated large block test for high level nuclear waste management.** Lin, W.; Wilder, D.G.; Blink, J.A.; Blair, S.C.; Buscheck, T.A.; Glassley, W.E.; Lee, K.; Owens, M.W.; Roberts, J.J. Lawrence Livermore National Lab., CA (United States). Jan 1995. 7p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-950435-2: 2. international conference on mechanics of jointed and faulted rock, Vienna (Austria), 10-14 Apr 1995). Order Number DE95011437. Source: OSTI; NTIS; INIS; GPO Dep.

The radioactive decay heat from high-level nuclear waste may, depending on the thermal load, create coupled thermal-mechanical-hydrological-chemical (TMHC) processes in the host rock of a repository. A heated large block test (LBT) is designed to understand some of the TNMC processes. A block of Topopah Spring tuff of about 3 x 3 x 4.5 m was isolated at Fran Ridge, Nevada Test Site. Small blocks of the rock adjacent to the large block were collected for laboratory testing of some individual thermal-mechanical, thermal-hydrological, and thermal-chemical processes. The large block will be heated by heaters within so that a dryout zone and a condensate zone will exist simultaneously. Guard heaters on the block sides will be used to minimize horizontal heat losses. A constant load of about 4 MPa will be applied to the top and sides of the large block. The sides will be sealed with moisture and thermal barriers. Temperature, moisture content, pore pressure, chemical composition, stress, displacement, electrical resistivity, acoustic emissions, and acoustic velocities will be measured throughout the block during the heating and cool-down phases. The results from the experiments on small blocks and the tests on the large block will provide a better understanding of some concepts of the coupled TMHC processes. The progress of the project is presented in this paper.

408 (UCRL-JC-116429) **The importance of thermal loading conditions to waste package performance at Yucca Mountain.** Buscheck, T.A.; Nitao, J.J. Lawrence Livermore National Lab., CA (United States). Oct 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-941075-7: 18. international symposium on the scientific basis for nuclear waste management, Kyoto (Japan), 23-27 Oct 1994). Order Number DE95006440. Source: OSTI; NTIS; INIS; GPO Dep.

Temperature and relative humidity are primary environmental factors affecting waste package corrosion rates for the potential repository in the unsaturated zone at Yucca Mountain, Nevada. Under ambient conditions, the repository environment is quite humid. If relative humidity is low enough (<70%), corrosion will be minimal. Under humid conditions, corrosion is reduced if the temperature is low (<60 C). Using the V-TOUGH code, the authors model thermo-hydrological flow to investigate the effect of repository heat on temperature and relative humidity in the repository for a wide range of thermal loads. These calculations indicate that repository heat may substantially reduce relative humidity on the waste package, over hundreds of years for low thermal loads and over tens of thousands of year for high thermal loads. Temperatures associated with a given relative humidity decrease with increasing thermal load. Thermal load distributions can be optimized to yield a more uniform reduction in relative humidity during the boiling period.

409 (UCRL-JC-116431) **A large block heater test for high level nuclear waste management.** Lin, W. (and others); Wilder, D.G.; Blink, J.A. Lawrence Livermore National Lab., CA (United States). Jul 1994. 13p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-941075-3: 18. international symposium on the scientific basis for nuclear waste management, Kyoto (Japan), 23-27 Oct 1994). Order Number DE95002403. Source: OSTI; NTIS; INIS; GPO Dep.

The radioactive decay heat from nuclear waste packages may, depending on the thermal load, create coupled thermal-mechanical-hydrological-chemical (TMHC) processes in the near-field environment of a repository. A group of tests on a large block (LBT) are planned to provide a timely opportunity to test and calibrate some of the TMHC model concepts. The LBT is advantageous for testing and verifying model concepts because the boundary conditions are controlled, and the block can be characterized before and after the experiment. A block of Topopah Spring tuff of about 3 x 3 x 4.5 m will be sawed and isolated at Fran Ridge, Nevada Test Site. Small blocks of the rock adjacent to the large block will be collected for laboratory testing of some individual thermal-mechanical hydrological and chemical processes. A constant load of about 4 MPa will be applied to the top and sides of the large block. The sides will be sealed with moisture and thermal barriers. The large block will be heated by heaters within and guard heaters on the sides so that a dry-out zone and a condensate zone will exist simultaneously. Temperature, moisture content, pore pressure, chemical composition, stress, and displacement will be throughout the block during the heating and cool-down phases. The results from the experiments on small blocks and the tests on the large block will provide a better understanding of some concepts of the coupled TMHC processes. The progress of the project is presented in this paper.

410 (UCRL-JC-116435) **Stochastic modeling of the influence of environment on pitting corrosion damage of radioactive-waste containers.** Henshall, G.A. Lawrence Livermore National Lab., CA (United States). Jun 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-941075-5: 18. international symposium on the scientific basis for nuclear waste management, Kyoto (Japan), 23-27 Oct 1994). Order Number DE95002395. Source: OSTI; NTIS; INIS; GPO Dep.

A physically-based, phenomenological stochastic model for pit initiation and growth is presented as a potential tool for predicting the degradation of high-level radioactive-waste containers by aqueous pitting corrosion. Included in the model are simple phenomenological equations describing the dependence of the controlling stochastic parameters on the applied (or corrosion) potential, chloride ion concentration, and absolute temperature. Results from this model are presented that demonstrate its ability to simulate several important environmental effects on pitting.

411 (UCRL-JC-116436) **Groundwater flux, travel time, and radionuclide transport.** Chesnut, D.A. Lawrence Livermore National Lab., CA (United States). Aug 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-941075-4: 18. international symposium on the scientific basis for nuclear waste management, Kyoto (Japan), 23-27 Oct 1994). Order Number DE95002401. Source: OSTI; NTIS; INIS; GPO Dep.

Lawrence Livermore National Laboratory (LLNL) provides the scientific and engineering bases for design and performance analyses of the waste package and other components of the engineered barrier system (EBS) for a potential repository at Yucca Mountain, Nevada. The EBS is an important component of a multi-barrier system designed to isolate radioactive waste until it decays to the point that it is no longer radiologically hazardous to humans or other species. Its performance depends strongly upon the amount, chemical composition, and temperature of liquid water in the "near field" region immediately surrounding the waste packages. For this reason, much of LLNL's Yucca Mountain research has been directed toward understanding flow, transport, and chemical processes in fractured rock under both preemplacement and post-emplacement conditions. Because the radioactive decay heat from a potential

repository at Yucca Mountain would dominate the movement of water for thousands of years within the entire repository block and possibly even beyond, the spatial domain of our investigations ranges from the scale of individual fracture apertures (micrometers) to a few kilometers.

412 (UCRL-JC-118689) **Integrated Corrosion Facility for long-term testing of candidate materials for high-level radioactive waste containment.** Estill, J.C.; Dalder, E.N.C.; Gdowski, G.E.; McCright, R.D. Lawrence Livermore National Lab., CA (United States). Oct 1994. 4p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-950570-3: International high-level radioactive waste management conference: progress toward understanding, Las Vegas, NV (United States), 1-5 May 1995). Order Number DE95005921. Source: OSTI; NTIS; INIS; GPO Dep.

A long-term-testing facility, the Integrated Corrosion Facility (I.C.F.), is being developed to investigate the corrosion behavior of candidate construction materials for high-level-radioactive waste packages for the potential repository at Yucca Mountain, Nevada. Corrosion phenomena will be characterized in environments considered possible under various scenarios of water contact with the waste packages. The testing of the materials will be conducted both in the liquid and high humidity vapor phases at 60 and 90°C. Three classes of materials with different degrees of corrosion resistance will be investigated in order to encompass the various design configurations of waste packages. The facility is expected to be in operation for a minimum of five years, and operation could be extended to longer times if warranted. A sufficient number of specimens will be emplaced in the test environments so that some can be removed and characterized periodically. The corrosion phenomena to be characterized are general, localized, galvanic, and stress corrosion cracking. The long-term data obtained from this study will be used in corrosion mechanism modeling, performance assessment, and waste package design. Three classes of materials are under consideration. The corrosion resistant materials are high-nickel alloys and titanium alloys; the corrosion allowance materials are low-alloy and carbon steels; and the intermediate corrosion resistant materials are copper-nickel alloys.

413 (UCRL-JC-119106) **The large block test, a progress report.** Lin, W. (and others); Wilder, D.; Blink, J.; Berge, P.; Blair, S.; Brugman, V.; Carlson, R.; Lee, K.; Owens, M.; Pletcher, R. Lawrence Livermore National Lab., CA (United States). Oct 1994. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-950570-20: International high-level radioactive waste management conference: progress toward understanding, Las Vegas, NV (United States), 1-5 May 1995). Order Number DE95011435. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project investigates Yucca Mountain, Nevada, for its suitability as a potential repository for high-level nuclear wastes. The major functional requirement of a nuclear waste repository is that radioactive nuclides should not significantly contaminate the accessible environment for the life span of a repository. When emplaced in a repository, the radioactive decay heat of the high-level nuclear waste may cause coupled thermal-mechanical-hydrological-chemical (TMHC) processes in the near-field. The coupled TMHC processes must be understood before model calculations can be performed to confidently predict the near-field environments. The Large Block Test (LBT) is designed to provide experiments with controlled boundary conditions so that they will be more useful for testing some of the concepts of the coupled TMHC processes. Specifically, the LBT will study the dominant heat transfer mechanism, condensate refluxing, rewetting of the dry-out zone following the cool-down of the block, deformation, and chemical variations in the water. The LBT will also evaluate test methodologies and instruments that may be employed in future tests at the Exploratory Studies Facility and evaluate the corrosion/oxidation potential of coupons of candidate waste package materials in a heated rock environment. This paper presents a progress report of the LBT.

414 (UCRL-JC-119116) **Permeability of fractured tuff as functions of temperature and confining pressure.** Roberts, J.J.; Lin, Wunan. Lawrence Livermore National Lab., CA (United States). Oct 1994. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-950570-16: International high-level radioactive waste management conference: progress toward understanding, Las Vegas, NV (United States), 1-5 May 1995). Order Number DE95006432. Source: OSTI; NTIS; INIS; GPO Dep.

Understanding the transport properties of water through fractured rock is critical to predicting and modeling the hydrothermal performance of a geologic nuclear waste repository. Previous studies indicate that intact Topopah Spring tuff from Yucca Mountain, Nevada has a low permeability, $\sim 1 \times 10^{-18}$ m^2 ($\sim$1 microDarcy). A single fracture in the tuff increases the permeability to $\sim 100 \times 10^{-15}$ m^2 (hundreds of milliDarcies). However, fracture healing may occur when high temperature water flows through the fracture lowering the permeability by one or more orders of magnitude. We report progress on laboratory experiments on permeability of fractured Topopah Spring tuff as functions of confining pressure, temperature, and water/rock ratio.

415 (UCRL-JC-119119) **Effect of areal power density and relative humidity on corrosion resistant container performance.** Gansemer, J.D. Lawrence Livermore National Lab., CA (United States). Oct 1994. 3p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-950570-9: International high-level radioactive waste management conference: progress toward understanding, Las Vegas, NV (United States), 1-5 May 1995). Order Number DE95006433. Source: OSTI; NTIS; INIS; GPO Dep.

The impact of the rewetting process on the performance of waste containers at the Yucca Mountain repository is analyzed. This paper explores the impact of the temperature-humidity relationships on pitting corrosion failure of stainless steel containers for different areal power densities (APDs)in the repository. It compares the likely performance of containers in a repository with a low APD, 55 Kw/acre, and a high APD, 110 kW/acre.

416 (UCRL-JC-119121) **Measuring geomechanical properties of Topopah Spring Tuff at the 1-meter scale.** Blair, S.C.; Berge, P.A. Lawrence Livermore National Lab., CA (United States). Nov 1994. 7p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-950570-18: International high-level radioactive waste management conference: progress toward understanding, Las Vegas, NV (United States), 1-5 May 1995). Order Number DE95011441. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project is studying physical and chemical properties of Topopah Spring tuff and coupled thermal, mechanical, hydrological, and geochemical processes expected in the near-field environment of the potential waste repository at Yucca Mountain, Nevada. Investigating the suitability of Topopah Spring tuff as a host rock for radioactive waste disposal includes measuring mechanical properties. Since heterogeneities vary with scale, from vugs and cracks at the hand-sample scale to fractures and vertical variations in degree of welding at the outcrop scale, mechanical properties of the tuff depend on scale. The Lawrence Livermore National Laboratory has planned a Large Block Test (LBT) to investigate rock mass properties and coupled processes at elevated temperatures in Topopah Spring tuff at the scale of a few meters. This paper describes planned laboratory experiments in support of the LBT, to measure elastic properties and mechanical behavior of Topopah Spring tuff at the scale of a few cm to 1 m. The laboratory experiments will include measurement of stress-strain behavior, acoustic emissions during heating, and elastic wave velocities in small blocks of tuff.

417 (UCRL-JC–119131) **Synthesis of tobermorite: A cement phase expected under repository conditions.** Martin, S.I. Lawrence Livermore National Lab., CA (United States). Nov 1994. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-950570–2: International high-level radioactive waste management conference: progress toward understanding, Las Vegas, NV (United States), 1-5 May 1995). Order Number DE95005917. Source: OSTI; NTIS; INIS; GPO Dep.

In this study I have synthesized tobermorite, $Ca_5Si_6O_{16}(OH)_2.4H_20$, a principal crystalline phase expected to form in cementitious materials subjected to elevated temperatures in a potential nuclear waste repository. Fluids interacting with these materials may have a profound effect on the integrity of the waste package and on transport of radionuclides. At ambient temperature, Portland cement reacts with water to form an amorphous calcium-silicate-hydrate (C-S-H) gel. At elevated temperatures, crystalline phases of various hydration states form. The C-S-H system has not been well characterized at elevated temperatures up to 250°C, which has been considered a bounding temperature for the potential Yucca Mountain repository. Physical, chemical, and thermodynamic data for these cement minerals that are predicted to be stable at these temperatures must be obtained from synthetic or natural samples to help predict fluid chemistry. For some of these minerals natural samples are difficult to obtain in sufficient quantity and purity. Therefore, monomineralic phases must be synthesized in order to unambiguously define their behavior. The synthetic or natural phases will be characterized as part of a comprehensive study to define the behavior of cementitious materials in a repository environment.

418 (UCRL-JC–119574) **The effect of rock-water interaction on permeability.** Lin, Wunan; Roberts, J.J.; Glassley, W.; Ruddle, D. Lawrence Livermore National Lab., CA (United States). Jun 1995. 14p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-9509200–1: International congress on rock mechanics, Tokyo (Japan), 25-30 Sep 1995). Order Number DE95016178. Source: OSTI; NTIS; INIS; GPO Dep.

Current investigations for managing high-level nuclear wastes focus on studying deep geologic repositories. The Yucca Mountain Site Characterization Project of the US Department of Energy conducts studies on Yucca Mountain, Nevada, to determine its suitability as a potential high-level nuclear waste repository. The potential host rock in Yucca Mountain is a layer of devitrified Topopah Spring tuff that is densely welded, fractured, and lithophysae-poor. The suitability of a potential nuclear waste repository site depends on, among other factors, how the near-field environment affects the integrity of waste package materials and the transport of radioactive nuclides away from waste packages. Model calculations are needed to predict the near-field environment for the entire life-span of a repository. Radioactive decay heat from nuclear waste packages is likely to create coupled thermal-mechanical-hydrological-chemical (TMHC) processes in the near field of a repository. The coupled TMHC processes must be understood so they can be incorporated in the model calculations. One of the coupled TMHC processes is the effect of the rock-water interaction (a chemical-mineralogical process) on the fluid flow in the rock mass (a hydrological process).

419 (UCRL-MA–111991) **CNGBOCHS: An integrated Ingres-Interleaf system for processing change requests associated with GEMBOCHS, EQ3/6, and other research groups.** Daveler, S.A.; Lundeen, S.R.; Johnson, J.W. Lawrence Livermore National Lab., CA (United States). Jun 1993. 21p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE94008701. Source: OSTI; NTIS; GPO Dep.

Over the years, users of the GEMBOCHS thermodynamic database (GEMBOCHS is an acronym for Geologic and Engineering Materials: Bibliography Of CHemical Species) and the EQ316 software package have periodically forwarded suggestions for improvement to the GEMBOCHS and EQ316 research groups. These correspondences typically report database or software errors that have been discovered during application, solicit the inclusion of additional or improved thermodynamic data, or suggest incorporation of new or alternate algorithms for performing various geochemical calculations. Traditionally, these suggestions have been made in person, over the phone, or via surface mail, and their resolution has often required additional correspondence. Hence, it has been difficult to maintain a complete, readily-accessible database of such transactions. This difficulty has been eliminated by development of the CNGBOCHS software package (CNGBOCHS is an acronym for ChaNGe Bibliography Of CHemical Species). This system permits GEMBOCHS and EQ316 users to submit suggestions for improvement using the standard electronic mail system (hereinafter referred to as email); facilitates timely review, status notification, and resolution of these suggestions; and greatly simplifies the task of maintaining a comprehensive change-request database that can be relationally searched and selectively printed in rapid fashion. The purpose of this document is to describe the procedure for submitting email change requests to CNGREQ and to present a succinct summary of the CNGBOCHS-CNGREQ interface: its local access, operation, and run-time options.

420 (UCRL-MA–116446) **User's guide to the Yucca Mountain Integrating Model (YMIM) Version 2.1.** Gansemer, J.; Lamont, A. Lawrence Livermore National Lab., CA (United States). Apr 1995. 35p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE96001066. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Integrating Model (YMIM) is an integrated model of the engineered barrier system. It contains

models of the processes of waste container failure and nuclide release from the fuel rods. YMIM is driven by scenarios of container and rod temperature, near-field chemistry, and near-field hydrology provided by other modules. It is designed to be highly modular so that a model of an individual process can be easily modified to replaced without interfering with the models of other processes. This manual describes the process models and provides instructions for setting up and running YMIM Version 2.1.

421 **Near-field diffusion releases through one and two finite planar zones from a nuclear waste package.** Ueng, T.S. (Lawrence Livermore National Lab., CA (United States)); O'Connell, W.J. *Nuclear Technology;* 108(1): 80-89 (Oct 1994). DOE Contract W-7405-ENG-48.

For a nuclear waste package emplacement in a potential repository in partially saturated rock, a rock rubble or backfill zone may act more as a barrier than as a pathway for diffusive release of radionuclides. The authors approximate the diffusive transport process using one-dimensional, one- and two-barrier geometries. The one-barrier model suffices when the effective diffusion coefficient in the first zone, the rubble, is substantially lower than that in the second zone, the host rock. For more generally, such as two zones of comparable diffusivities, or for an additional barrier zone, the authors model two barrier zones both of finite extent. They present solutions for three types of radionuclide mobilization at the source: a pulse transient input, a steady input rate, and a constant concentration. The algebraic series form of the solutions aids analysis of sensitivity of break-through times and peak release rates. For the one-zone case, dimensionless parameters allow plotting of the family of transient solutions on a single graph. Comparisons between results of one- and two-zone models and with published results for different geometries and solution methods support verification of the solutions in this study.

422 **Repository heat and hydrological behavior at Yucca Mountain.** Buscheck, T.A. (Lawrence Livermore National Lab., CA (United States)); Nitao, J.J. *Radwaste Magazine;* 1(2): 71-76 (Apr 1994). DOE Contract W-7405-ENG-48.

The US DOE is investigating the suitability of Yucca Mountain as a potential site for a high-level nuclear waste repository. To safely and permanently store high-level radioactive waste, the potential repository system must limit gas or liquid phase transport of radionuclides to the accessible environment for tens of thousands of years. For a repository located in the saturated zone, the presence of liquid water is assumed; consequently, the degradational mechanisms depend primarily on the geochemistry near the waste wackages. For a repository located in the unsaturated zone, the primary concern is whether liquid water may come in contact with the waste package. radioactive heat of decay from spent nuclear fuel will play a dominant role in the performance of a potential repository at Yucca Mountain. This article summarizes informations on the following: major potential sources of fracture flow; heat driven flow processes; thermal loading strategies. 2 figs., 1 tab.

423 **Hydrologic impact of exploratory shaft extension into nonwelded tuff.** Nichols, W.E. (Pacific Northwest Laboratory, Geoscience Dep., Richland (United States)); Freshley, M.D.; Rockhold, M.L. *Radioactive Waste Management and Environmental Restoration;* 19(1-3): 21-44 (1994).

Special issue Yucca Mountain.

The Calico Hills nonwelded unit of volcanic tuff at Yucca Mountain, Nevada is considered a primary natural barrier to radionuclide migration between a potential high-level nuclear waste repository at Yucca Mountain and the regional water table. Numerical simulations using a verified and benchmarked code of unsaturated flow in nonwelded volcanic tuff were performed in support of a risk/benefit analysis to assess the hydrologic impact of extending exploratory shafts into the Calico Hills nonwelded unit for characterization purposes. Additional characterization of the Calico Hills nonwelded unit would improve the accuracy of model predictions of its performance as a natural barrier to radionuclide migration, while the presence of shaft(s) required to characterize the unit may reduce the effectiveness of the barrier. Numerical simulations were used to predict that the presence of a shaft and the surrounding modified permeability zone caused by shaft construction would reduce travel time for water in a radial zone with a diameter for approximately 40 m by at least 58% compared to undisturbed conditions. The results show that the choice of backfill materials used to seal the shaft will be the most important factor in design to exploratory shafts with respect to hydrologic impacts. Heterogeneities, in the form of layers of contrasting hydraulic properties, may also be important in the vicinity of a shaft where differences may result in preferential paths for water flow. (author) 17 figs., 1 tab., 19 refs.

424 **Impact of thermal loading on waste package material performance.** Stahl, D. (B&W, Las Vegas, NV (United States)); McCright, R.D. *Transactions of the American Nuclear Society;* 71: 97 (1994). (CONF-941102--: Winter meeting of the American Nuclear Society (ANS), Washington, DC (United States), 13-18 Nov 1994).

The question of waste package performance with respect to thermal load and container surface temperature has been investigated. The performance of the waste package over time is critical in ensuring that radionuclides are contained within the packages during the containment period and that releases from the engineered barrier system to the accessible environment after waste package breach do not exceed regulatory limits. Based on many years of scientific and engineering experience with many different alloy families, it has been observed that the worst corrosion occurs above ~60°C. For general corrosion of steel and copper in neutral pH aqueous environments, the corrosion rate is governed principally by the oxygen content in the water. As temperature increases, the diffusion of oxygen increases, but the solubility of oxygen decreases. The result of these opposing factors is a maximum in the corrosion rate occurring at ~80°C. Many localized forms of corrosion and stress corrosion have a strong dependence on temperature, and it has been observed in several alloy families that these forms of corrosion occur above a threshold temperature, which is ~60°C. Other factors, such as pH, oxygen content, and chloride ion concentration, also influence the threshold temperature. Corrosion does occur below 60°C, but the rate is greatly reduced.

425 **Calculated compositions of porewater affected by a nuclear waste repository in a tuff geologic environment from 0 to 10,000 years.** Criscenti, L.C. (Pacific Northwest Lab., Richland, WA (United States)); Arthur, R.C. *Radioactive Waste Management and Environmental Restoration;* 19(1-3): 231-246 (1994).

Special issue Yucca Mountain.

Porewater compositions were estimated for an environment assuming that high-level radioactive waste has been

stored for 10,000 years under geologic conditions analogous to those at the Yucca Mountain site in Nevada. The porewater compositions calculated with the EQ3/EQ6 geochemical code are intended for use in preliminary performance assessments of borosilicate glass waste packages. The porewater compositions were calculated using water-rock interaction models that are loosely coupled with two time-temperature periods in the host rocks: a cooling period between 900 years and 3,000 years after repository closure and an isothermal period from 3,000 years to 10,000 years. Significant changes in water composition are predicted to occur during the initial period of water-rock interaction; for example, the pH of the porewater increases from 6.4 to 9.1. Constant porewater compositions are predicted during the isothermal period. The results suggest that major changes in porewater composition will occur over a relatively short time frame and that these changes will persevere throughout the repository lifetime. (author) 5 figs., 3 tabs., 28 refs.

426 **Behavior of carbon-14 in waste packages for spent fuel in a tuff repository.** Van Konynenburg, R.A. (Lawrence Livermore National Lab., CA (United States). Chemistry and Materials Science Dept.). *Waste Management;* 14(5): 363-383 (1994). DOE Contract W-7405-ENG-48.

Light water reactor spent fuel in the US contains only about 37 MBq of carbon-14 per kg U (1 curie per metric ton of initial uranium); however, the potential US repository at Yucca Mountain would be located above the water table, where air is presents. Temperatures might be intentionally elevated by design in order to drive away water. If waste package containment is breached prior to depletion by radioactive decay, C-14 could be released as $^{14}CO_2$ and transported in the gas phase. Since it appears that transport would be rapid relative to radioactive decay, release to the accessible environment would be possible. This paper reviews the evaluation of the inventory of C-14 and what can be projected about its likely behavior. Uncertainties in the containment lifetimes of waste packages, and costs involved in attempting to assure long-term containment, are discussed. Consequences of total release are placed in perspective. An opinion is offered that these consequences are too small to justify the costs of trying to assure that releases would be below the previously prevailing US regulatory limits. The regulations are currently being reconsidered by a committee of the National Academy of Sciences.

427 **Implications of episodic nonequilibrium fracture-matrix flow on repository performance.** Nitao, J.J. (Lawrence Livermore National Lab., CA (United States). Earth Sciences Dept.); Buscheck, T.A.; Chesnut, D.A. *Nuclear Technology;* 104(3): 385-402 (Dec 1993). DOE Contract W-7405-ENG-48.

Some of the possible water transport mechanisms through fractured rock in the unsaturated zone at Yucca Mountain are studied to analyze the performance of a high-level nuclear repository at the potential Yucca Mountain site. Analysis shows that water can flow in fractures as opposed to flow through the rock matrix if the incoming flux and the fracture aperture size exceed critical values. The rock matrix does not have to be nearly saturated for fracture flow to occur because the fractures and matrix can be in capillary disequilibrium during transient episodic infiltration events. As an example, the type of flow, fracture or matrix, is calculated for vertical fractures in the hydrogeologic units at Yucca Mountain. The results affect such issues as natural and total system performance, site characterization activities, and site suitability determination. Also, the important differences between an unsaturated an a saturated site are pointed out. The traditional concepts of near-field, far-field, and disturbed zone become blurred when talking about the unsaturated zone. The heat of decay may have beneficial aspects for an unsaturated site. Current regulations containing such concepts such as "groundwater travel time" are not consistent with some of the physical processes inherent in an unsaturated system.

428 **Repository-heat-driven hydrothermal flow at Yucca Mountain, Part 1: Modeling and analysis.** Buscheck, T.A. (Lawrence Livermore National Lab., CA (United States)); Nitao, J.J. *Nuclear Technology;* 104(3): 418-448 (Dec 1993).

To safely and permanently store high-level nuclear waste, the potential Yucca Mountain repository site must mitigate the release and transport of radionuclides for tens of thousands of years. In the failure scenario of greatest concern, water would contact a waste package, accelerate its failure rate, and eventually transport radionuclides to the water table. Analyses have demonstrated that (a) the ambient hydrological system will be dominated by repository-heat-driven hydrothermal flow for tens of thousands of years and (b) the only significant source of liquid water is from nonequilibrium fracture flow, driven either by meteoric sources or by the condensation of repository-heat-driven flow of water vapor. For sub-boiling conditions, the infiltration of meteoric water and condensate drainage are controlled by the highly heterogeneous distribution of hydrological properties, while for above-boiling conditions, they are largely determined thermodynamically. In a concept called the "extended-dry repository," the heat of radioactive decay generates a region of above-boiling temperatures around the repository, thereby extending the time before liquid water can contact a waste package. It is also found that the magnitude of repository-heat-driven, buoyant, liquid-phase convection in the saturated zone is more dependent on the total mass of emplaced spent nuclear fuel (SNF) than on the details of SNF emplacement, such as the areal power density (expressed in kilowatts per acre) or SNF age.

429 **Repository-heat-driven hydrothermal flow at Yucca Mountain, Part II. Large-scale in situ heater test.** Buscheck, T.A. (Lawrence Livermore National Lab., CA (United States)); Nitao, J.J.; Wilder, D.G. *Nuclear Technology;* 104(3): 449-471 (Dec 1993). DOE Contract W-7405-ENG-48.

In situ heater tests are needed to provide an understanding of coupled geomechanical-hydrothermal-geochemical behavior in the engineered and natural barriers under repository thermal loadings and to support the validation of related numerical and conceptual models. Hypothesis testing can help focus characterization, modeling, and testing activities required to support model validation and build robust site suitability and licensing arguments. In situ heater tests can address the following hypotheses: (a) repository-driven heat flow is dominated by heat conduction; (b) a region of above-boiling temperatures surrounding the repository corresponds to the absence of liquid water at the waste package environment; (c) fracture density and connectivity are sufficient to promote rock dryout due to boiling and condensate shedding; (d) rewetting of the dryout zone lags significantly behind the end of the boiling period; and (e) large-scale, buoyant, gas-phase convection may eventually dominate moisture movement in the unsaturated zone. Because of limited time, some of the in situ tests will have to

be accelerated relative to actual thermal loading conditions. The tradeoffs between the limited test duration and generating hydrothermal conditions applicable to repository performance during the entire thermal loading cycle are examined, including heating (boiling and dryout) and cooldown (rewetting). For in situ heater tests to be applicable to actual repository conditions, a minimum heater test duration of 6 to 7 yr (including 4 yr of fullpower heating) is required. The parallel use of highly accelerated, shorter duration tests may also provide timely information for the license application.

SANDIA NATIONAL LABORATORIES

430 Weapons test seismic investigations at Yucca Mountain. Phillips, J.S. (Sandia National Labs., Albuquerque, NM (United States)); Walck, M.C.; Shephard, L.E. pp. 83-90 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Yucca Mountain, located on and adjacent to the Nevada Test Site, is being characterized as part of an ongoing effort to identify a potential high-level nuclear waste repository. This site will be subjected to seismic ground motions induced by underground nuclear explosions. A knowledge of expected ground motion levels from these tests will enable the designers to provide for the necessary structural support in the designs of the various components of the repository. The primary objective of the Weapons Test Seismic Investigation project is to develop a method to predict the ground motions expected at the repository site as a result of future weapons tests. This paper summarizes the data base presently assembled for the Yucca Mountain Project, characteristics of expected ground motions, and characterization of the two-dimensional seismic properties along paths between Yucca Mountain and the testing areas of the Nevada Test Site.

431 Performance assessment in early phases of the repository design process. Blejwas, T.E. (Sandia National Labs., Albuquerque, NM (United States)). pp. 210-215 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Assessments of post-closure performance are an integral part of the design process for a repository for high-level nuclear waste. They provide input to the establishment of design requirements and to the evaluation of designs against these requirements. During early design phases, the assessments are limited by capabilities of analytical models, uncertainties about conceptual models, and a lack of site data. The use of performance assessment in recent design activities for the Yucca Mountain Site Characterization Project, including a study of alternatives for an exploratory shaft facility (ESF), demonstrates the necessity of significant engineering judgment in the interpretation and application of early analyses. Maintaining flexibility for some aspects of repository design is prudent.

432 Mechanical anisotropy of the Yucca Mountain tuffs. Price, R.H. (Sandia National Labs., Albuquerque, NM (United States)); Boyd, P.J.; Martin, R.J.; Haupt, R.W.; Noel, J.S. pp. 268-271 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Three series of measurements were performed on oriented cores of several Yucca Mountain tuffs to determine the importance of mechanical anisotropy in the intact rock. Outcrop and drillhole samples were tested for acoustic velocities, linear compressibilities, and strengths in different orientations. The present data sets are preliminary, but suggest the tuffs are transversely anisotropic for these mechanical properties. The planar fabric that produces the anisotropy is believed to be predominantly the result of the preferred orientation of shards and pumice fragments. The potential of significant anisotropy has direct relevance to the formulation of constitutive formulation and the analyses of an underground opening within the Yucca Mountain.

433 Predicted thermal and stress environments in the vicinity of repository openings. Bauer, S.J. (Sandia National Labs., Albuquerque, NM (United States)); Hardy, M.P.; Lin, M. pp. 564-571 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

An understanding of the thermal and stress environment in the vicinity of repository openings is important for preclosure performance considerations and worker health and safety considerations for the proposed high-level radioactive waste repository at Yucca Mountain. This paper presents the results of two and three dimensional numerical analyses which have determined the thermal and stress environments for typical repository openings. In general, it is predicted that openings close to heat sources attain high temperatures and experience a significant stress increase. Openings away from heat sources experience more uniform temperature changes and experience a stress change which results in part from a far-field thermal loading.

434 Research program to develop and validate conceptual models for flow and transport through unsaturated, fractured rock. Glass, R.J. (Sandia National Labs., Albuquerque, NM (United States)); Tidwell, V.C. pp. 977-987 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

As part of the Yucca Mountain Project, our research program to develop and validate conceptual models for flow and transport through unsaturated fractured rock integrates

fundamental physical experimentation with conceptual model formulation and mathematical modeling. Our research is directed toward developing and validating macroscopic, continuum-based models and supporting effective property models because of their widespread utility within the context of this project. Success relative to the development and validation of effective property models is predicted on a firm understanding of the basic physics governing flow through fractured media, specifically in the areas of unsaturated flow and transport in a single fracture and fracture-matrix interaction.

435 **Mechanical excavator performance in Yucca Mountain tuffs.** Ozdemir, L. (Colorado School of Mines, Golden, CO (United States)); Hansen, F.D. pp. 1091-1097 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

A research effort of four phases is in progress at the Colorado School of Mines. The overall program will evaluate the cutability of welded tuff and other lithologies likely to be excavated at Yucca Mountain in the site characterization process. Several mechanical systems are considered with emphasis given to the tunnel boring machine. The research comprises laboratory testing, linear drag bit and disc cutter tests, and potentially large-scale lab. demonstrations to support potential use of a tunnel boring machine in welded tuff. Preliminary estimates of mechanical excavator performance in Yucca Mountain tuff are presented here. As phases of the research project are completed, well-quantified estimates will be made of performance of mechanical excavators in the Yucca Mountain tuffs.

436 **Performance assessment calculational exercises (PACE-90): Overview and summary.** Barnard, R.W. (Sandia National Labs., Albuquerque, NM (United States)); Dockery, H.A. pp. 1189-1197 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

PACE-90 was undertaken by the Yucca Mountain Site Characterization Project in order to develop expertise in computational capabilities and to aid in identification of critical elements and processes necessary for performance assessment. One- and two-dimensional codes simulated groundwater flow and transport of selected radionuclides through Yucca Mountain for a period of 100,000 years. Using an groundwater percolation flux of 0.01 mm/yr and a new interpretation of the hydrostratigraphy, the calculations showed no contamination reaching the water table. However, these results should be interpreted with caution because the calculations were based on unvalidated conceptual models and parameters. In a separate part of the exercise, disturbed-condition problems (human intrusion, climate change, and volcanism) were developed as a basis for future calculations.

437 **Estimating geochemical behavior of concretes to be placed at Yucca Mountain.** Hinkebein, T.E. (Sandia National Labs., Albuquerque, NM (United States)); Gardiner, M.A. pp. 1404-1409 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The interactions of J-13 water with cementitious materials were examined at 25°C using the geochemical code EQ3NR/EQ6. Results of the modeling suggested the following conclusions: (1) Solution chemistry for calcium-rich concretes was similar to that for silica-rich concretes. (2) Solution pH was strongly buffered by J-13 added concrete. For larger amounts of concrete the pH was dominated by the concrete and typically had values near 12. (3) If ettringite or excess portlandite are present, their decomposition opens the concrete structure. Excess silica reacts with hydrogarnet to tighten the concrete structure. (4) The permeability changes for the limited conditions discussed here are small.

438 **Preliminary assessment of the impact of conceptual model uncertainty on site performance.** Gallegos, D.P. (Sandia National Labs., Albuquerque, NM (United States)); Pohl, P.I.; Updegraff, C.D. pp. 1469-1479 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Performance assessment modeling for high-level radioactive waste (HLW) disposal incorporates three different types of uncertainty. These include data and parameter uncertainty, modeling uncertainty (conceptual, mathematical, and numerical), and uncertainty associated with predicting future state of the system. In this study, the potential impact of conceptual model uncertainty on the performance of a hypothetical high-level radioactive waste disposal site in unsaturated, fractured tuff has been assessed for a given group of conceptual models. This was accomplished by taking a series of six, one-dimensional conceptual models, which differed only by the fundamental assumptions used to develop them, and conducting ground water flow and radionuclide transport simulations. Complementary cumulative distribution functions (CCDFs) of integrated radionuclide release to the water table indicate that differences in basic assumptions can have a significant impact on the performance of the site. Because each of the conceptual models employed the same mathematical and numerical models, did not consider future states of the system, changes in the CCDF could be attributed primarily to differences in conceptual modeling assumptions.

439 **Scenario evolution: Interaction between event tree construction and numerical analyses.** Barr, G.E. (Sandia National Labs., Albuquerque, NM (United States)); Barnard, R.W.; Dockery, H.A.; Dunn, E.; MacIntyre, A.T. pp. 1480-1486 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Construction of well-posed scenarios for the range of conditions possible at any proposed repository site is a critical

first step to assessing total system performance. Even tree construction is the method that is being used to develop potential failure scenarios for the proposed nuclear waste repository at Yucca Mountain. An event tree begins with an initial event or condition. Subsequent events are listed in a sequence, leading eventually to release of radionuclides to the accessible environment. Ensuring the validity of the scenarios requires iteration between problems constructed using scenarios contained in the event tree sequence, experimental results, and numerical analyses. Details not adequately captured within the tree initially may become more apparent as a result of analyses. To illustrate this process, we discuss the iterations used to develop numerical analyses for PACE-90 using basaltic igneous activity and human-intrusion event trees.

440 A formalism to generate probability distributions for performance-assessment modeling. Kaplan, P.G. (Sandia National Labs., Albuquerque, NM (United States)). pp. 1487-1490 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Estimates of compliance with regulatory criteria for nuclear waste respositories are often based on Monte Carlo simulation, a process which requires that the distribution of the model input parameters be specified. For many parameters there are sparse data available. A formalism is presented for generating probability distributions of parameters used in performance-assessment modeling. The formalism is used when data are either sparse or nonexistent. The appropriate distribution is a function of the known or estimated constraints and is chosen to maximize a quantity known as Shannon's informational entropy. The formalism is applied to a parameter used in performance-assessment modeling. The functional form of the model that defines the parameter, data from the actual field site, and natural analog data are analyzed to estimate the constraints. A beta probability distribution of the example parameter is generated after finding four constraints.

441 Characterization uncertainty and its effects on models and performance. Rautman, C.A. (Sandia National Labs., Albuquerque, NM (United States)); Treadway, A.H. pp. 1491-1495 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Geostatistical simulation is being used to develop multiple geologic models of rock properties at the proposed Yucca Mountain repository site. Because each replicate model contains the same known information, and is thus essentially indistinguishable statistically from others, the differences between models may be thought of as representing the uncertainty in the site description. The variability among performance measures, such as ground water travel time, calculated using these replicate models therefore quantifies the uncertainty in performance that arises from uncertainty in site characterization.

442 Uncertainty analysis of preclosure accident doses for the Yucca Mountain repository. Ma, C.W. (Bechtel National Inc., San Francisco, CA (United States)); Miller, D.D.; Zavoshy, S.J.; Jardine, L.J. pp. 1694-1703 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

This study presents a generic methodology that can be used to evaluate the uncertainty in the calculated accidental offsite doses at the Yucca Mountain repository during the preclosure period. For demonstration purposes, this methodology is applied to two specific accident scenarios: The first involves a crane dropping an open container with consolidated fuel rods, the second involves container failure during emplacement or removal operations. The uncertainties of thirteen parameters are quantified by various types of probability distributions. The Latin Hypercube Sampling method is used to evaluate the uncertainty of the offsite dose. For the crane-drop scenario with concurrent filter failure, the doses due to the release of airborne fuel particles are calculated to be 0.019, 0.32, and 2.8 rem at confidence levels of 10%, 50%, and 90%, respectively. For the container failure scenario with concurrent filter failure, the 90% confidence-level dose is 0.21 rem.

443 Total-system analyzer for performance assessment of Yucca Mountain. Wilson, M.L. (Sandia National Labs., Albuquerque, NM (United States)); Lauffer, F.C.; Cummings, J.C.; Zieman, N.B. pp. 1734 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Total-System Analyzer is a modular computer program for probabilistic total-system performance calculations. The code employs stratified random sampling from model parameter distribution functions to generate multiple "realizations" of the system. The results of flow and transport calculations for each realization are combined into a probability distribution function of the system response as indicated by the performance measure. We give a detailed description of the code and present results for four example problems simulating the release of radionuclides from a proposed high-level-waste repository at Yucca Mountain, Nevada. The example simulations illustrate the impact of significant variation of percolation flux and sorption on radionuclide releases. We discuss the effects of numerical sampling error and of correlations among the model parameters.

444 TRM performance prediction in Yucca Mountain welded tuff from linear cutter tests. Gertsch, R. (Colorado School of Mines, Golden, CO (United States)); Ozdemir, L.; Gertsch, L. pp. 1516-1520 of High level radioactive waste management: Proceedings. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1992). pp. 1238 From 3. international high level radioactive waste management (IHLRWM) conference; Las Vegas, NV (United States); 12-16 Apr 1992.

Performance predictions were developed for tunnel boring machines operating in welded tuff for the construction of the

experimental study facility and the potential nuclear waste repository at Yucca Mountain. The predictions were based on test data obtained from an extensive series of linear cutting tests performed on samples of Topopah Spring welded tuff from the Yucca Mountain Project site. Using the cutter force, spacing, and penetration data from the experimental program, the thrust, torque, power, and rate of penetration were estimated for a 25 ft diameter tunnel boring machine (TBM) operating in welded tuff. Guidelines were developed for the optimal design of the TBM cutterhead to achieve high production rates at the lowest possible excavation costs. The results show that the Topopah Spring welded tuff (TSw2) can be excavated at relatively high rates of advance with state-of-the-art TBMs. The results also show, however, that the TBM torque and power requirements will be higher than estimated based on rock physical properties and past tunneling experience in rock formations of similar strength.

445 **Sensitivity analyses for total-system performance assessment.** Wilson, M.L. (Sandia National Labs., Albuquerque, NM (United States)). pp. 14-21 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

As a follow-on to Sandia's 1991 preliminary total-system performance assessment of the Yucca Mountain site, this paper presents results of some sensitivity analyses that were done using results from the 1991 study. Two conceptual models of unsaturated-zone flow and transport at Yucca Mountain were included in the study, including both aqueous and gaseous releases. The sensitivities are quite different for the two models. For the composite-porosity model, the results are most sensitive to groundwater percolation flux, gaseous transport time, container lifetime, and fuel-matrix-alteration rate. For the weeps model, the results are most sensitive to parameters used to characterize fracture flow (fracture aperture and fracture connectivity) and infiltration (percolation flux and weep-episode factor).

446 **Numerical methods for fluid flow in unsaturated heterogeneous tuff.** Robey, T.H. (Spectra Research Institute, Albuquerque, NM (United States)). pp. 138-145 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

A numerical approach for modeling unsaturated flow is developed for heterogeneous simulations of fractured tuff generated using a geostatistical method. Cross correlations of hydrologic properties and upscaling of moisture retention curves is discussed. The approach is demonstrated for a study of infiltration at Yucca Mountain.

447 **The most likely groundwater flux through the unsaturated tuff matrix at USW H-1.** Gauthier, J.H. (Spectra Research Institute, Albuquerque, NM (United States)). pp. 146-151 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Using a probabilistic inverse method, an estimate is made of the groundwater flux through the unsaturated tuff matrix at drill hole USW H-1 in Yucca Mountain. The most likely flux is found to be between 0 and 0.01 mm/yr-virtually a hydrostatic condition. This result is consistent at all elevations where in-situ data are available, including an upper nonwelded strata. This study has implications for flow-model validation and future data collection.

448 **Investigation of fracture-matrix interaction: Preliminary experiments in a simple system.** Foltz, S.D. (Univ. of New Mexico, Albuquerque, NM (United States)); Tidwell, V.C.; Glass, R.J.; Sobolik, S.R. pp. 328-335 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Paramount to the modeling of unsaturated flow and transport through fractured porous media is a clear understanding of the processes controlling fracture-matrix interaction. As a first step toward such an understanding, two preliminary experiments have been performed to investigate the influence of matrix imbibition on water percolation through unsaturated fractures in the plane normal to the fracture. Test systems consisted of thin slabs of either tuff or an analog material cut by a single vertical fracture into which a constant fluid flux was introduced. Transient moisture content and solute concentration fields were imaged by means of x-ray absorption. Flow fields associated with the two different media were significantly different owing to differences in material properties relative to the imposed flux. Richards' equation was found to be a valid means of modeling the imbibition of water into the tuff matrix from a saturated fracture for the current experiment.

449 **Preliminary characterization of materials for a reactive transport model validation experiment.** Siegel, M.D. (Sandia National Labs., Albuquerque, NM (United States)); Ward, D.B.; Cheng, W.C.; Bryant, C.; Chocas, C.S.; Reynolds, C.G. pp. 348-365 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The geochemical properties of a porous sand and several tracers (Ni, Br, and Li) have been characterized for use in a caisson experiment designed to validate sorption models used in models of reactive transport. The surfaces of the sand grains have been examined by a combination of techniques including potentiometric titration, acid leaching, optical microscopy, and scanning electron microscopy with energy-dispersive spectroscopy. The surface studies indicate the presence of small amounts of carbonate, kaolinite and iron-oxyhydroxides. Adsorption of nickel, lithium and bromide by the sand was measured using batch techniques. Bromide was not sorbed by the sand. A linear (K_d) or an isotherm sorption model may adequately describe transport of Li; however, a model describing the changes of pH and the concentrations of other solution species as a function of time and position within the caisson and the concomitant effects on Ni sorption may be required for accurate predictions of nickel transport.

450 Scenario development for performance assessment - some questions for the near-field modelers. Barr, G.E. (Sandia National Labs., Albuquerque, NM (United States)); Barnard, R.W. pp. 478-484 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

In an attempt to achieve completeness and consistency, the performance-assessment analyses developed by the Yucca Mountain Project are tied to scenarios described in event trees. Development of scenarios requires describing the constituent features, events, and processes in detail. Several features and processes occurring at the waste packages and the rock immediately surrounding the packages (i.e., the near field) have been identified: The effects of radiation on fluids in the near-field rock, the path-dependency of rock-water interactions, and the partitioning of contaminant transport between colloids and solutes. This paper discusses some questions regarding these processes that the near-field performance-assessment modelers will need to have answered to specify those portions of scenarios dealing with the near field.

451 Implications of stability analysis for heat transfer at Yucca Mountain. Ross, B. (Disposal Safety Inc., Washington, DC (United States)); Zhang, Y.; Lu, N. pp. 584-589 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

An analytical solution has been obtained to the stability problem for an infinite horizontal layer of gas with its humidity constrained to 100%. Latent heat transfer makes convective heat transfer much more important for this moist gas than for a dry gas. The critical Rayleigh number for the onset of convective flow in the moist gas, with a lower no-flow boundary at 97°C and an upper no-flow boundary at 27°C, is 0.18, much less than the value of $4n^2$ for a dry gas. Although the heat source at Yucca Mountain will be finite in extent, the solution for an infinite horizontal layer still gives a useful criterion for the qualitative importance of convective heat transfer. The critical Rayleigh number of 0.18 corresponds to a permeability of 4×10^{-12} m^2 if other parameters are given values measured at Yucca Mountain. This value falls roughly in the middle of the range of measured permeabilities. The analysis also gives a time constant for the onset of convection, which at twice the critical Rayleigh number of 1000 yr. Thus convection will probably make an important contribution to heat transfer at Yucca Mountain if the rock permeability falls in the upper portion of the range of measurements to date, but only at times after a few hundred or thousand years.

452 Comparison of predicted far-field temperatures for discrete and smeared heat sources. Ryder, E.E. (Sandia National Labs., Albuquerque, NM (United States)). pp. 841-846 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

A fundamental concern in the design of the potential repository at Yucca Mountain, Nevada is the response of the host rock to the emplacement of heat-generating waste. The thermal perturbation of the rock mass has implications regarding the structural hydrologic, and geochemical performance of the potential repository. The phenomenological coupling of many of these performance aspects makes repository thermal modeling a difficult task. For many of the more complex, coupled models, it is often necessary to reduce the geometry of the potential repository to a smeared heat-source approximation. Such simplifications have impacts on induced thermal profiles that in turn may influence other predicted responses through one- or two-way thermal couplings. The effect of waste emplacement layout on host-rock thermal response was chosen as the primary emphasis of this study. Using a consistent set of modeling and input assumptions, far-field thermal response predictions were made for discrete-source as well as plate source approximations of the repository geometry. Input values used in the simulations are consistent with a design-basis areal power density (APD) of 80 kW/acre as would be achieved assuming a 2010 emplacement start date, a levelized receipt schedule, and a limitation on available area as published in previous design studies. It was found that edge effects resulting from general repository layout have a significant influence on the shapes and extents of isothermal profiles, and should be accounted for in far-field modeling efforts.

453 The results of near-field thermal and mechanical calculations of thermal loading schemes. Holland, J.F. (Technadyne Engineering Consultants Inc., Albuquerque, NM (United States)). pp. 868-873 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Two waste emplacement schemes, borehole and in-drift, are under evaluation as potential repository drift geometries for the Yucca Mountain Site Characterization Project. Calculations were performed to examine the systems implications of various thermal loadings on the near- and far-field repository environments. This paper reports the results of two-dimensional finite element analyses of the near-field thermal and structural response of the potential repository. Thermal calculations were run to 1000 years and mechanical calculations were run to 75 years, the time when the drifts will be backfilled. Local areal power densities (LAPDs) of 57, 80, and 100 kW/acre were used in the calculations. Both emplacement schemes meet current near-field thermal performance goals for all loadings examined. The mechanical calculations predict no intact rock failure, limited joint slippage around the drifts, and closure of apertures for vertical fractures above and below the drifts.

454 Influence of deterministic geologic trends on spatial variability of hydrologic properties in volcanic tuff. Rautman, C.A. (Sandia National Labs., Albuquerque, NM (United States)); Flint, A.L.; Chornack, M.P.; Istok, J.D.; Flint, L.E. pp. 921-929 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Hydrologic properties have been measured on outcrop samples taken from a detailed, two-dimensional grid covering a 1.4 km outcrop exposure of the 10-m thick nonwelded-to-welded, shardy base microstratigraphic unit of the Tiva Canyon Member of the Paintbrush Tuff of Miocene age at Yucca Mountain, Nevada. These data allow quantification of spatial trends in rock matrix properties that exist in this important hydrologic unit. Geologic investigation, combined with statistical and geostatistical analyses of the numerical data, indicates that spatial variability of matrix properties is related to deterministic geologic processes that operated throughout the region. Linear vertical trends in hydrologic properties are strongly developed in the shardy base microstratigraphic unit, and they are more accurately modeled using the concept of a thickness-normalized stratigraphic elevation within the unit, rather than absolute elevation. Hydrologic properties appear to be correlated over distances of 0.25 to 0.3 of the unit thickness after removing the deterministic vertical trend. The use of stratigraphic elevation allows scaling of identical trends by unit thickness, which may be of particular importance in a basal, topography-blanketing unit such as this one. Horizontal changes in hydrologic properties do not appear to form obvious trends within the limited lateral geographic extent of the ash-flow environment that was examined. Matrix properties appear to be correlated horizontally over distances between 100 and 400 m. The existence and quantitative description of these trends and patterns of vertical spatial continuity should increase confidence in models of hydrologic properties and groundwater flow in this area that may be constructed to support the design of a potential high-level nuclear waste repository at Yucca Mountain.

455 **Rock mass mechanical property estimation strategy for the Yucca Mountain Site Characterization Project.** Lin, M. (J.F.T. Agapito & Associates Inc., Grand Junction, CO (United States)); Brechtel, C.E.; Hardy, M.P.; Bauer, S.J. pp. 937-942 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Rock mass mechanical properties are required in the design of repository drifts and ramps to assess the impact of thermal loads from the heat-generating wastes on excavation performance and long-term structural stability. The ramps, exploratory drifts and repository excavations will intersect both welded and nonwelded tuffs with varying abundances of fractures, degree of welding and lithophyisal content. Rock mass mechanical properties are dependent on both intact rock properties and joint characteristics, and were derived from empirically based relationships of laboratory determined intact rock properties and rock mass quality indices (Q and RMR). Definition and verification of these empirical relationships is considered critical to the drift design methodology because planned thermomechanical testing in the Exploratory Studies Facility (ESF) is limited. Rock mass quality determinations may provide the only practical vehicle for assessment of the effects of variability in drift performance under thermal loads. This paper presents a method of estimating the rock mass properties for the welded and nonwelded tuffs based on currently available information on intact rock and joint characteristics at the Yucca Mountain site. Variability of the expected ground conditions at the potential repository horizon (the TSw2 thermomechanical unit) and in the Calico Hills nonwelded tuffs is accommodated by defining five rock mass quality categories in each unit based upon assumed and observed distributions of the data.

456 **Instrumentation requirements for the ESF thermomechanical experiments.** Pott, J. (Sandia National Labs., Albuquerque, NM (United States)); Brechtel, C.E. pp. 967-974 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

In situ thermomechanical experiments are planned as part of the Yucca Mountain Site Characterization Project that require instruments to measure stress and displacement at temperatures that exceed the typical specifications of existing geotechnical instruments. A high degree of instrument reliability will also be required to satisfy the objectives of the experiments, therefore a study was undertaken to identify areas where improvement in instrument performance was required. A preliminary list of instruments required for the experiments was developed, based on existing test planning and analysis. Projected temperature requirements were compared to specifications of existing instruments to identify instrumentation development needs. Different instrument technologies, not currently employed in geotechnical instrumentation, were reviewed to identify potential improvements of existing designs for the high temperature environment. Technologies with strong potentials to improve instrument performance with relatively high reliability include graphite fiber composite materials, fiber optics, and video imagery.

457 **Scale dependence of effective media properties.** Tidwell, V.C. (Sandia National Labs., Albuquerque, NM (United States)); VonDoemming, J.D.; Martinez, K. pp. 1059-1065 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

For problems where media properties are measured at one scale and applied at another, scaling laws or models must be used in order to define effective properties at the scale of interest. The accuracy of such models will play a critical role in predicting flow and transport through the Yucca Mountain Test Site given the sensitivity of these calculations to the input property fields. Therefore, a research program has been established to gain a fundamental understanding of how properties scale with the aim of developing and testing models that describe scaling behavior in a quantitative manner. Scaling of constitutive rock properties is investigated through physical experimentation involving the collection of suites of gas permeability data measured over a range of discrete scales. Also, various physical characteristics of property heterogeneity and the means by which the heterogeneity is measured and described are systematically investigated to evaluate their influence on scaling behavior. This paper summarizes the approach that is being taken toward this goal and presents the results of a scoping study that was conducted to evaluate the feasibility of the proposed research.

458 **A working definition of scenario and a method of scenario construction.** Barr, G.E. (Sandia National Laboratories, Albuquerque, NM (United States)); Dunn, E. pp. 1093-1098 of High Level Radioactive Waste Management:

Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The event-tree method of scenario construction has been chosen for the Yucca Mountain performance assessment. Its applicability and suitability to the problem are discussed and compared with those of the Nuclear Regulatory Commission (NRC) method. The event-tree method is appropriate for an incompletely characterized site, where there must be an evolving understanding, over time, of the processes at work, for a site that may require analysis of details in specific context, and when the scenario functions to guide site characterization. Anticipating the eventual requirement for using the NRC method, we show that the event-tree method can be translated to the NRC format after final scenario screening.

459 **Recent developments in stochastic modeling and upscaling of hydrologic properties in Tuff.** Rautman, C.A. (Sandia National Laboratories, Albuquerque, NM (United States)); Robey, T.H. pp. 1437-1445 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

A set of detailed geostatistical simulations of porosity has been produced for a layered stratigraphic sequence of welded and non-welded volcanic tuffs at Yucca Mountain, Nevada. The simulations are produced using a composite model of spatial continuity and they are highly conditioned to abundant drill hole (core) information. A set of derivative simulations of saturated hydraulic conductivity has been produced, in the absence of conditioning data, using a cross-variable relationship developed from similar data elsewhere. The detailed simulations reproduce both the major stratigraphic units and finer scale layering indicated by the drill hole data. These simulations have been scaled up several orders of magnitude to represent block-scale effective hydrologic properties suitable for use in numerical modeling of groundwater flow and transport. The upscaling process involves the reformulation of a previously reported method that iteratively adapts and initial arbitrary grid to 'homogenize' the detailed hydraulic properties contained within the adjusted cell limits and to minimize the size of cells in highly heterogeneous regions. Although the computation of the block-effective property involves simple numerical averaging, the blocks over which these averages are computed are relatively homogeneous, which reduces the numerical difficulties involved in averaging non-additive properties, such as permeability. The entire process of simulation and upscaling is rapid and computationally efficient compared with alternative techniques. It is thus suitable for the Monte Carlo evaluation of the uncertainty in site characterization as it affects the results of groundwater flow and transport calculations.

460 **Characterization of porosity in support of mechanical property analysis.** Price, R.H. (Sandia National Laboratories, Albuquerque, NM (United States)); Martin, R.J. III; Boyd, P.J. pp. 1847-1853 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The general applicability of laboratory data for engineering purposes is a prime concern for the design and licensing of a potential repository of high level nuclear waste at Yucca Mountain. In order for the results of experiments to be applicable to the repository scale, the data must be scaled to in situ size and conditions. Previous laboratory investigations of tuff have shown that porosity has a dominant, general effect on mechanical properties. As a result, it is very important for the interpretation of mechanical property data that porosity is measured on each sampled test. Porosity alone, however, does not address all of the issues important to mechanical behavior. Variability in size and distribution of pore space produces significantly different mechanical properties. A nondestructive technique for characterizing the internal structure of the sample prior to testing is being developed and the results are being analyzed. The information obtained from this technique can help in both qualitative and quantitative interpretation of test results.

461 **Small-scale behavior of single gravity-driven fingers in an initially dry fracture.** Nicholl, M.J. (Sandia National Laboratories, Albuquerque, NM (United States)); Glass, R.J.; Nguyen, H.A. pp. 2023-2032 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Gravity-driven infiltration instability under full-field conditions in initially dry, rough-walled analog fractures and natural fractures in volcanic tuff similar to that found at Yucca Mountain has been demonstrated. Experiments investigating the behavior of individual, gravity-driven fingers in an initially dry, rough-walled analog fracture are presented. Fingers were initiated from constant flow to a point source. Finger structure is described in detail; specific phenomena observed include: desaturation behind the finger-tip bifurcation, and formation of dendritic sub-fingers. Measurements were made of finger-tip velocity, finger width, and finger-tip length. Non-dimensional forms of the measured variables are analyzed relative to the independent parameters, flow rate and gravitational gradient.

462 **Modeling gravity-driven fingering in rough-walled fractures using modified percolation theory.** Glass, R.J. (Sandia National Laboratories, Albuquerque, NM (United States)). pp. 2042-2052 of High Level Radioactive Waste Management: Proceedings. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Pore scale invasion percolation theory is modified for imbibition of wetting fluids into fractures. The effects of gravity, local aperture field geometry, and local in-plane air/water interfacial curvature are included in the calculation of aperture filling potential which controls wetted structure growth within the fracture. The inclusion of gravity yields fingers oriented in the direction of the gravitational gradient. These fingers widen and tend to meander and branch more as the gravitational gradient decrease. In-plane interfacial curvature also greatly affects the wetted structure in both horizontal and non-horizontal fractures causing the formation of macroscopic wetting fronts. The modified percolation model is used

to simulate imbibition into an analogue rough-walled fracture where both fingering and horizontal imbibition experiments were previously conducted. Comparison of numerical and experimental results showed reasonably good agreement. This process oriented physical and numerical modeling is a necessary step toward including gravity-driven fingering in models of flow and transport through unsaturated, fractured rock, similar to that found at Yucca Mountain.

463 **Wetting front instability in an initially wet unsaturated fracture.** Nicholl, M.J. (Sandia National Laboratories, Albuquerque, NM (United States)); Glass, R.J.; Nguyen, H.A. pp. 2061-2070 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Experimental results exploring gravity-driven wetting from instability in a pre-wetted, rough-walled analog fractures such as those at Yucca Mountain are presented. Initial conditions considered include a uniform moisture field wetted to field capacity of the analog fracture and the structured moisture field created by unstable infiltration into an initially dry fracture. As in previous studies performed under dry initial conditions, instability was found to result both at the cessation of stable infiltration and at flux lower than the fracture capacity under gravitational driving force. Individual fingers were faster, narrower, longer, and more numerous than observed under dry initial conditions. Wetting fronts were found to follow existing wetted structure, providing a mechanism for rapid recharge and transport.

464 **Analyses of releases due to drilling at the potential Yucca Mountain repository.** Barnard, R.W. (Sandia National Labs., Albuquerque, NM (United States)). pp. 1292-1297 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Radionuclide releases due to drilling into the potential Yucca Mountain nuclear-waste repository have been evaluated as part of a recent total-system performance assessment. The probability that a drilling event intersects a waste package is a function of the sizes of the drill bit and the waste package, and the density of placement of the containers in the repository. The magnitude of the release is modeled as a random function that also depends on the amount of decay the radionuclides have undergone. Four cases have been analyzed, representing the combinations of two waste-package designs (small-capacity, thin-wall, vertically emplaced; and large-capacity, thick-wall, horizontally emplaced) and two repository layouts (lower thermal power dissipation, low waste-package placement density; and higher thermal power dissipation, high waste-package placement density). The results show a fairly pronounced dependence on waste-package design and slight dependence on repository layout. Given the assumptions in the model, releases from the larger containers are 4-5 times greater than from the smaller packages.

465 **Appropriateness of one-dimensional calculations for repository analysis.** Eaton, R.R. (Sandia National Labs., Albuquerque, NM (United States)). pp. 1492-1500 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

This paper brings into focus the result of numerous studies that have addressed issues associated with the validity of assumptions which are used to justify reducing the dimensionality of numerical calculations of water flow through Yucca Mountain, NV. It is shown that in many cases, one-dimensional modeling is more rigorous than previously assumed.

466 **Some results from the second iteration of total-system performance assessment for Yucca Mountain.** Wilson, M.L. (Sandia National Labs., Albuquerque, NM (United States)). pp. 1655-1662 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 DOE Contract AC04-94AL85000. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The second preliminary total-system performance assessment for the potential radioactive-waste-repository site at Yucca Mountain has recently been completed. This paper summarizes results for nominal aqueous and gaseous releases using the composite-porosity flow model. The results are found to be sensitive to the type of unsaturated-zone flow, to percolation flux and climate change, to saturated-zone dilution, to container-wetting processes and container-corrosion processes, to fuel-matrix alteration rate and radionuclide solubilities (especially for ^{237}Np), and to bulk permeability and retardation of gases ^{14}C. There are areas that should be given priority in the site-characterization program. Specific recommendations are given in the full report of the study.

467 **An updated fracture-flow model for total-system performance assessment of Yucca Mountain.** Gauthier, J.H. (SPECTRA Research Institute, Albuquerque, NM (United States)). pp. 1663-1670 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 DOE Contract AC04-94AL85000. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Improvements have been made to the fracture-flow model being used in the total-system performance assessment of a potential high-level radioactive waste repository at Yucca Mountain, Nevada. The "weeps model" now includes (1) weeps of varied sizes, (2) flow-pattern fluctuations caused by climate change, and (3) flow-pattern perturbations caused by repository heat generation. Comparison with the original weeps model indicates that allowing weeps of varied sizes substantially reduces the number of weeps and the number of containers contacted by weeps. However, flow-pattern perturbations caused by either climate change or repository heat generation greatly increases the number of containers contacted by weeps. In preliminary total-system calculations, using a phenomenological container-failure and radionuclide-release model, the weeps model predicts that radionuclide releases from a high-level radioactive waste repository at Yucca Mountain will be below the EPA standard specified in 40 CFR 191, but that the maximum radiation dose to an individual could be significant. Specific

data from the site are required to determine the validity of the weep-flow mechanism and to better determine the parameters to which the dose calculation is sensitive.

468 **Constraining local 3-D models of the saturated-zone, Yucca Mountain, Nevada.** Barr, G.E. (Sandia National Labs., Albuquerque, NM (United States)); Shannon, S.A. pp. 1814-1821 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A qualitative three-dimensional analysis of the saturated zone flow system was performed for a 8 km × 8 km region including the potential Yucca Mountain repository site. Certain recognized geologic features of unknown hydraulic properties were introduced to assess the general response of the flow field to these features. Two of these features, the Solitario Canyon fault and the proposed fault in Drill Hole Wash, appear to constrain flow and allow calibration.

469 **Modeling infiltration into a tuff matrix from a saturated vertical fracture.** Ho, C.K. (Sandia National Labs., Albuquerque, NM (United States)). pp. 1897-1904 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AC04-94AL85000. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The evaluation of Yucca Mountain as a potential high-level radioactive waste repository relies on predictive hydrologic models in unsaturated tuff surrounding the proposed site. Saturation profiles resulting from TOUGH2 numerical simulations of water infiltration into a tuff matrix from a saturated vertical fracture have been compared to experimental results. The purpose was to determine the sensitivity of the infiltration on local heterogeneities and different representations of two-phase characteristic curves used by the model. Findings indicate that the use of simplified (linearized) capillary pressure curves with rigorous (van Genuchten) relative permeability curves resulted in a more computationally efficient solution without a loss in accuracy. However, linearized forms of the relative permeability functions produced poor results, regardless of the form of the capillary pressure function. In addition, numerical simulations revealed that the presence of local heterogeneities in the tuff caused non-uniform saturation distributions and wetting fronts in the matrix.

470 **Fracture-matrix interaction in Topopah Spring Tuff: Experiment and numerical analysis.** Glass, R.J. (Sandia National Labs., Albuquerque, NM (United States)); Tidwell, V.C.; Flint, A.L.; Peplinski, W.; Castro, Y. pp. 1905-1914 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Fracture-matrix interaction is investigated through combined physical and numerical experimentation. Two slabs of Topopah Spring Tuff are mated to form a vertical saw cut fracture to which water is supplied. X-ray imaging is used to obtain the matrix porosity field and transient saturation fields as water moves from the fracture into the matrix. Porosity, hydraulic conductivity, and pressure/saturation relations of the matrix are measured on small cores taken from adjacent rock. Correlations between hydraulic properties and porosity are developed and modeled. Numerical simulations using TOUGH2 are accomplished with a series of property fields of increasing detail. Property fields are modeled using the measured porosity field divided into 1, 3, 5, 11, and 21 porosity groups with the hydraulic properties assigned from the developed correlations and the average porosity within each group. Comparison with experimental results allows us to begin to evaluate current matrix property measurement techniques, specific matrix property models, property estimation procedures, and effects of matrix property variability.

471 **Thermal and seismic impacts on the North Ramp at Yucca Mountain.** Lin, M. (J.F.T. Agapito & Associates, Inc., Grand Junction, CO (United States)); Hardy, M.P.; Jung, J. pp. 1971-1978 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The impacts of thermal and seismic loads on the stability of the Exploratory Studies Facility North Ramp at Yucca Mountain were assessed using both empirical and analytical approaches. This paper presents the methods and results of the analyses. Thermal loads were first calculated using the computer code STRES3D. This code calculates the conductive heat transfer through a semi-infinite elastic, isotropic, homogeneous solid and the resulting thermally-induced stresses. The calculated thermal loads, combined with simulated earthquake motion, were then modeled using UDEC and DYNA3D, numerical codes with dynamic simulation capabilities. The thermal- and seismic-induced yield zones were post-processed and presented for assessment of damage. Uncoupled bolt stress analysis was also conducted to evaluate the seismic impact on the ground support components.

472 **Mechanical and bulk properties in support of ESF design issues.** Price, R.H. (Sandia National Labs., Albuquerque, NM (United States)); Martin, R.J. III; Boyd, P.J.; Noel, J.S. pp. 1987-1992 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AC04-94AL85000. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

An intensive laboratory investigation is determining the mechanical properties of tuffs for the Yucca Mountain Site Characterization Project (YMP). Most recently, experiments have been performed on tuff samples from a series of drill holes along the proposed alignment of the Exploratory Study Facilities (ESF) north ramp. Unconfined compression and indirect tension experiments were performed and the results are being analyzed with the help of bulk property information. The results on samples from five of the drill holes are presented here. In general, the properties vary widely, but are highly dependent on the sample porosity.

473 **Construction monitoring activities in the ESF starter tunnel.** Pott, J. (Sandia National Labs., Albuquerque, NM (United States)); Carlisle, S. pp. 1993-1998 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American

Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AC04-94AL85000. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

In situ design verification activities are being conducted in the North Ramp Starter Tunnel of the Yucca Mountain Project Exploratory Studies Facility. These activities include: monitoring the peak particle velocities and evaluating the damage to the rock mass associated with construction blasting, assessing the rock mass quality surrounding the tunnel, monitoring the performance of the installed ground support, and monitoring the stability of the tunnel. In this paper, examples of the data that have been collected and preliminary conclusions from the data are presented.

474 **Wetting phase permeability in a partially saturated horizontal fracture.** Nicholl, M.J. (Sandia National Labs., Albuquerque, NM (United States)); Glass, R.J. pp. 2007-2019 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AC04-94AL85000. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Fractures within geologic media can dominate the hydraulic properties of the system. Therefore, conceptual models used to assess the potential for radio-nuclide migration in unsaturated fractured rock such as that composing Yucca Mountain, Nevada, must be consistent with flow processes in individual fractures. A major obstacle to the understanding and simulation of unsaturated fracture flow is the paucity of physical data on both fracture aperture structure and relative permeability. An experimental procedure is developed for collecting detailed data on aperture and phase structure from a transparent analog fracture. To facilitate understanding of basic processes and provide a basis for development of effective property models, the simplest possible rough-walled fracture is used. Stable phase structures of varying complexity are created within the horizontal analog fracture. Wetting phase permeability is measured under steady-state conditions. A process based model for wetting phase relative permeability is then explored. Contributions of the following processes to reduced wetting phase permeability under unsaturated conditions are considered: reduction in cross-sectional flow area, increased path length, localized flow restriction, and preferential occupation of large apertures by the non-wetting phase.

475 **Detailed characterization and preliminary adsorption model for materials for an intermediate-scale reactive-transport experiment.** Ward, D.B. (Univ. of New Mexico, Albuquerque, NM (United States)); Bryan, C.R.; Siegel, M.D. pp. 2048-2062 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AC04-94AL85000. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

An intermediate-scale transport-model experiment, involving the migration of fluid and tracers (Li, Br, Ni) through a 6-m-high × 3-m-diameter caisson filled with Wedron 510 sand, is being carried out for the Yucca Mountain Site Characterization Project. The surface chemistry of the sand has been studied and a preliminary surface-complexation model of Ni adsorption has been formulated for use in transport calculations. XPS and leaching studies suggest that the surface of the quartz sand is partially covered by thin layers of Fe-oxyhydroxide and Ca-Mg carbonate and by flakes of kaolinite. Ni adsorption by the sand is strongly pH-dependent, showing no adsorption at pH 5 and near-total adsorption at pH 7. Ni adsorption edges for goethite and quartz, two components of the sand were also measured. Ni adsorption on pure quartz is only moderately pH-dependent and differs in shape and location from that of the sand, whereas Ni adsorption by goethite is strongly pH-dependent. A triple-layer surface-complexation model developed for goethite provides a good fit to the Ni-adsorption curve of the sand. Based on this model, the apparent surface area of the Fe-oxyhydroxide coating is estimated to be ~560 m^2/g, compatible with its occurrence as amorphous Fe-oxyhydroxide. Potentiometric titrations on the sand also differ from those of pure quartz and suggest that the effective surface area of the sand may be significantly greater than that measured by N_2-BET gas adsorption. Attempts to model the adsorption characteristics of the bulk sand in terms of the properties of pure end member components suggest that much of the sand surface is inert. Although the exact mechanisms of Ni adsorption remain ambiguous, this preliminary adsorption model provides an initial set of parameters that can be used in transport calculations.

476 **Modeling a ponded infiltration experiment at Yucca Mountain, NV.** Hudson, D.B. (Foothill Engineering, Inc., Mercury, NV (United States)); Guertal, W.R.; Flint, A.L. pp. 2168-2174 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

One-dimensional and two-dimensional radial flow numerical models were used to evaluate the results for a 60.5 h ponded infiltration experiment done around a 24 m deep, 0.15 m diameter, cased borehole at Yucca Mountain, NV. Nine distinct morphological horizons in the soil profile has been identified; physical and hydraulic properties had been measured for each horizon; and a porosity profile at the borehole had been measured. During the infiltration experiment, 10 cm of water was ponded in a 3.5 m diameter infiltrometer around the borehole, the volume of water applied was measured, and water content profiles were measured with a neutron moisture meter. The infiltrometer applied 86.9 cm of water during the first 60.5 h of infiltration, but only 52.8 cm of additional water was measured in the borehole profiles. Assuming a linear relationship between cumulative infiltration (I) and the square root of time ($t^{0.5}$), an experimental sorptivity of 11.5 cm h^{-1} was estimated for the first 4.5 h of infiltration. An assumed washout zone around the borehole casing accounted for the discrepancy between the measured water content profiles and the applied water. A uniform property, 1-D model with an applied flux upper boundary described by the sorptivity confirmed the probable washout zone, and indicated that significant lateral flow into the dry soil around the infiltrometer could occur. A 2-D radial flow model with the same properties and upper boundary demonstrated that significant lateral flow occurred. The upper boundary in this model caused the upper portion of the profile to drain. This suggested using a saturated upper boundary to keep the upper portion of the profile saturated. When the saturated upper boundary was used, the permeability of the soil was decreased from the measured value of

3.28 E-11 m^2 to 1.5E-12 m^2 so that the simulated wetting front at a similar depth as the observed wetting front after 60.5 h.

477 Effect of fractures on repository dryout. Eaton, R.R. (Sandia National Labs., Albuquerque, NM (United States)). pp. 2442-2449 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Calculations of water flow through Yucca Mountain show significant dryout and water perching in the vicinity of the proposed nuclear waste repository. These calculations also show that the extent of the dryout and perched water zones is a strong function of the material characteristics which are used to represent the fracture zones. The results show that for 100 μm fracture case appreciable dryout and perched regions exist. When 1 μm fractures are used no dryout or perched regions are calculated.

478 Studies of non-isothermal flow in saturated and partially saturated porous media. Ho, C.K. (Sandia National Labs., Albuquerque, NM (United States)); Maki, K.S.; Glass, R.J. pp. 2481-2491 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Coupled thermal and hydrologic flow processes in unsaturated fractured rocks are important in the evaluation of Yucca Mountain as a potential repository for high level nuclear waste. Physical and numerical experiments have been performed to investigate the behavior of non-isothermal flow in two-dimensional saturated and partially saturated porous media. The physical experiments were performed to identify non-isothermal flow fields and temperature distributions in fully saturated, half-saturated, and residually saturated two-dimensional porous media with bottom heating and top cooling. Two counter-rotating liquid-phase convective cells were observed to develop in the saturated regions of all three cases. Gas-phase convection was also evidenced in the unsaturated regions of the partially saturated experiments. TOUGH2 numerical simulations of the saturated case were found to be strongly dependent on the assumed boundary conditions of the physical system. Models including heat losses through the boundaries of the test cell produced temperature and flow fields that were in better agreement with the observed temperature and flow fields than models that assumed insulated boundary conditions. A sensitivity analysis also showed that a reduction of the bulk permeability of the porous media in the numerical simulations depressed the effect of convection, flattening the temperature profiles across the test cell.

479 Scaling behavior of gas permeability measurements in volcanic tuffs. Tidwell, V.C. (Sandia National Labs., Albuquerque, NM (United States)). pp. 2500-2509 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AC04-94AL85000. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

One of the critical issues facing the Yucca Mountain site characterization and performance assessment programs is the manner in which property scaling is addressed. Property scaling becomes an issue whenever heterogeneous media properties are measured at one scale but applied at another. A research program has been established to challenge current understanding of property scaling with the aim of developing and testing models that describe scaling behavior in a quantitative manner. Scaling of constitutive rock properties is investigated through physical experimentation involving the collection of suites of gas-permeability data measured over a range of discrete scales. The approach is to systematically isolate those factors believed to influence property scaling and investigate their relative contributions to overall scaling behavior. Two blocks of tuff, each exhibiting differing heterogeneity structure, have recently been examined. Results of the investigation show very different scaling behavior, as exhibited by changes in the distribution functions and variograms, for the two tuff samples. Even for the relatively narrow range of measurement scales employed significant changes in the distribution functions, variograms, and summary statistics occurred. Because such data descriptors will likely play an important role in calculating effective media properties, these results demonstrate both the need to understand and accurately model scaling behavior.

480 Development of stochastic indicator models of lithology, Yucca Mountain, Nevada. Rautman, C.A. (Sandia National Labs., Albuquerque, NM (United States)); Robey, T.H. pp. 2510-2519 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AC04-94AL85000. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Indicator geostatistical techniques have been used to produce a number of fully three-dimensional stochastic simulations of large-scale lithologic categories at the Yucca Mountain site. Each realization reproduces the available drill hole data used to condition the simulation. Information is propagated away from each point of observation in accordance with a mathematical model of spatial continuity inferred through soft data taken from published geologic cross sections. Variations among the simulated models collectively represent uncertainty in the lithology at unsampled locations. These stochastic models succeed in capturing many major features of welded-nonwelded lithologic framework of Yucca Mountain. However, contacts between welded and nonwelded rock types for individual simulations appear more complex than suggested by field observation, and a number of probable numerical artifacts exist in these models. Many of the apparent discrepancies between the simulated models and the general geology of Yucca Mountain represent characterization uncertainty, and can be traced to the sparse site data used to condition the simulations. Several vertical stratigraphic columns have been extracted from the three-dimensional stochastic models for use in simplified total-system performance assessment exercises. Simple, manual adjustments are required to eliminate the more obvious simulation artifacts and to impose stratigraphic framework provided by the indicator models.

481 Modeling heterogeneous unsaturated porous media flow at Yucca Mountain. Robey, T.H. (Spectra Research Institute, Albuquerque, NM (United States)). pp. 2678-2684 of High Level Radioactive Waste Management:

Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Geologic systems are inherently heterogeneous and this heterogeneity can have a significant impact on unsaturated flow through porous media. Most previous efforts to model groundwater flow through Yucca Mountain have used stratigraphic units with homogeneous properties. However, modeling heterogeneous porous and fractured tuff in a more realistic manner requires numerical methods for generating heterogeneous simulations of the media, scaling of material properties from core scale to computational scale, and flow modeling that allows channeling. The Yucca Mountain test case of the INTRAVAL project is used to test the numerical approaches. Geostatistical methods are used to generate more realistic representations of the stratigraphic units and heterogeneity within units is generated using sampling from property distributions. Scaling problems are reduced using an adaptive grid that minimizes heterogeneity within each flow element. A flow code based on the dual mixed-finite-element method that allows for heterogeneity and channeling is employed. In the Yucca Mountain test case, the simulated volumetric water contents matched the measured values at drill hole USW UZ-16 except in the non-welded portion of Prow Pass.

482 **Paleoclimate validation of a numerical climate model.** Schelling, F.J. (Sandia National Labs., Las Vegas, NV (United States)); Church, H.W.; Zak, B.D.; Thompson, S.L. pp. 2746-2749 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

An analysis planned to validate regional climate model results for a past climate state at Yucca Mountain, Nevada, against paleoclimate evidence for the period is described. This analysis, which will use the GENESIS model of global climate nested with the RegCM2 regional climate nested with the RegCM2 regional climate model, is part of a larger study for DOE's Yucca Mountain Site Characterization Project that is evaluating the impacts of long term future climate change on performance of the potential high level nuclear waste repository at Yucca Mountain. The planned analysis and anticipated results are presented.

483 **Assessing alternative conceptual models of fracture flow.** Ho, C.K. (Sandia National Lab., Albuquerque, NM (United States)); Wilson, M.L. pp. 17-19 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Liquid- and vapor-phase flow in fractures are important processes that may impact several potential performance aspects of Yucca Mountain including groundwater travel time and the migration of water and radionuclides around a hot waste package. As a result, conceptual and mathematical models of multiphase flow in fractures are needed to predict the behavior and performance of the potential repository. However, modeling flow in fractured rock is very complex due to the significant heterogeneities and uncertainties that exist in the fracture network. As a result, simplified conceptual models of fracture flow are often used to represent flow through fractures and its interaction with the rock matrix. Understanding the capabilities, strengths, and weaknesses of these conceptual models relative to the actual flow processes is the focus of this work. Three conceptual models of fracture flow are addressed and compared in this paper. They include the equivalent-continuum (for composite-porosity) model, the dual-porosity model, and the dual-permeability model. Sketches of the representative domains for each model are shown in Figure 1, along with a discrete-fracture model. The discrete fracture model, while most rigorous, is also the most complex of the conceptual models of fracture flow. Multiphase analysis capabilities for discrete-fracture models are currently very limited.

484 **Effective media models for unsaturated fractured rock: A field experiment.** Nicholl, M.J. (Sandia National Lab., Albuquerque, NM (United States)); Glass, R.J. pp. 39-40 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AC04-94AL85000. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

A thick unsaturated rock mass at Yucca Mountain is currently under consideration as a potential repository site for disposal of high level radioactive waste. In accordance with standard industry and scientific practices, abstract numerical models will be used to evaluate the potential for radionuclide release through the groundwater system. At this time, currently available conceptual models used to develop effective media properties are based primarily on simplistic considerations. The work presented here is part of an integrated effort to develop effective media models at the intermediate block scale (approximately 8-125m) through a combination of physical observations, numerical simulations and theoretical considerations. A multi-purpose field experiment designed and conducted as part of this integrated effort is described. Specific goals of this experimental investigation were to: (1) obtain fracture network data from Topopah Spring Tuff for use in block scale simulations; (2) identity positions of the network conducting flow under three different boundary conditions; (3) visualize preferential flow paths and small-scale flow structures; (4) collect samples for subsequent hydraulic testing and use in block-scale simulations; and (5) demonstrate the ability of Electrical Resistance Tomography (ERT) to delineate fluid distribution within fractured rock.

485 **Ventilation and vapor-phase transport near the ESF tunnel.** Ho, C.K. (Sandia National Lab., Albuquerque, NM (United States)); Dunn, E.; Sobolik, S.R. pp. 50-52 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Ventilation and vapor-phase transport processes have been investigated to determine the potential drying effects of the Exploratory Studies Facility (ESF) tunnel on the surrounding Topopah Springs welded unit (TSw2) at Yucca Mountain. Previous studies simulated the ventilation process near the ESF tunnel for 100 years using the single-phase flow code NORIA-SP. Kelvin's equation was used in those

studies to relate the relative humidity at the tunnel wall (assumed to be 90%) to a capillary pressure, which was then used as a boundary condition for the ventilation simulations. Thus, the 'drying' of the surrounding rock was actually a capillary-driven liquid imbibition process to the tunnel walls. The result was that significant amounts of water were removed from the rock surrounding the ESF tunnel. In this study, a more physically realistic model that includes vapor-phase transport is used for the ventilation process. The model produced qualitatively similar results to the single-phase flow model.

486 Numerical and physical testing of upscaling techniques for constitutive properties. McKenna, S.A. (Sandia National Lab., Albuquerque, MN (United States)); Tidwell, V.C. pp. 67-68 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This paper evaluates upscaling techniques for hydraulic conductivity measurements based on accuracy and practicality for implementation in evaluating the performance of the potential repository at Yucca Mountain. Analytical and numerical techniques are compared to one another, to the results of physical upscaling experiments, and to the results obtained on the original domain. The results from different scaling techniques are then compared to the case where unscaled point scale statistics are used to generate realizations directly at the flow model grid-block scale. Initital results indicate that analytical techniques provide upscaling constitutive properties from the point measurement scale to the flow model grid-block scale. However, no single analytic technique proves to be adequate for all situations. Numerical techniques are also accurate, but they are time intensive and their accuracy is dependent on knowledge of the local flow regime at every grid-block.

487 Modeling spatial heterogeneity of thermal conductivity using a surrogate property. Rautman, C.A. (Sandia National Lab., Albuquerque, NM (United States)). pp. 83-84 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AC04-94AL85000. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Design of potential high-level nuclear waste repository at Yucca Mountain, Nevada, requires modeling of the thermal response of the geologic system to imposed heat loads. Predicting the thermal profiles produced by alternate design configurations requires input models of thermal and bulk properties. We have used geostatistical techniques to create geologically reasonable, two-dimensional models of thermal conductivity from surrogate, measured porosity data obtained from several drill holes and multiple regression relationships among porosity, saturation level, initial temperature and thermal conductivity. The resulting models of thermal conductivity and bulk density appear to be reasonable numerical representations of the layered sequence of welded and nonwelded tuffs. Successful comparison of the resulting thermal profiles against independently generated thermal profiles modeled directly from averaged thermal conductivity data appears to justify the use of porosity data as a surrogate for spatially limited thermal conductivity measurements.

488 Particle tracking for unsaturated-zone groundwater travel time analysis at Yucca Mountain. Arnold, B.W. (Sandia National Lab., Albuquerque, NM (United States)); Skinner, L.H.; Zieman, N.B. pp. 107-109 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

A particle tracking code developed to link numerical modeling of groundwater flow in the unsaturated zone to the analysis of groundwater travel times was used to produce preliminary estimates of the distribution of groundwater-travel time from a potential repository at Yucca Mountain, Nevada to the water table. Compliance with 10CFR960 requires the demonstration that pre-waste-emplacement groundwater travel time from the disturbed zone to the accessible environment is expected to exceed 1,000 years along any path of likely and significant radionuclide travel. The use of multiple particles and multiple realizations of the geology and parameter distributions in the unsaturated zone allows a probabilistic analysis of groundwater travel times that may be applied for evaluating compliance.

489 Unsaturated-zone fast-path flow calculations for Yucca Mountain GWTT analyses. Barnard, R.W. (Sandia National Lab., Albuquerque, NM (United States)); Brown, T.J.; Altman, S.J. pp. 220-222 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Sandia National Laboratories has developed calculational tools and modeling domains for groundwater-flow analyses; these tools are being used for evaluation of the Postclosure Geohydrology guideline in 10 CFR 960 [with emphasis on the Groundwater Travel Time (GWTT) disqualifying condition] for a potential nuclear waste repository at Yucca Mountain, NV. The emphasis of this work is on investigations of hydrologic processes and hydrogeologic features that may produce fast-path flow in the unsaturated zone (UZ) at Yucca Mountain. Based on the current understanding, conceptual models for UZ flow at Yucca Mountain generally assume that flow in fractures will be the mechanism for fastest water movement, and thus for fastest contaminant transport. The models used for these analyses require saturated conditions in the rock before UZ fracture flow can be initiated and sustained. This work investigates the initiation of fracture flow due to the creation of locally saturated zones in the unsaturated Yucca Mountain tuffs caused by natural heterogeneities in the rock units. For this purpose, we have developed model domain, using the composite-porosity flow model, where local saturation can be achieved without arbitrarily introducing saturated boundary conditions.

490 Preliminary sensitivity studies of fast-path flow on a cross-section of Yucca Mountain, Nevada. Altman, S.J. (Sandia National Lab., Albuquerque, NM (United States)); Arnold, B.W.; Brown, T.J. pp. 223-225 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La

Grange Park, IL (United States) (1995). pp. 811 DOE Contract AC04-94AL85000. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

One criterion of 10CFR960 used to determine suitability of Yucca Mountain, NV as a potential nuclear waste repository site is that the groundwater travel time (GWTT) from the repository to the accessible environment must exceed 1,000 years along the fastest path of likely and significant radionuclide travel. Sandia National Laboratories has developed modeling tools in order to evaluate fast-path flow and the time it takes a particle to travel from the repository to the saturated zone. The analyses reported to date represent only a portion of a complete GWTT evaluation, since they only consider potential fast-path flow through the unsaturated zone. In addition to the above mentioned work, sensitivity analyses on a numerical flow model assist in evaluating GWTT. This study focuses on understanding the importance of intra-formation heterogeneities and the effects of the geostatistically versus deterministically determined unit thickness on an unsaturated flow system. Preliminary sensitivity analyses were conducted on a cross-section of Yucca Mountain. Results show that the system with intra-unit heterogeneities may serve as a conservative estimator of fast-path flow GWTT because of the higher saturations which lead to greater fluxes than the system with homogeneous units.

491 **TOUGH2 model of the G-tunnel heater test.** Ho, C.K. (Sandia National Lab., Albuquerque, NM (United States)); Eaton, R.R. pp. 331-333 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

An experiment designed to observe water migration under non-isothermal conditions in welded tuff was performed in 1980 in the welded portion of the Grouse Canyon Member in the U12g tunnel (G-tunnel) at Rainier Mesa. Significant amounts of water were observed to migrate towards a heated hole bored into the welded tuff. The water migration was attributed to vapor phase diffusion, but other processes such as gravity driven flow were not considered and may have contributed significantly to the observed water migration. The modeling studies presented here address processes of water migration near heated regions in partially saturated tuff. The multiphase, non-isothermal numerical code TOUGH2 was used to model the G-Tunnel heater experiment. The numerical simulation consisted of 10 days of heating at 1000 W. Temperatures, liquid saturations, gas pressures, gas and liquid velocities, and vapor mass fractions were recorded to determine the processes affecting water migration. Results of the simulation indicated that water migration near heated tuffaceous rock involves a combination of processes. Gas-phase advection and diffusion transported water vapor that was evaporated near the heater toward outer regions. Water vapor condensed in cooler regions away from the heater, increasing the saturations. As liquid water accumulated in the heater borehole, capillary suction pulled some of the liquid toward the drier heated region while gravity drained some of the liquid away from the heater. In natural systems, high permeability fractures could mimic the role of the heater hole.

492 **Use of geostatistical modeling to capture complex geology in finite-element analyses.** Rautman, C.A. (Sandia National Lab., Albuquerque, NM (United States)); Longenbaugh, R.S.; Ryder, E.E. pp. 352-354 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This paper summarizes a number of transient thermal analyses performed for a representative two-dimensional cross section of volcanic tuffs at Yucca Mountain using the finite element, nonlinear heat-conduction code COYOTE-II. In addition to conventional design analyses, in which material properties are formulated as a uniform single material and as horizontally layered, internally uniform matters, an attempt was made to increase the resemblance of the thermal property field to the actual geology by creating two fairly complex, geologically realistic models. The first model was created by digitizing an existing two-dimensional geologic cross section of Yucca Mountain. The second model was created using conditional geostatistical simulation. Direct mapping of geostatistically generated material property fields onto finite element computational meshes was demonstrated to yield temperature fields approximately equivalent to those generated through more conventional procedures. However, the ability to use the geostatistical models offers a means of simplifying the physical-process analyses.

493 **Proposed models of colloid-facilitated transport for total-system performance assessment.** Gauthier, J.H. (SPECTRA Research Institute, Albuquerque, NM (United States)). pp. 448-450 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AC04-94AL85000. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

In calculations of total-system performance assessment (TSPA) for Yucca Mountain, radionuclide transport in groundwater is modeled simply as solute undergoing advection, dispersion, and retardation. Some actinides (e.g., plutonium and americium), sorb so strongly to tuffs that solute transport is virtually nil. Evidence from field tests and laboratory experiments suggests that colloids can facilitate transport of highly sorbing actinides, causing migration over time scales much shorter than TSPA models predict. Colloids appear to be ubiquitous in natural groundwater systems, and they have been found in waters around Yucca Mountain. Colloids are also expected to be formed by corrosion of the engineered barrier system and the deterioration of the spent fuel itself. The purpose of this paper is to present some ideas to the geochemistry community on how colloid-facilitated transport can be modeled for TSPA of Yucca Mountain; because this work is in the initial stages, calculations have not yet been performed. Two models are presented that could be used to describe colloid-facilitated transport, one for reversible sorption and the other for irreversible sorption.

494 (DOE/ER/14352--1, pp. 443-446) **Construction monitoring activities in the Yucca Mountain ESF Starter Tunnel.** Pott, J. (Sandia National Labs., Albuquerque, NM (United States)); Costin, L.S.; Brechtel, C.E. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644--Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the*

1990s: Proceedings: Volume 2. 396p. Order Number DE94014602. Source: OSTI; NTIS.

An underground test facility known as the Exploratory Studies Facility (ESF) is planned as part of the characterization of a site for a potential high-level nuclear waste repository at Yucca Mountain, NV. The first part of the ESF that will be constructed is the North Ramp Starter Tunnel (NRST), which will provide a facility for launching the tunnel-boring machine to be used in the construction of the ESF. Geotechnical monitoring activities are planned for the NRST to provide for the collection of data to confirm design concepts and to enhance safety during construction. This paper describes the activities to be conducted and their objectives. The construction monitoring activities are part of a study defined in the In Situ Design Verification Study Plan. The objectives of this study are to (1) monitor and observe the long-term behavior of openings in a range of ground conditions in the repository host rock, and (2) to observe and evaluate the construction of the ESF with respect to implications for repository construction and performance. Initiating geotechnical monitoring activities in the NRST will allow geotechnical data required to confirm adequate design, construction and long term performance to be collected from the very beginning of underground construction. In addition, the planned monitoring is consistent with standard practice for assuring quality and safety during similar rock excavation for civil construction. The geotechnical monitoring activities addressed by this experiment plan are grouped into three tasks: (1) evaluation of mining methods, (2) monitoring of ground support systems and (3) monitoring drift stability. A general description of each of the tasks is presented below.

495 (DOE/ER/14352–1, pp. 451-454) **Thermal-mechanical analyses for the Yucca Mountain Project.** Jung, J. (Sandia National Labs., Albuquerque, NM (United States)); Ryder, E.E. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

As part of Sandia National Laboratories' (SNL) work in support of the Yucca Mountain Site Characterization Project (YMP), thermal-mechanical analyses are being performed that assist in the design, operations and waste retrieval planning, and performance assessment. In the design area, thermal-mechanical analyses help address safety issues by providing insight into the stability of openings and the related ground support requirements. Also, these analyses help establish thermal design goals for the potential repository. Operationally, predictions of the thermal environment form part of the necessary input for designing the ventilation systems for both emplacement and retrieval operations. In the area of performance assessment, thermal-mechanical models assist in estimating the potential of transporting radionuclides from waste packages. This paper is intended to provide an overview of the thermal-mechanical efforts as SNL in support of the Yucca Mountain Site Characterization Project.

496 (DOE/ER/14352–1, pp. 455-458) **An overview of the Yucca Mountain Site Characterization Project field test program for evaluating seal performance.** Fernandez, J.A. (Sandia National Labs., Albuquerque, NM (United States)); Case, J.B. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

Sandia National Laboratories (SNL), a participant in the Yucca Mountain Site Characterization Project, is responsible for implementing the repository sealing program. One aspect of this program is the definition and fielding of tests related to sealing components which comprise the sealing subsystem. The sealing components are identified in the Site Characterization Plan (U.S. DOE, 1988) and Fernandez et al. (1987). These include an anchor-to-bedrock plug, single dams (or single bulkheads with not settlement), general shaft fill, drift backfill, station and shaft plugs, double bulkheads, backfilled sumps, and channels in a backfilled room. The materials used to create these components are cementitious and earthen. Earthen materials will be used for as many applications as possible to minimize potential degradation of physical properties and potential adverse effects on ground-water chemistry in the repository environment. In places where low strength is acceptable, earthen materials may be used. The most likely application for cementitious materials is where high strength and low deformability may be required. (Hinkebein and Fernandez, 1989). The basis for performing seal component testing is divided into two parts: regulatory requirements and technical requirements. The regulatory requirements are derived primarily from Title 10 Code of Federal Regulations, Part 60 (10 CFR 60) (U.S. Nuclear Regulatory Commission, 1986). The technical requirements are defined by the uncertainties associated with seal performance and seal emplacement. Both categories of requirements are discussed below.

497 (DOE/ER/14352–1, pp. 685-688) **Hydromechanical response of a fracture undergoing compression and shear.** Olsson, W.A. (Sandia National Labs., Albuquerque, NM (United States)); Brown, S.R. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

Coupled fluid flow-rock deformation processes can be important in several geotechnical and natural phenomena. Water may flow through rock joints or faults into mined openings or around dams, stress sensitive fractures may affect hydrocarbon reservoir management, or radionuclides may migrate along joints away from underground nuclear waste repositories. The effect of normal stress and closure on fracture flow rates has been much studied. The effect of slip on fracture flow has been estimated theoretically, but there has been little experimental work done on this effect. Olsson combined the rotary shear test with the radial flow geometry to study the effect of joint shear on fracture flow rates for a sawed and ground surface in tuff. In this study, we extend this work to the study of a natural fracture from drill core. We evaluate the effects of normal stress and shear offset on fluid flow rates with predictions from a microscopic theory of surface contact constrained by surface roughness measurements.

498 (DOE/ER/14352–1, pp. 753-756) **The influence of strain rate and sample inhomogeneity on the moduli and strength of welded tuff.** Martin, R.J. III (New England Research, Inc., White River Junction, VT (United States)); Boyd, P.J.; Noel, J.S.; Price, R.H. Wisconsin Univ., Madison, WI (United States). 1993. DOE Contract AC04-76DP00789.

(CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

The strength of brittle rock is not a single values function of confining pressure and temperature. Strength is, in fact, a rather ambiguous term and depends on many parameters such as the loading conditions (in particular, rate), the effective pressure, composition of the pore fluid, the distribution of cracks and heterogeneities within the rock, and the scale of the sample under consideration. It is well known that brittle rocks are strongly influenced by the moisture content in the pore space. Water facilitates stress corrosion at the tips of micro-cracks under load. The effect of stress corrosion cracking in brittle rocks is to reduce the strength with increasing partial pressure of water, increasing temperature, and decreasing loading rate. In most cases, it is difficult to document the partial pressure of water within the pore space. Complete water saturation provides the most unambiguous condition. In light of the significance of environmental parameters and strain rate on the strength of rocks, it is important that the functional relation between each of these properties be considered when incorporated into models for the potential nuclear waste repository at Yucca Mountain, Nevada. This report address the effect of strain rate and heterogeneity of the strength and moduli of fully saturated tuff specimens from the potential repository horizon at Yucca Mountain.

499 (SAND–91-1653) **Scenarios constructed for basaltic igneous activity at Yucca Mountain and vicinity: Yucca Mountain Site Characterization Project.** Barr, G.E. (Sandia National Labs., Albuquerque, NM (United States)); Dunn, E.; Dockery, H.; Barnard, R.; Valentine, G.; Crowe, B. Sandia National Labs., Albuquerque, NM (United States). Aug 1993. 186p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94001779. Source: OSTI; NTIS; INIS; GPO Dep.

Basaltic volcanism has been identified as a possible future event initiating a release of radionuclides from a potential repository at the proposed Yucca Mountain high-level waste repository site. The performance assessment method set forth in the Site Characterization Plan (DOE, 1988) requires that a set of scenarios encompassing all significant radionuclide release paths to the accessible environment be described. This report attempts to catalogue the details of the interactions between the features and processes produced by basaltic volcanism in the presence of the presumed groundwater flow system and a repository structure, the engineered barrier system (EBS), and waste. This catalogue is developed in the form of scenarios. We define a scenario as a well-posed problem, starting from an initiating event or process and proceeding through a logically connected and physically possible combination or sequence of features, events, and processes (FEPs) to the release of contaminants.

500 (SAND–92-0119) **An experimental comparison of laboratory techniques in determining bulk properties of tuffaceous rocks: Yucca Mountain Site Characterization Project.** Boyd, P.J. (New England Research, Inc., White River Junction, VT (United States)); Martin, R.J. III; Price, R.H. Sandia National Labs., Albuquerque, NM (United States). Apr 1994. 53p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94011000. Source: OSTI; NTIS; INIS; GPO Dep.

Samples of tuffaceous rock were studied as part of the site characterization for a potential nuclear waste repository at Yucca Mountain in southern Nevada. These efforts were scoping in nature, and their results, along with those of other investigations, are being used to develop suitable procedures for determining bulk properties of tuffaceous rock in support of thermal and mechanical properties evaluations. Comparisons were made between various sample preparation, handling, and measurement techniques for both zeolitized and nonzeolitized tuff in order to assess their effects on bulk property determinations. Laboratory tests included extensive drying regimes to evaluate dehydration behavior, the acquisition of data derived from both gas and water pycnometers to compare their suitability in determining grain densities, a comparison of particle size effects, and a set of experiments to evaluate whole core saturation methods. The results affirm the added complexity of these types of measurements where there is a zeolite component in the sample mineralogy. Absolute values for the bulk properties of zeolitized tuff are immeasurable due to the complex nature of their dehydration behavior. However, the results of the techniques that were investigated provide a basis for the development of preferred, consistent methods for determining the grain density, dry and saturated bulk densities, and porosity of tuffaceous rock, including zeolitic tuff in support of thermal and mechanical properties evaluations.

501 (SAND–92-0449) **Fracture analysis and rock quality designation estimation for the Yucca Mountain Site Characterization Project: Yucca Mountain Site Characterization Project.** Lin, M. (Agapito (J.F.T.) and Associates, Inc., Grand Junction, CO (United States)); Hardy, M.P.; Bauer, S.J. Sandia National Labs., Albuquerque, NM (United States). Feb 1993. 127p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-76DP00789. Order Number DE94008700. Source: OSTI; NTIS; INIS; GPO Dep.

Within the Yucca Mountain Site Characterization Project, the design of drifts and ramps and evaluation of the impacts of thermomechanical loading of the host rock requires definition of the rock mass mechanical properties. Ramps and exploratory drifts will intersect both welded and nonwelded tuffs with varying abundance of fractures. The rock mass mechanical properties are dependent on the intact rock properties and the fracture joint characteristics. An understanding of the effects of fractures on the mechanical properties of the rock mass begins with a detailed description of the fracture spatial location and abundance, and includes a description of their physical characteristics. This report presents a description of the abundance, orientation, and physical characteristics of fractures and the Rock Quality Designation in the thermomechanical stratigraphic units at the Yucca Mountain site. Data was reviewed from existing sources and used to develop descriptions for each unit. The product of this report is a data set of the best available information on the fracture characteristics.

502 (SAND–92-0847) **The effect of frequency on Young's modulus and seismic wave attenuation.** Price, R.H. (Sandia National Labs., Albuquerque, NM (United States). YMP Performance Assessment Applications Dept.); Martin, R.J. III; Haupt, R.W. Sandia National Labs., Albuquerque, NM (United States). Jul 1994. 57p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94017498. Source: OSTI; NTIS; INIS; GPO Dep.

Laboratory experiments were performed to measure the effect of frequency, water-saturation, and strain amplitude on Young's modulus and seismic wave attenuation on rock cores recovered on or near the site of a potential nuclear waste repository at Yucca Mountain, Nevada. The purpose of this investigation is to perform the measurements using four techniques: cyclic loading, waveform inversion, resonant bar, and ultrasonic velocity. The measurements ranged in frequency between 10^{-2} and 10^{6} Hz. For the dry specimens Young's modulus and attenuation were independent of frequency; that is, all four techniques yielded nearly the same values for modulus and attenuation. For saturated specimens, a frequency dependence for both Young's modulus and attenuation was observed. In general, saturation reduced Young's modulus and increased seismic wave attenuation. The effect of strain amplitude on Young's modulus and attenuation was measured using the cyclic loading technique at a frequency of 10^{-1} Hz. The effect of strain amplitude in all cases was small. For some rocks, such as the potential repository horizon of the Topopah Spring Member tuff (TSw2), the effect of strain amplitude on both attenuation and modulus was minimal.

503 (SAND–92-2186) **Scenarios constructed for nominal flow in the presence of a repository at Yucca Mountain and vicinity.** Barr, G.E. (Sandia National Labs., Albuquerque, NM (United States)); Hunter, R.L.; Dunn, E.; Flint, A. Sandia National Labs., Albuquerque, NM (United States). Mar 1995. 218p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95009315. Source: OSTI; NTIS; INIS; GPO Dep.

Scenario development for the system performance assessment of the Yucca Mountain Site Characterization Project defines a scenario as a well-posed problem connecting an initiating event with radionuclide release to the accessible environment by a logical and physically possible combination or sequence of features, events, and processes. Drawing on the advice and assistance of the Project's principal investigators (PIs), a collection of release scenarios initiated by the nominal ground-water flow occurring in the vicinity of the potential Yucca Mountain high-level-waste repository is developed and described in pictorial form. This collection of scenarios is intended to provide a framework to assist PIs in recognizing essential field and calculational analyses, to assist performance assessment in providing guidance to site characterization, and to continue the effort to exhaustively identify all features, events, and processes important to releases. It represents a step in the iterative process of identifying what details of the potential site are important for safe disposal. 67 refs.

504 (SAND–92-2248) **Estimations of the extent of migration of surficially applied water for various surface conditions near the potential repository perimeter: Yucca Mountain Site Characterization Project.** Sobolik, S.R.; Fewell, M.E. Sandia National Labs., Albuquerque, NM (United States). Dec 1993. 105p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94006117. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project is studying Yucca Mountain in southwestern Nevada as a potential site for a high-level nuclear waste repository. Site characterization includes surface-based and underground testing. Analyses have been performed to support the design of site characterization activities so to have minimal impact on the ability of the site to isolate waste, and on tests performed as part of the characterization process. Two examples of site characterization activities are the construction of an Exploratory Studies Facility, which may include underground shafts, drifts, and ramps, and surface-based testing activities, which may require borehole drilling, excavation of test pits, and road watering for dust control. The information in this report pertains to two-dimensional numerical calculations modeling the movement of surficially applied water and the potential effects of that water on repository performance and underground experiments. This document contains information that has been used in preparing recommendations for two Yucca Mountain Site Characterization Project documents: Appendix I of the Exploratory Studies Facility Design Requirements document, and the Surface-Based Testing Field Requirements Document.

505 (SAND–92-2333) **The effect of sliding velocity on the mechanical response of an artificial joint in Topopah Spring Member tuff: Yucca Mountain Site Characterization Project.** Olsson, W.A. Sandia National Labs., Albuquerque, NM (United States). Apr 1994. 25p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94009248. Source: OSTI; NTIS; INIS; GPO Dep.

A smooth artificial joint in Topopah Spring Member tuff was sheared at constant normal stress at velocities from 0 to 100 μm/s to determine the velocity-dependence of shear strength. Two different initial conditions were used: (1) unprimed – the joint had been shear stress-free since last application of normal stress, and before renewed shear loading; and (2) primed – the joint had undergone a slip history after application of normal stress, but before the current shear loading. Observed steady-state rate effects were found to be about 3 times lager than for some other silicate rocks. These different initial conditions affected the character of the stress-slip curve immediately after the onset of slip. Priming the joint causes a peak in the stress-slip response followed by a transient decay to the steady-state stress, i.e., slip weakening. Slide-hold-slide tests exhibit time-dependent strengthening. When the joint was subjected to constant shear stress, no slip was observed; that is, joint creep did not occur. One set of rate data was collected from a surface submerged in tap water, the friction was higher for this surface, but the rate sensitivity was the same as that for surfaces tested in the air-dry condition.

506 (SAND–92-2625) **A computational model for three-dimensional jointed media with a single joint set: Yucca Mountain Site Characterization Project.** Koteras, J.R. Sandia National Labs., Albuquerque, NM (United States). Feb 1994. 49p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94007582. Source: OSTI; NTIS; INIS; GPO Dep.

This report describes a three-dimensional model for jointed rock or other media with a single set of joints. The joint set consists of evenly spaced joint planes. The normal joint response is nonlinear elastic and is based on a rational polynomial. Joint shear stress is treated as being linear elastic in the shear stress versus slip displacement before attaining a critical stress level governed by a Mohr-Coulomb faction criterion. The three-dimensional model represents an extension of a two-dimensional, multi-joint model that has been in use for several years. Although most of the concepts in the two-dimensional model translate in a straightforward manner to three dimensions, the concept of

slip on the joint planes becomes more complex in three dimensions. While slip in two dimensions can be treated as a scalar quantity, it must be treated as a vector in the joint plane in three dimensions. For the three-dimensional model proposed here, the slip direction is assumed to be the direction of maximum principal strain in the joint plane. Five test problems are presented to verify the correctness of the computational implementation of the model.

507 (SAND–93-0817C) **Using an Augmented Lagrangian Method and block fracturing in the DDA method.** Lin, C.T. (Colorado Univ., Boulder, CO (United States). Dept. of Civil Engineering); Amadei, B.; Sture, S.; Jung, J. Sandia National Labs., Albuquerque, NM (United States). [1994]. 6p. Sponsored by USDOE, Washington, DC (United States);National Science Foundation, Washington, DC (United States). DOE Contract AC04-76DP00789. Grant MS-9215397. (CONF-940506–3: 8. international conference on computer methods and advances in geomechanics, Morgantown, WV (United States), 22-28 May 1994). Order Number DE94005270. Source: OSTI; NTIS; INIS; GPO Dep.

This paper presents two extensions to the Discontinuous Deformation Analysis (DDA) method orginally proposed by Shi for modeling the response of blocky rock masses to mechanical loading. The first extension consists of improving the block contact algorithm. An Augmented Lagrangian Method is used to replace the Penalty Method orginally proposed. It allows Lagrange multipliers to be introduced without increasing the number of equations that need to be solved and thus, block contract forces can be calculated more accurately. A block fracturing capability based on a three-parameter Mohr-Coulomb criterion represents the second extension. It allows for shear or tensile fracturing of intact blocks and the formation of smaller blocks.

508 (SAND–93-0852) **The appropriateness of one-dimensional Yucca Mountain hydrologic calculations: Yucca Mountain Site Characterization Project.** Eaton, R.R. Sandia National Labs., Albuquerque, NM (United States). Jul 1993. 51p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94003314. Source: OSTI; NTIS; INIS; GPO Dep.

This report brings into focus the results of numerous studies that have addressed issues associated with the validity of assumptions which are used to justify reducing the dimensionality of numerical calculations of water flow through Yucca Mountain, NV. It is shown that, in many cases, one-dimensional modeling is more rigorous than previously assumed.

509 (SAND–93-1157) **Geometric moire method of strain analysis with displacement discontinuities: Yucca Mountain Site Characterization Project.** Brown, S.R. (Sandia National Labs., Albuquerque, NM (United States). Geomechanics Dept.); Hardy, R.D. Sandia National Labs., Albuquerque, NM (United States). Aug 1994. 57p. Sponsored by USDOE, Washington, DC (United States);Department of Defense, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95001114. Source: OSTI; NTIS; INIS; GPO Dep.

Prediction of the deformation behavior of large engineering structures in jointed rock under a specified loading history requires the extensive use of numerical simulation. For example, the evaluation of the stability of the openings for the Exploratory Studies Facility and a potential repository for high-level nuclear waste at Yucca Mountain, Nevada will require computer codes capable of predicting slip on rock joints resulting from changes in thermal stresses. The testing and ultimate validation of these complex finite element computer codes is an important step in their development before their use as a design tool for an engineering structure or for the study of some other practical problem. While field tests may be ultimately necessary, the authors propose a different and more thorough approach where early tests are done on a bench scale with easily characterized materials and geometries. For these bench-scale tests, the basic approach is to construct a laboratory specimen with a known geometry from an easily characterized material. Digital video imaging combined with the geometric moire fringe method of strain analysis is used to measure and derive the displacements on the sample under load. Here the authors present the method of acquiring and analyzing the moire data and give an analysis of its problems and benefits.

510 (SAND–93-1182) **Evaluation of the effects of underground water usage and spillage in the Exploratory Studies Facility: Yucca Mountain Site Characterization Project.** Dunn, E.; Sobolik, S.R. Sandia National Labs., Albuquerque, NM (United States). Dec 1993. 60p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94005956. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project is studying Yucca Mountain in southwestern Nevada as a potential site for a high-level radioactive waste repository. Analyses reported herein were performed to support the design of site characterization activities so that these activities will have a minimal impact on the ability of the site to isolate waste and a minimal impact on underground tests performed as part of the characterization process. These analyses examine the effect of water to be used in the underground construction and testing activities for the Exploratory Studies Facility on in situ conditions. Underground activities and events where water will be used include construction, expected but unplanned spills, and fire protection. The models used predict that, if the current requirements in the Exploratory Studies Facility Design Requirements are observed, water that is imbibed into the tunnel wall rock in the Topopah Springs welded tuff can be removed over the preclosure time period by routine or corrective ventilation, and also that water imbibed into the Paintbrush Tuff nonwelded tuff will not reach the potential waste storage area.

511 (SAND–93-1184) **A strategy to seal exploratory boreholes in unsaturated tuff: Yucca Mountain Site Characterization Project.** Fernandez, J.A. (Sandia National Labs., Albuquerque, NM (United States)); Case, J.B.; Givens, C.A.; Carney, B.C. Sandia National Labs., Albuquerque, NM (United States). Apr 1994. 522p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94015043. Source: OSTI; NTIS; INIS; GPO Dep.

This report presents a strategy for sealing exploratory boreholes associated with the Yucca Mountain Site Characterization Project. Over 500 existing and proposed boreholes have been considered in the development of this strategy, ranging from shallow (penetrating into alluvium only) to deep (penetrating into the groundwater table). Among the comprehensive list of recommendations are the following: Those boreholes within the potential repository boundary and penetrating through the potential repository horizon are the most significant boreholes from a performance standpoint and should be sealed. Shallow boreholes are comparatively insignificant and require only nominal

sealing. The primary areas in which to place seals are away from high-temperature zones at a distance from the potential repository horizon in the Paintbrush nonwelded tuff and the upper portion of the Topopah Spring Member and in the tuffaceous beds of the Calico Hills Unit. Seals should be placed prior to waste emplacement. Performance goals for borehole seals both above and below the potential repository are proposed. Detailed construction information on the boreholes that could be used for future design specifications is provided along with a description of the environmental setting, i.e., the geology, hydrology, and the in situ and thermal stress states. A borehole classification scheme based on the condition of the borehole wall in different tuffaceous units is also proposed. In addition, calculations are presented to assess the significance of the boreholes acting as preferential pathways for the release of radionuclides. Design calculations are presented to answer the concerns of when, where, and how to seal. As part of the strategy development, available technologies to seal exploratory boreholes (including casing removal, borehole wall reconditioning, and seal emplacement) are reviewed.

512 (SAND–93-1891) **JAC2D: A two-dimensional finite element computer program for the nonlinear quasi-static response of solids with the conjugate gradient method: Yucca Mountain Site Characterization Project.** Biffle, J.H.; Blanford, M.L. Sandia National Labs., Albuquerque, NM (United States). May 1994. 128p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94014302. Source: OSTI; NTIS; INIS; GPO Dep.

JAC2D is a two-dimensional finite element program designed to solve quasi-static nonlinear mechanics problems. A set of continuum equations describes the nonlinear mechanics involving large rotation and strain. A nonlinear conjugate gradient method is used to solve the equations. The method is implemented in a two-dimensional setting with various methods for accelerating convergence. Sliding interface logic is also implemented. A four-node Lagrangian uniform strain element is used with hourglass stiffness to control the zero-energy modes. This report documents the elastic and isothermal elastic/plastic material model. Other material models, documented elsewhere, are also available. The program is vectorized for efficient performance on Cray computers. Sample problems described are the bending of a thin beam, the rotation of a unit cube, and the pressurization and thermal loading of a hollow sphere.

513 (SAND–93-2365) **Laboratory measurements of frictional slip on interfaces in a polycarbonate rock mass model.** Brown, S.R. (Sandia National Labs., Albuquerque, NM (United States). Geomechanics Dept.). Sandia National Labs., Albuquerque, NM (United States). Aug 1994. 19p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95000709. Source: OSTI; NTIS; INIS; GPO Dep.

The evaluation of the stability of the openings for the Exploratory Studies Facility and a potential repository for high-level nuclear waste at Yucca Mountain, Nevada will require computer codes capable of predicting slip on rock joints resulting from changes in thermal stresses. The geometrical method of analysis of moire fringe analysis was used to evaluate the magnitude and extent of frictional sliding in a layered polycarbonate rock mass model containing a circular hole. Slips were observed in confined zones around the hole and micron resolutions were obtained. Unpredicted and uncontrolled uniform slip of several interfaces in the model were observed giving considerable uncertainty in the boundary conditions of the model, perhaps making detailed comparison with numerical models impossible.

514 (SAND–93-2507C) **Towards a realistic approach to validation of reactive transport models for performance assessment.** Siegel, M.D. Sandia National Labs., Albuquerque, NM (United States). [1993]. 30p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-9309228–8: Focus 93: site characterization and model validation, Las Vegas, NV (United States), 26-29 Sep 1993). Order Number DE94005249. Source: OSTI; NTIS; INIS; GPO Dep.

Performance assessment calculations are based on geochemical models that assume that interactions among radionuclides, rocks and groundwaters under natural conditions, can be estimated or bound by data obtained from laboratory-scale studies. The data include radionuclide distribution coefficients, measured in saturated batch systems of powdered rocks, and retardation factors measured in short-term column experiments. Traditional approaches to model validation cannot be applied in a straightforward manner to the simple reactive transport models that use these data. An approach to model validation in support of performance assessment is described in this paper. It is based on a recognition of different levels of model validity and is compatible with the requirements of current regulations for high-level waste disposal. Activities that are being carried out in support of this approach include (1) laboratory and numerical experiments to test the validity of important assumptions inherent in current performance assessment methodologies,(2) integrated transport experiments, and (3) development of a robust coupled reaction/transport code for sensitivity analyses using massively parallel computers.

515 (SAND–93-2675) **Total-system performance assessment for Yucca Mountain – SNL second iteration (TSPA-1993): Executive summary.** Wilson, M.L. (Sandia National Labs., Albuquerque, NM (United States)); Barnard, R.W.; Gauthier, J.H. Sandia National Labs., Albuquerque, NM (United States). Apr 1994. 67p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94012995. Source: OSTI; NTIS; INIS; GPO Dep.

Sandia National Laboratories has completed the second iteration of the periodic total-system performance assessments (TSPA-93) for the Yucca Mountain Site Characterization Project (YMP). Scenarios describing expected conditions (aqueous and gaseous transport of contaminants) and low-probability events (human-intrusion drilling and volcanic intrusion) are modeled. The hydrologic processes modeled include estimates of the perturbations to ambient conditions caused by heating of the repository resulting from radioactive decay of the waste. TSPA-93 incorporates significant new detailed process modeling, including two- and three-dimensional modeling of thermal effects, groundwater flow in the saturated-zone aquifers, and gas flow in the unsaturated zone. Probabilistic analyses are performed for aqueous and gaseous flow and transport, human intrusion, and basaltic magmatic activity. Results of the calculations lead to a number of recommendations concerning studies related to site characterization. Primary among these are the recommendations to obtain better information on percolation flux at Yucca Mountain, on the presence or absence of flowing fractures, and on physical and chemical processes influencing gaseous flow. Near-field thermal and chemical processes, and waste-container degradation are also areas

where additional investigations may reduce important uncertainties. Recommendations for repository and waste-package design studies are: (1) to evaluate the performance implications of large-size containers, and (2) to investigate in more detail the implications of high repository thermal power output on the adjacent host rock and on the spent fuel.

516 (SAND–93-2675-Vol.1) **Total-system performance assessment for Yucca Mountain - SNL second iteration (TSPA-1993): Volume 1.** Wilson, M.L. (and others); Gauthier, J.H.; Barnard, R.W.; Barr, G.E.; Dockery, H.A.; Dunn, E.; Eaton, R.R.; Guerin, D.C.; Lu, N.; Martinez, M.J. Sandia National Labs., Albuquerque, NM (United States). Apr 1994. 338p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94013818. Source: OSTI; NTIS; INIS; GPO Dep.

Sandia National Laboratories has completed the second iteration of the periodic total-system performance assessments (TSPA-93) for the Yucca Mountain Site Characterization Project (YMP). These analyses estimate the future behavior of a potential repository for high-level nuclear waste at the Yucca Mountain, Nevada, site under consideration by the Department of Energy. TSPA-93 builds upon previous efforts by emphasizing YMP concerns relating to site characterization, design, and regulatory compliance. Scenarios describing expected conditions (aqueous and gaseous transport of contaminants) and low-probability events (human-intrusion drilling and volcanic intrusion) are modeled. The hydrologic processes modeled include estimates of the perturbations to ambient conditions caused by heating of the repository resulting from radioactive decay of the waste. Hydrologic parameters and parameter probability distributions have been derived from available site data. Possible future climate changes are modeled by considering two separate groundwater infiltration conditions: "wet" with a mean flux of 10 mm/yr, and "dry" with a mean flux of 0.5 mm/yr. Two alternative waste-package designs and two alternative repository areal thermal power densities are investigated. One waste package is a thin-wall container emplaced in a vertical borehole, and the second is a container designed with corrosion-resistant and corrosion-allowance walls emplaced horizontally in the drift. Thermal power loadings of 57 kW/acre (the loading specified in the original repository conceptual design) and 114 kW/acre (a loading chosen to investigate effects of a "hot repository") are considered. TSPA-93 incorporates significant new detailed process modeling, including two- and three-dimensional modeling of thermal effects, groundwater flow in the saturated-zone aquifers, and gas flow in the unsaturated zone.

517 (SAND–93-2675-Vol.2) **Total-system performance assessment for Yucca Mountain - SNL second iteration (TSPA-1993): Volume 2.** Wilson, M.L. (Sandia National Labs., Albuquerque, NM (United States)); Barnard, R.W.; Barr, G.E.; Dockery, H.A.; Dunn, E.; Eaton, R.R.; Martinez, M.J.; Gauthier, J.H.; Guerin, D.C.; Lu, N. Sandia National Labs., Albuquerque, NM (United States). Apr 1994. 477p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94013819. Source: OSTI; NTIS; INIS; GPO Dep.

Sandia National Laboratories has completed the second iteration of the periodic total-system performance assessments (TSPA-93) for the Yucca Mountain Site Characterization Project (YMP). These analyses estimate the future behavior of a potential repository for high-level nuclear waste at the Yucca Mountain, Nevada, site under consideration by the Department of Energy. TSPA-93 builds upon previous efforts by emphasizing YMP concerns relating to site characterization, design, and regulatory compliance. Scenarios describing expected conditions (aqueous and gaseous transport of contaminants) and low-probability events (human-intrusion drilling and volcanic intrusion) are modeled. The hydrologic processes modeled include estimates of the perturbations to ambient conditions caused by heating of the repository resulting from radioactive decay of the waste. Hydrologic parameters and parameter probability distributions have been derived from available site data. Possible future climate changes are modeled by considering two separate groundwater infiltration conditions: "wet" with a mean flux of 10 mm/yr, and "dry" with a mean flux of 0.5 mm/yr. Two alternative waste-package designs and two alternative repository areal thermal power densities are investigated. One waste package is a thin-wall container emplaced in a vertical borehole, and the second is a container designed with corrosion-resistant and corrosion-allowance walls emplaced horizontally in the drift. Thermal power loadings of 57 kW/acre (the loading specified in the original repository conceptual design) and 114 kW/acre (a loading chosen to investigate effects of a "hot repository") are considered. TSPA-93 incorporates significant new detailed process modeling, including two- and three-dimensional modeling of thermal effects, groundwater flow in the saturated-zone aquifers, and gas flow in the unsaturated zone.

518 (SAND–93-3903C) **Modeling infiltration into a tuff matrix from a saturated vertical fracture.** Ho, C.K. Sandia National Labs., Albuquerque, NM (United States). [1993]. 23p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–26: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94008953. Source: OSTI; NTIS; INIS; GPO Dep.

Saturation profiles resulting from TOUGH2 numerical simulations of water infiltration into a tuff matrix from a saturated vertical fracture have been compared to experimental results. The purpose was to determine the sensitivity of the infiltration on local heterogeneities and different representations of two-phase characteristic curves used by the model. Findings indicate that the use of simplified (linearized) capillary pressure curves with rigorous (van Genuchten) relative permeability curves resulted in a more computationally efficient solution without a loss in accuracy. However, linearized forms of the relative permeability functions produced poor results, regardless of the form of the capillary pressure function. In addition, numerical simulations revealed that the presence of local heterogeneities in the tuff caused non-uniform saturation distributions and wetting fronts in the in matrix.

519 (SAND–93-3997) **A review of the available technologies for sealing a potential underground nuclear waste repository at Yucca Mountain, Nevada.** Fernandez, J.A. (Sandia National Labs., Albuquerque, NM (United States)); Richardson, A.M. Sandia National Labs., Albuquerque, NM (United States). Nov 1994. 420p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95008439. Source: OSTI; NTIS; INIS; GPO Dep.

The purpose of this report is to assess the availability of technologies to seal underground openings. The technologies are needed to seal the potential high-level radioactive waste repository at Yucca Mountain. Technologies are evaluated for three basic categories of seal components: backfill (general fill and graded fill), bulkheads, and grout curtains. Not only is placement of seal components assessed, but also preconditioning of the placement area and seal component durability. The approach taken was: First, review selected sealing case histories (literature searches and site visits) from the mining, civil, and defense industries; second, determine whether reasonably available technologies to seal the potential repository exist; and finally, identify deficiencies in existing technologies. It is concluded that reasonably available technologies do exist to place backfill, bulkheads, and grout curtains. Technologies also exist to precondition areas where seal components are to be placed. However, if final performance requirements are stringent for these engineered structures, some existing technologies may need to be developed. Deficiencies currently do exist in technologies that demonstrate the long-term durability and performance of seal components. Case histories do not currently exist that demonstrate the placement of seal components in greatly elevated thermal and high-radiation environments and in areas where ground support (rock bolts and concrete liners) has been removed. The as-placed, in situ material properties for sealing materials appropriate to Yucca Mountain are not available.

520 (SAND–93-4002C) **Paleoclimate validation of a numerical climate model.** Schelling, F.J. (Sandia National Laboratories, Las Vegas, NV (United states)); Church, H.W.; Zak, B.D.; Thompson, S.L. Sandia National Labs., Albuquerque, NM (United States). [1994]. 4p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–30: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94009287. Source: OSTI; NTIS; INIS; GPO Dep.

An analysis planned to validate regional climate model results for a past climate state at Yucca Mountain, Nevada, against paleoclimate evidence for the period is described. This analysis, which will use the GENESIS model of global climate nested with the RegCM2 regional climate model, is part of a larger study for DOE's Yucca Mountain Site Characterization Project that is evaluating the impacts of long term future climate change on performance of the potential high level nuclear waste repository at Yucca Mountain. The planned analysis and anticipated results are presented.

521 (SAND–93-4020) **Bulk and mechanical properties of the Paintbrush tuff recovered from borehole USW NRG-6: Data report.** Martin, R.J. (New England Research, Inc., White River Junction, VT (United States)); Boyd, P.J.; Noel, J.S.; Price, R.H. Sandia National Labs., Albuquerque, NM (United States). Nov 1994. 105p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95004385. Source: OSTI; NTIS; INIS; GPO Dep.

Experimental results are presented for bulk and mechanical properties measurements on specimens of the Paintbrush tuff recovered from borehole USW NRG-6 at Yucca Mountain, Nevada. Measurements have been performed on four thermal/mechanical units, TCw, PTn, TSw1 and TSw2. On each specimen the following bulk properties have been reported: dry bulk density, saturated bulk density, average grain density, and porosity. Unconfined compression to failure, confined compression to failure, and indirect tensile strength tests were performed on selected specimens recovered from the borehole. In addition, compressional and shear wave velocities were measured on specimens designated for unconfined compression and confined compression experiments. Measurements were conducted at room temperature on nominally water saturated specimens; however, some specimens of PTn were tested in a room dry condition. The nominal strain rate for the fracture experiments was 10^{-5} s $^{-1}$.

522 (SAND–93-4045C) **Studies of non-isothermal flow in saturated and partially saturated porous media.** Ho, C.K.; Maki, K.S.; Glass, R.J. Sandia National Labs., Albuquerque, NM (United States). [1993]. 27p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–44: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94010395. Source: OSTI; NTIS; INIS; GPO Dep.

Physical and numerical experiments have been performed to investigate the behavior of nonisothermal flow in two-dimensional saturated and partially saturated porous media. The physical experiments were performed to identify non-isothermal flow fields and temperature distributions in fully saturated, half-saturated, and residually saturated two-dimensional porous media with bottom heating and top cooling. Two counter-rotating liquid-phase convective cells were observed to develop in the saturated regions of all three cases. Gas-phase convection was also evidenced in the unsaturated regions of the partially saturated experiments. TOUGH2 numerical simulations of the saturated case were found to be strongly dependent on the assumed boundary conditions of the physical system. Models including heat losses through the boundaries of the test cell produced temperature and flow fields that were in better agreement with the observed temperature and flow fields than models that assumed insulated boundary conditions. A sensitivity analysis also showed that a reduction of the bulk permeability of the porous media in the numerical simulations depressed the effects of convection, flattening the temperature profiles across the test cell.

523 (SAND–93-4097C) **Appropriateness of one-dimensional calculations for repository analysis.** Eaton, R.R. Sandia National Labs., Albuquerque, NM (United States). [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–5: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94005588. Source: OSTI; NTIS; INIS; GPO Dep.

This paper brings into focus the results of numerous studies that have addressed issues associated with the validity of assumptions which are used to justify reducing the dimensionality of numerical calculations of water flow through Yucca Mountain, NV. It is shown that in many cases, one-dimensional modeling is more rigorous than previously assumed.

524 (SAND–93-7079) **Effect of boundary conditions on the strength and deformability of replicas of natural fractures in welded tuff: Data analysis.** Wibowo, J. (Colorado Univ., Boulder, CO (United States). Dept. of Civil, Environmental, and Architectural Engineering); Amadei, B.; Sture, S.; Price, R.H. Sandia National Labs., Albuquerque, NM (United States); Colorado Univ., Boulder, CO (United

States). Dept. of Civil, Environmental, and Architectural Engineering. Apr 1994. 223p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94013363. Source: OSTI; NTIS; INIS; GPO Dep.

Assessing the shear behavior of intact rock & rock fractures is an important issue in the design of a potential nuclear waste repository at Yucca Mountain Nevada. Cyclic direct shear experiments were conducted on replicas of three natural fractures and a laboratory-developed tensile fracture of welded tuff. The tests were carried out under constant normal loads or constant normal stiffnesses with different initial normal load levels. Each test consisted of five cycles of forward and reverse shear motion. Based on the results of the shear tests conducted under constant normal load, the shear behavior of the joint replicas tested under constant normal stiffness was predicted by using the graphical analysis method of Saeb (1989), and Amadei and Saeb (1990). Comparison between the predictions and the actual constant stiffness direct shear experiment results can be found in a report by Wibowo et al. (1993b). Results of the constant normal load shear experiments are analyzed using several constitutive models proposed in the rock mechanics literature for joint shear strength, dilatancy, and joint surface damage. It is shown that some of the existing models have limitations. New constitutive models are proposed and are included in a mathematical analysis tool that can be used to predict joint behavior under various boundary conditions.

525 (SAND–93-7081) **Users' manual for LEHGC: A Lagrangian-Eulerian finite-element model of HydroGeoChemical transport through saturated-unsaturated media – Version 1.0.** Yeh, G.T. (Pennsylvania State Univ., University Park, PA (United States). Dept. of Civil Engineering). Sandia National Labs., Albuquerque, NM (United States). Mar 1995. 170p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95010513. Source: OSTI; NTIS; INIS; GPO Dep.

The computer program LEHGC is a Hybrid Lagrangian-Eulerian Finite-Element Model of HydroGeoChemical (LEHGC) Transport Through Saturated-Unsaturated Media. LEHGC iteratively solves two-dimensional transport and geochemical equilibrium equations and is a descendant of HYDROGEOCHEM, a strictly Eulerian finite-element reactive transport code. The hybrid Lagrangian-Eulerian scheme improves on the Eulerian scheme by allowing larger time steps to be used in the advection-dominant transport calculations, causing less numerical dispersion and alleviating the problem of negative concentration, and it also is more computationally efficient. LEHGC is designed for generic application to reactive transport problems associated with such systems as contaminant transport in subsurface media. Input to the program includes the geometry of the system, the spatial distribution of finite elements and nodes, the properties of the media, the potential chemical reactions, and the initial and boundary conditions. Output includes the spatial distribution of chemical element concentrations as a function of time and space and the chemical speciation at user-specified nodes.

526 (SAND–93-7106C) **Mountain scale modeling of transient, coupled gas flow, heat transfer and carbon-14 migration.** Lu, Ning (Disposal Safety, Inc., Washington, DC (United States)); Ross, B. Sandia National Labs., Albuquerque, NM (United States). [1993]. 7p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-9309228–13: Focus 93: site characterization and model validation, Las Vegas, NV (United States), 26-29 Sep 1993). Order Number DE95003351. Source: OSTI; NTIS; INIS; GPO Dep.

We simulate mountain-scale coupled heat transfer and gas flow at Yucca Mountain. A coupled rock-gas flow and heat transfer model, TGIF2, is used to simulate mountain-scale two-dimensional transient heat transfer and gas flow. The model is first verified against an analytical solution for the problem of an infinite horizontal layer of fluid heated from below. Our numerical results match very well with the analytical solution. Then, we obtain transient temperature and gas flow distributions inside the mountain. These distributions are used by a transient semianalytical particle tracker to obtain carbon-14 travel times for particles starting at different locations within the repository. Assuming that the repository is filled with 30-year-old waste at an initial areal power density of 57 kw/acre, we find that repository temperatures remain above 60°C for more than 10,000 years. Carbon-14 travel times to the surface are mostly less than 1000 years, for particles starting at any time within the first 10,000 years.

527 (SAND–93-7109) **Development of models for fast fluid pathways through unsaturated heterogeneous porous media.** Robey, T.H. (Spectra Research Inst., Albuquerque, NM (United States)). Sandia National Labs., Albuquerque, NM (United States). Nov 1994. 112p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95004269. Source: OSTI; NTIS; INIS; GPO Dep.

The pre-waste-emplacement ground water travel time requirement is a regulatory criterion that specifies ground water travel time to the accessible environment shall be greater than 1,000 years. Satisfying the ground water travel time criterion for the potential repository at Yucca Mountain requires the study of fast travel path formation in the unsaturated zone and development of models that simulate the formation of fast paths. Conceptual models for unsaturated flow that have been used for total-systems performance assessment generally fall into the categories of composite-porosity or fracture models. The actual hydrologic conditions at Yucca Mountain are thought to lie somewhere between the extremes of these two types of models. The current study considers the effects of heterogeneities on composite-porosity models and seeks to develop numerical methods (and models) that can produce locally saturated zones where fracture flow can occur. The credibility of the model and numerical methods is investigated by using test data from the INTRAVAL project (Swedish Nuclear Inspectorate, 1992) to attempt to predict in-situ volumetric water content at specific locations in Yucca Mountain. Work based on the numerical methods presented in this study is eventually intended to allow the calculation of ground water travel times in heterogeneous media. 60 refs.

528 (SAND–93-7116C) **Development of methods to evaluate uranium distribution coefficients in unsaturated media.** Sautman, M.T. (Massachusetts Inst. of Tech., Cambridge, MA (United States). Dept. of Nuclear Engineering); Simonson, S.A. Sandia National Labs., Albuquerque, NM (United States). [1993]. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-9309146–7: 5. annual American Chemical Society (ACS) Industrial and Engineering Chemistry (I&EC) Division special symposium on emerging technologies for hazardous waste management, Atlanta, GA

(United States), 27-29 Sep 1993). Order Number DE94004694. Source: OSTI; NTIS; INIS; GPO Dep.

To date, batch sorption and dynamic column experiments have been performed for many elements as part of site characterization programs. These experiments were often conducted with samples having relatively high liquid/solid ratios (in some cases the solid volume was much smaller than the solution volume). The development of methods for measuring sorption parameters at low liquid/solid ratios was undertaken to attempt to judge whether or not results of saturated experiments are valid for use in performance assessments of sites located in unsaturated rocks. The amount of hydrologic saturation can affect the ionic strength, pH, and redox potential which can in turn affect sorption. In addition, the presence of the gas phase may affect the amount of wetting occurring on the solid's surface. This paper describes experimental procedures which were developed to evaluate the sorption of uranium by silica sand at predetermined levels of unsaturation.

529 (SAND–94-0087C) **Effect of fractures on repository dryout.** Eaton, R.R. Sandia National Labs., Albuquerque, NM (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–64: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014184. Source: OSTI; NTIS; INIS; GPO Dep.

Calculations of water flow through Yucca Mountain show significant dryout and water perching in the vicinity of the proposed nuclear waste repository. These calculations also show that the extent of the dryout and perched water zones is a strong function of the material characteristics which are used to represent the fracture zones. The results show that for 100 μm fracture case appreciable dryout and perched regions exist. When 1 μm fractures are used no dryout or perched regions are calculated.

530 (SAND–94-0155C) **Development of stochastic indicator models of lithology, Yucca Mountain, Nevada.** Rautman, C.A. (Sandia National Labs., Albuquerque, NM (United States)); Robey, T.H. Sandia National Labs., Albuquerque, NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–66: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014177. Source: OSTI; NTIS; INIS; GPO Dep.

Indicator geostatistical techniques have been used to produce a number of fully three-dimensional stochastic simulations of large-scale lithologic categories at the Yucca Mountain site. Each realization reproduces the available drill hole data used to condition the simulation. Information is propagated away from each point of observation in accordance with a mathematical model of spatial continuity inferred through soft data taken from published geologic cross sections. Variations among the simulated models collectively represent uncertainty in the lithology at unsampled locations. These stochastic models succeed in capturing many major features of welded-nonwelded lithologic framework of Yucca Mountain. However, contacts between welded and nonwelded rock types for individual simulations appear more complex than suggested by field observation, and a number of probable numerical artifacts exist in these models. Many of the apparent discrepancies between the simulated models and the general geology of Yucca Mountain represent characterization uncertainty, and can be traced to the sparse site data used to condition the simulations. Several vertical stratigraphic columns have been extracted from the three-dimensional stochastic models for use in simplified total-system performance assessment exercises. Simple, manual adjustments are required to eliminate the more obvious simulation artifacts and to impose a secondary set of deterministic geologic features on the overall stratigraphic framework provided by the indictor models.

531 (SAND–94-0185) **Modeling heterogeneous unsaturated porous media flow at Yucca Mountain.** Robey, T.H. (Spectra Research Inst., Albuquerque, NM (United States)). Sandia National Labs., Albuquerque, NM (United States). [1994]. 7p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–18: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94008612. Source: OSTI; NTIS; INIS; GPO Dep.

Geologic systems are inherently heterogeneous and this heterogeneity can have a significant impact on unsaturated flow through porous media. Most previous efforts to model groundwater flow through Yucca Mountain have used stratigraphic units with homogeneous properties. However, modeling heterogeneous porous and fractured tuff in a more realistic manner requires numerical methods for generating heterogeneous simulations of the media, scaling of material properties from core scale to computational scale, and flow modeling that allows channeling. The Yucca Mountain test case of the INTRAVAL project is used to test the numerical approaches. Geostatistics is used to generate more realistic representations of the stratigraphic units and heterogeneity within units is generated using sampling from property distributions. Scaling problems are reduced using an adaptive grid that minimizes heterogeneity within each flow element. A flow code based on the dual mixed-finite-element method that allows for heterogeneity and channeling is employed. In the Yucca Mountain test case, the simulated volumetric water contents matched the measured values at drill hole USW UZ-16 except in the nonwelded portion of Prow Pass.

532 (SAND–94-0189) **Characterization of materials for a reactive transport model validation experiment: Interim report on the caisson experiment. Yucca Mountain Site Characterization Project.** Siegel, M.D. (Sandia National Labs., Albuquerque, NM (United States)); Cheng, W.C.; Ward, D.B.; Bryan, C.R. Sandia National Labs., Albuquerque, NM (United States). Aug 1995. 250p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95017630. Source: OSTI; NTIS; INIS; GPO Dep.

Models used in performance assessment and site characterization activities related to nuclear waste disposal rely on simplified representations of solute/rock interactions, hydrologic flow field and the material properties of the rock layers surrounding the repository. A crucial element in the design of these models is the validity of these simplifying assumptions. An intermediate-scale experiment is being carried out at the Experimental Engineered Test Facility at Los Alamos Laboratory by the Los Alamos and Sandia National Laboratories to develop a strategy to validate key geochemical and hydrological assumptions in performance assessment models used by the Yucca Mountain Site Characterization Project.

533 (SAND–94-0207C) **Constraining local 3-D models of the saturated-zone, Yucca Mountain, Nevada.** Barr, G.E.; Shannon, S.A. Sandia National Labs., Albuquerque,

NM (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–20: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94008956. Source: OSTI; NTIS; INIS; GPO Dep.

A qualitative three-dimensional analysis of the saturated zone flow system was performed for a 8 km × 8 km region including the potential Yucca Mountain repository site. Certain recognized geologic features of unknown hydraulic properties were introduced to assess the general response of the flow field to these features. Two of these features, the Solitario Canyon fault and the proposed fault in Drill Hole Wash, appear to constrain flow and allow calibration.

534 (SAND–94-0244) **Stochastic hydrogeologic units and hydrogeologic properties development for total-system performance assessments. Yucca Mountain Site Characterization Project.** Schenker, A.R. (Los Alamos Technical Associates, Albuquerque, NM (United States)); Guerin, D.C.; Robey, T.H.; Rautman, C.A.; Barnard, R.W. Sandia National Labs., Albuquerque, NM (United States). Sep 1995. 150p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE96000699. Source: OSTI; NTIS; INIS; GPO Dep.

A stochastic representation of the lithologic units and associated hydrogeologic parameters of the potential high-level nuclear waste repository are developed for use in performance-assessment calculations, including the Total-System Performance Assessment for Yucca Mountain-SNL Second Iteration (TSPA-1993). A simplified lithologic model has been developed based on the physical characteristics of the welded and nonwelded units at Yucca Mountain. Ten hydrogeologic units are developed from site-specific data (lithologic and geophysical logs and core photographs) obtained from the unsaturated and saturated zones. The three-dimensional geostatistical model of the ten hydrogeologic units is based on indicator-coding techniques and improves on the two-dimensional model developed for TSPA91. The hydrogeologic properties (statistics and probability distribution functions) are developed from the results of laboratory tests and in-situ aquifer tests or are derived through fundamental relationships. Hydrogeologic properties for matrix properties, bulk conductivities, and fractures are developed from existing site specific data. Extensive data are available for matrix porosity, bulk density, and matrix saturated conductivity. For other hydrogeologic properties, the data are minimal or nonexistent. Parameters for the properties are developed as beta probability distribution functions. For the model units without enough data for analysis, parameters are developed as analogs to existing units. A relational, analytic approach coupled with bulk conductivity parameters is used to develop fracture parameters based on the smooth-wall-parallel-plate theory. An analytic method is introduced for scaling small-core matrix properties to the hydrogeologic unit scales.

535 (SAND–94-0261C) **Analyses of releases due to drilling at the potential Yucca Mountain repository.** Barnard, R.W. Sandia National Labs., Albuquerque, NM (United States). [1994]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–28: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94009282. Source: OSTI; NTIS; INIS; GPO Dep.

Radionuclide releases due to drilling into the potential Yucca Mountain nuclear-waste repository have been evaluated as part of a recent total-system performance assessment. The probability that a drilling event intersects a waste package is a function of the sizes of the drill bit and the waste package, and the density of placement of the containers in the repository. The magnitude of the releases is modeled as a random function that also depends on the amount of decay the radionuclides have undergone. Four cases have been analyzed, representing the combinations of two waste-package designs (small-capacity, thin-wall, vertically emplaced; and large-capacity, thick-wall, horizontally emplaced) and two repository layouts (lower thermal power dissipation, low waste-package placement density; and higher thermal power dissipation, high waste-package placement density). The results show a fairly pronounced dependence on waste-package design and slight dependence on repository layout. Given the assumptions in the model, releases from the larger containers are 4–5 times greater than from the smaller packages.

536 (SAND–94-0278) **Test interference calculations for the Yucca Mountain Project ESF thermomechanical experiments: Yucca Mountain Site Characterization Project.** Holland, J.F. (Technadyne, Albuquerque, NM (United States)); Pott, J. Sandia National Labs., Albuquerque, NM (United States). Oct 1994. 106p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95001856. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Project, managed by the U.S. Department of Energy, is examining the feasibility of siting a repository for high-level nuclear waste at Yucca Mountain on and adjacent to the Nevada Test Site. As part of the site characterization, a series of in situ thermomechanical experiments are planned, which are to be conducted in the Exploratory Studies Facility (ESF). In this report, the results of preliminary analyses of three of the in situ thermomechanical experiments are presented. The major objective of these analyses was to determine the boundaries of the thermally perturbed zones surrounding each of the experiments. The boundaries of the thermal zones needs to be known in order to avoid test interference between the experiments planned for the ESF. A second objective of these analyses was to calculate the displacements and stresses associated with the experiments, in order to advance the planning of the experiments.

537 (SAND–94-0305C) **Text for Mechanical and bulk properties in support of ESF design issues.** Price, R.H. (Sandia National Labs., Albuquerque, NM (United States)); Martin, R.J.; Boyd, P.J.; Noel, J.S. Sandia National Labs., Albuquerque, NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–78: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94015280. Source: OSTI; NTIS; INIS; GPO Dep.

An intensive laboratory investigation is being performed to determine the mechanical properties of tuffs for the Yucca Mountain Site Characterization Project (YMP). Most recently, experiments are being performed on tuff samples from a series of drill holes along the proposed alignment of the Exploratory Study Facilities (ESF) north ramp. Unconfined compression and indirect tension experiments are being performed and the results are being analyzed with the help of bulk property information. The results on samples

from five of the drill holes are presented here. In general, the properties vary widely, but are highly dependent on the sample porosity.

538 (SAND–94-0306C) **Relation between static and dynamic rock properties in welded and nonwelded tuff.** Price, R.H. (Sandia National Labs., Albuquerque, NM (United States)); Boyd, P.J.; Noel, J.S.; Martin, R.J. III. Sandia National Labs., Albuquerque, NM (United States). [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940642–6: 1. North American rock mechanics symposium, Austin, TX (United States), 1-3 Jun 1994). Order Number DE94014176. Source: OSTI; NTIS; INIS; GPO Dep.

An integral part of the licensing procedure for the potential nuclear waste repository at Yucca Mountain, Nevada involves accurate prediction of the in situ rheology for design and construction of the facility and emplacement of the canisters containing radioactive waste. The data required as input to successful thermal and mechanical models of the behavior of the repository and surrounding lithologies include bulk density, grain density, porosity, compressional and shear wave velocities, elastic moduli, and compressional and tensile strengths. In this study a suite of experiments was performed on cores recovered from the USW-NRG-6 borehole drilled to support the Exploratory Studies Facility (ESF) at Yucca Mountain. USW-NRG-6 was drilled to a depth of 1100 feet through four thermal/mechanical units of Paintbrush tuff. A large data set has been collected on specimens recovered from borehole USW-NRG-6. Analysis of the results of these experiments showed that there is a correlation between fracture strength, Young's modulus, compressional wave velocity and porosity. Additional scaling laws relating; static Young's modulus and compressional wave velocity; and fracture strength and compressional wave velocity are promising. Since there are no other distinct differences in material properties, the scatter that is present at each fixed porosity suggests that the differences in the observed property can be related to the pore structure of the specimen. Image analysis of CT scans performed on each test specimen are currently underway to seek additional empirical relations to aid in refining the correlations between static and dynamic properties of tuff.

539 (SAND–94-0323C) **Detailed characterization and preliminary adsorption model for materials for an intermediate-scale reactive-transport experiment.** Ward, D.B. (New Mexico Univ., Albuquerque, NM (United States). Dept. of Earth and Planetary Sciences); Bryan, C.R.; Siegel, M.D. Sandia National Labs., Albuquerque, NM (United States). [1994]. 15p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–84: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE95014216. Source: OSTI; NTIS; INIS; GPO Dep.

An experiment involving migration of fluid and tracers (Li, Br, Ni) through a 6-m-high x 3-m-dia caisson Wedron 510 sand, is being carried out for Yucca Mountain Site Characterization Project. Sand's surface chemistry of the sand was studied and a preliminary surface-complexation model of Ni adsorption formulated for transport calculations. XPS and leaching suggest that surface of the quartz sand is partially covered by thin layers of Fe-oxyhydroxide and Ca-Mg carbonate and by flakes of kaolinite. Ni adsorption by the sand is strongly pH-dependent, showing no adsorption at pH 5 and near-total adsorption at pH 7. Location of adsorption edge is independent of ionic strength and dissolved Ni concentration; it is shifted to slightly lower pH with higher pCO2 and to slightly higher pH by competition with Li. Diminished adsorption at alkiline pH with higher pCO2 implies formation of dissolved Ni-carbonato complexes. Ni adsorption edges for goethite and quartz, two components of the sand were also measured. Ni adsorption on pure quartz is only moderately pH-dependent and differs in shape and location from that of the sand, whereas Ni adsorption by goethite is strongly pH-dependent. A triple-layer surface-complexation model developed for goethite provides a good fit to the Ni-adsorption curve of the sand. Based on this model, the apparent surface area of the Fe-oxyhydroxide coating is estimated to be 560 m^2/g, compatible with its occurrence as amorphous Fe-oxyhydroxide. Potentiometric titrations on sand also differ from pure quartz and suggest that effective surface area of sand may be much greater than that measured by N_2-BET gas adsorption. Attempts to model the adsorption of bulk sand in terms of properties of pure end member components suggest that much of the sand surface is inert. Although the exact Ni adsorption mechanisms remain ambiguous, this preliminary adsorption model provides an initial set of parameters that can be used in transport calculations.

540 (SAND–94-0326C) **Scaling behavior of gas permeability measurements in volcanic tuffs.** Tidwell, V.C. Sandia National Labs., Albuquerque, NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–65: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014178. Source: OSTI; NTIS; INIS; GPO Dep.

One of the critical issues facing the Yucca Mountain site characterization and performance assessment programs is the manner in which property scaling is addressed. Property scaling becomes an issue whenever heterogeneous media properties are measured at one scale but applied at another. A research program has been established to challenge current understanding of property scaling with the aim of developing and testing models that describe scaling behavior in a quantitative manner. Scaling of constitutive rock properties is investigated through physical experimentation involving the collection of suites of gas-permeability data measured over a range of discrete scales. The approach is to systematically isolate those factors believed to influence property scaling and investigate their relative contributions to overall scaling behavior. Two blocks of tuff, each exhibiting differing heterogeneity structure, have recently been examined. Results of the investigation show very different scaling behavior, as exhibited by changes in the distribution functions and variograms, for the two tuff samples. Even for the relatively narrow range of measurement scales employed significant changes in the distribution functions, variograms, and summary statistics occurred. Because such data descriptors will likely play an important role in calculating effective media properties, these results demonstrate both the need to understand and accurately model scaling behavior.

541 (SAND–94-0343C) **Thermal and seismic impacts on the North Ramp at Yucca Mountain.** Lin, M. (Agapito (J.F.T.) and Associates, Inc., Grand Junction, CO (United States)); Hardy, M.P.; Jung, J. Sandia National Labs., Albuquerque, NM (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE

Contract AC04-94AL85000. (CONF-940553–41: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94010389. Source: OSTI; NTIS; INIS; GPO Dep.

The impacts of thermal and seismic loads on the stability of the Exploratory Studies Facility North Ramp at Yucca Mountain were assessed using both empirical and analytical approaches. This paper presents the methods and results of the analyses. Thermal loads were first calculated using the computer code STRES3D. This code calculates the conductive heat transfer through a semi-infinite elastic, isotropic, homogeneous solid and the rafts thermally-induced stresses. The calculated thermal loads, combined with simulated earthquake motion, were then modeled using UDEC and DYNA3D, numerical codes with dynamic simulation capabilities. The thermal- and seismic-induced yield zones were post-processed and presented for assessment of damage. Uncoupled bolt stress analysis was also conducted to evaluate the seismic impact on the ground support components.

542 (SAND–94-0348C) **Construction monitoring activities in the ESF starter tunnel.** Pott, J. (Sandia National Labs., Albuquerque, NM (United States)); Carlisle, S. Sandia National Labs., Albuquerque, NM (United States). [1994]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–42: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94010386. Source: OSTI; NTIS; INIS; GPO Dep.

In situ design verification activities am being conducted in the North Ramp Starter Tunnel of the Yucca Mountain Project Exploratory Studies Facility. These activities include: monitoring the peak particle velocities and evaluating the damage to the rock mass associated with construction blasting, assessing the rock mass quality surrounding the tunnel, monitoring the performance of the installed ground support, and monitoring the stability of the tunnel. In this paper, examples of the data that have been collected and preliminary conclusions from the data are presented.

543 (SAND–94-0351C) **Some results from the second iteration of total-system performance assessment for Yucca Mountain.** Wilson, M.L. Sandia National Labs., Albuquerque, NM (United States). [1994]. 15p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–45: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94010380. Source: OSTI; NTIS; INIS; GPO Dep.

The second preliminary total-system performance assessment for the potential radioactive-waste-repository site at Yucca Mountain has recently been completed. This paper summarizes results for nominal aqueous and gaseous releases using the composite-porosity flow model. The results are found to be sensitive to the type of unsaturated-zone flow, to percolation flux and climate change, to saturated-zone dilution, to container-wetting processes and container-corrosion processes, to fuel-matrix alteration rate and radionuclide solubilities (especially for ^{237}Np), and to bulk permeability and retardation of gaseous ^{14}C. These are areas that should be given priority in the site-characterization program. Specific recommendations are given in the full report of the study.

544 (SAND–94-0379) **Formulation and numerical analysis of nonisothermal multiphase flow in porous media.** Martinez, M.J. (Sandia National Labs., Albuquerque, NM (United States). Engineering Sciences Center). Sandia National Labs., Albuquerque, NM (United States). Jun 1995. 35p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95013836. Source: OSTI; NTIS; INIS; GPO Dep.

A mathematical formulation is presented for describing the transport of air, water and energy through porous media. The development follows a continuum mechanics approach. The theory assumes the existence of various average macroscopic variables which describe the state of the system. Balance equations for mass and energy are formulated in terms of these macroscopic variables. The system is supplemented with constitutive equations relating fluxes to the state variables, and with transport property specifications. Specification of various mixing rules and thermodynamic relations completes the system of equations. A numerical simulation scheme, employing the method of lines, is described for one-dimensional flow. The numerical method is demonstrated on sample problems involving nonisothermal flow of air and water. The implementation is verified by comparison with existing numerical solutions.

545 (SAND–94-0414C) **An updated fracture-flow model for total-system performance assessment of Yucca Mountain.** Gauthier, J.H. (Spectra Research Inst., Albuquerque, NM (United States)). Sandia National Labs., Albuquerque, NM (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–68: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014179. Source: OSTI; NTIS; INIS; GPO Dep.

Improvements have been made to the fracture-flow model being used in the total-system performance assessment of a potential high-level radioactive waste repository at Yucca Mountain, Nevada. The "weeps model" now includes (1) weeps of varied sizes, (2) flow-pattern fluctuations caused by climate change, and (3) flow-pattern perturbations caused by repository heat generation. Comparison with the original weeps model indicates that allowing weeps of varied sizes substantially reduces the number of weeps and the number of containers contacted by weeps. However, flow-pattern perturbations caused by either climate change or repository heat generation greatly increases the number of containers contacted by weeps. In preliminary total-system calculations, using a phenomenological container-failure and radionuclide-release model, the weeps model predicts that radionuclide releases from a high-level radioactive waste repository at Yucca Mountain will be below the EPA standard specified in 40 CFR 191, but that the maximum radiation dose to an individual could be significant. Specific data from the site are required to determine the validity of the weep-flow mechanism and to better determine the parameters to which the dose calculation is sensitive.

546 (SAND–94-0437) **SURFSCAN: Program to operate a LASER profilometer. Yucca Mountain Site Characterization Project.** Hardy, R.D. Sandia National Labs., Albuquerque, NM (United States). Sep 1995. 72p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE96000207. Source: OSTI; NTIS; INIS; GPO Dep.

This paper is written to document the SURFSCAN program. A large section of the code is devoted to error recovery. The heavy emphasis on error recovery allows unattended operation for extended periods. By combining

error recovery with the use of control files, SURFSCAN has been operated for periods of several days with no operator intervention. At this time, the Surface Profilometer is a useful and productive tool in the Rock Mechanics Laboratory at Sandia National Laboratories/New Mexico. In the Rock Mechanics Laboratory we have been conducting studies of the normal and shear mechanical behavior of fractures and the flow of fluid through fractured rock formations. To estimate these properties, we need to know the average aperture size and surface texture of a fracture. These data may be obtained from surface profiles of mating pieces of rock. By scanning corresponding regions on two mating surfaces, the aperture size may be easily determined.

547 (SAND–94-0443C) **Fracture-matrix interaction in Topopah Spring Tuff: Experiment and numerical analysis.** Glass, R.J. (Sandia National Labs., Albuquerque, NM (United States)); Tidwell, V.C.; Flint, A.L.; Peplinski, W.; Castro, Y. Sandia National Labs., Albuquerque, NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–46: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94010754. Source: OSTI; NTIS; GPO Dep.

Fracture-matrix interaction is investigated through combined physical and numerical experimentation. Two slabs of Topopah Spring Tuff are mated to form a vertical saw cut fracture to which water is supplied. X-ray imaging is used to obtain the matrix porosity field and transient saturation fields as water moves from the fracture into the matrix. Porosity, hydraulic conductivity, and pressure/saturation relations of the matrix are measured on small cores taken from adjacent rock. Correlations between hydraulic properties and porosity are developed and modeled. Numerical simulations using TOUGH2 are accomplished with a series of property fields of increasing detail. Property fields are modeled using the measured porosity field divided into 1, 3, 5, 11, and 21 porosity groups with the hydraulic properties assigned from the developed correlations and the average porosity within each group. Comparison with experimental results allows us to begin to evaluate current matrix property measurement techniques, specific matrix property models, property estimation procedures, and effects of matrix property variability.

548 (SAND–94-0668C) **Zeroing in on requirements: Sandia National Laboratories' approach to meaningful program improvement.** Friend, J.C. (MACTEC, Albuquerque, NM (United States)); Richards, R.R.; Jaramillo, C.P. Sandia National Labs., Albuquerque, NM (United States). [1994]. 7p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940985–4: American Society for Quality Control Energy and Environmental Quality Division conference, Tucson, AZ (United States), 18-21 Sep 1994). Order Number DE94015738. Source: OSTI; NTIS; GPO Dep.

The necessity to evaluate our participant Quality Assurance (QA) Program for the Yucca Mountain Site Characterization Project (YMP) against the Office of Civilian Radioactive Waste Management (OCRWM) Quality Assurance Requirements and Description (QARD) issued December 1992, presented an opportunity to improve the QA Program. For some time, the SNL YMP technical staff had complained that the QA requirements imposed on their work were cumbersome and inhibited their ability to perform investigations using scientific methods. There was some truth to this, since SNL had over the years developed some procedures with many detailed controls that were far beyond what was required by project QA requirements. This had occurred either as a result of responding to numerous audit findings with a "make the auditor happy" attitude or with an attempt to cover every contingency. Procedures affecting scientific work were authored by the technical staff in an effort to provide them with ownership of the process; unfortunately, there were problems. Procedures were inconsistent because of the varied writing styles and differing perceptions of the degree of QA controls required to implement the program. It was extremely difficult to get all of the technical staff to accept the QA program as it was intended. These issues were endemic to the program and resulted in the QARD, the actual requirements, being written by a team of QA professionals. Once new QARD requirements were issued, an opportunity to evaluate the QA Program and to revise it not only to meet the QARD, but also to make it more plausible and meaningful to the technical staff, was presented. The discussion that follows will describe how the program was changed, will present both the positive and negative experiences observed by SNL personnel during the QARD transition, and will provide some recommendations.

549 (SAND–94-0712C) **Design verification activities in the Exploratory Studies Facility Starter Tunnel at Yucca Mountain.** Pott, J. (Sandia National Labs., Albuquerque, NM (United States)); Grant, J.; Carlisle, S. Sandia National Labs., Albuquerque, NM (United States). [1994]. 12p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-9406262–1: North American tunneling conference and exhibition, Denver, CO (United States), 6-9 Jun 1994). Order Number DE94019183. Source: OSTI; NTIS; INIS; GPO Dep.

In situ design verification activities are being conducted in the North Ramp Starter Tunnel of the Yucca Mountain Project Exploratory Studies Facility. These activities include: monitoring the construction blasting, evaluating the damage to the rock mass associated with construction, assessing the rock mass quality surrounding the tunnel, monitoring the performance of the installed ground support, and monitoring the stability of the tunnel. In this paper, examples of the data that have been collected and preliminary conclusions from the data are presented.

550 (SAND–94-1370C) **The effect of stratigraphic uncertainty on repository performance.** Wilson, M.L. (Sandia National Labs., Albuquerque, NM (United States)); Robey, T.H. Sandia National Labs., Albuquerque, NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940815–71: SPECTRUM '94: international nuclear and hazardous waste management conference, Atlanta, GA (United States), 14-18 Aug 1994). Order Number DE94015750. Source: OSTI; NTIS; INIS; GPO Dep.

One source of uncertainty in calculating radionuclide releases from a potential radioactive-waste at Yucca Mountain, Nevada, is uncertainty in the unsaturated-zone stratigraphy. Uncertainty stratigraphy results from sparse drillhole data; possible variations in stratigraphy are modeled using the geostatistical method of indicator simulation. One-dimensional stratigraphic columns are generated and used for calculations of groundwater flow and radionuclide transport. There are indications of a dependence of release on hydrogeologic-unit thicknesses, but the resulting variation in release is smaller than variations produced by other sources of uncertainty.

551 (SAND–94-1941) **Effect of roughness and material strength on the mechanical properties of fracture replicas.** Wibowo, J. (Univ. of Colorado, Boulder, CO (United States)); Amadei, B.; Sture, S. Sandia National Labs., Albuquerque, NM (United States). Aug 1995. 110p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95016953. Source: OSTI; NTIS; INIS; GPO Dep.

This report presents the results of 11 rotary shear tests conducted on replicas of three hollow cylinders of natural fractures with JRC values of 7.7, 9.4 and 12.0. The JRC values were determined from the results of laser profilometer measurements. The replicas were created from gypsum cement. By varying the water-to-gypsum cement ratio from 30 to 45%, fracture replicas with different values of compressive strength (JCS) were created. The rotary shear experiments were performed under constant normal (nominal) stresses ranging between 0.2 and 1.6 MPa. In this report, the shear test results are compared with predictions using Barton's empirical peak shear strength equation. observations during the experiments indicate that only certain parts of the fracture profiles influence fracture shear strength and dilatancy. Under relatively low applied normal stresses, the JCS does not seem to have a significant effect on shear behavior. As an alternative, a new procedure for predicting the shear behavior of fractures was developed. The approach is based on basic fracture properties such as fracture surface profile data and the compressive strength, modulus of elasticity, and Poisson's ratio of the fracture walls. Comparison between predictions and actual shear test results shows that the alternative procedure is a reliable method.

552 (SAND–94-1995) **Mechanical properties of seven fractures from drillholes NRG-4 and NRG-6 at Yucca Mountain, Nevada.** Olsson, W.A. (Sandia National Labs., Albuquerque, NM (United States). Geomechanics Dept.); Brown, S.R. Sandia National Labs., Albuquerque, NM (United States). Nov 1994. 42p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95003470. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project has been assigned the task of determining the suitability of the Yucca Mountain site. Among the concerns being investigated, the characterization of the mechanical properties of the fractures present in the host rock had direct relevance to repository design, and the pre- and post-closure performance assessment. Cores from drillholes NRG-4 and NRG-6 containing natural fractures were obtained from the Sample Management Facility at Yucca Mountain, Nevada. Seven selected fracture were sheared at constant normal stress, either 5 or 10 MPa, in the as-received condition (air-dry). Detailed profilometer data was collected from each fracture surface before testing. The tests yielded the normal closure as a function of normal stress, and the shear stress and dilation as a function of shear offset. The constitutive properties resulting from the measurements were: normal stiffness, shear stiffness, shear strength and coefficient of friction, and dilation. Peak friction ranged from 0.89 to 1.11; residual friction ranged from 0.76 to 1.00. The lowest initial dilation angel was found to be 5.29° and the highest was 11.28°. The roughness characteristics of the fracture surfaces agree qualitatively with the simple mathematical model of Brown (1984) derived from fracture data in many other rock types.

553 (SAND–94-1996) **Bulk and mechanical properties of the Paintbrush tuff recovered from borehole USW NRG-7/7A: Data report. Yucca Mountain Site Characterization Project.** Martin, R.J. (New England Research, Inc. White River Junction, VT (United States)); Boyd, P.J.; Noel, J.S.; Price, R.H. Sandia National Labs., Albuquerque, NM (United States). May 1995. 99p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95011831. Source: OSTI; NTIS; INIS; GPO Dep.

An integral part of the licensing procedure for the potential nuclear waste repository at Yucca Mountain, Nevada, involves prediction of the in situ rheology for the design and construction of the facility and the emplacement of canisters containing radioactive waste. The data used to model the thermal and mechanical behavior of the repository and surrounding lithologies include dry and saturated bulk densities, average grain density, porosity, compressional and shear wave velocities, elastic moduli, and compressional and tensional fracture strengths. In this study, a suite of experiments was performed on cores recovered from the USW NRG-717A borehole drilled in support of the Exploratory Studies Facility (ESF) at Yucca Mountain. USW NRG-7/7A was drilled to a depth of 1,513.4 feet through five thermal/mechanical units of Paintbrush tuff and terminating in the tuffaceous beds of the Calico IEUS. The thermal/mechanical stratigraphy was defined by Orfiz et al. to group rock horizons of similar properties for the purpose of simplifying modeling efforts. The relationship between the geologic stratigraphy and the thermal/mechanical stratigraphy is presented. The tuff samples in this study have a wide range of welding characteristics, and a smaller range of mineralogy and petrology characteristics. Generally, the samples are silicic, ash-fall tuffs that exhibit large variability in their elastic and strength properties.

554 (SAND–94-2011) **Studies of thermohydrologic flow processes using TOUGH2. Yucca Mountain Site Characterization Project.** Ho, C.K.; Eaton, R.R. Sandia National Labs., Livermore, CA (United States). Dec 1994. 119p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95010777. Source: OSTI; NTIS; INIS; GPO Dep.

Coupled thermal and hydrologic flow processes have been recognized as important factors in the evaluation of Yucca Mountain as a potential repository for high-level radioactive wastes. As a result, several models and numerical codes such as TOUGH2 have been used to investigate the thermohydrologic conditions near a potential nuclear waste repository. However, very few of these models have been tested through laboratory or field scale studies. This work has therefore focused on modeling well-controlled experiments of non-isothermal flow processes in porous media at different scales to serve two primary objectives: (1) identify processes that are potentially important to thermal and hydrologic transport at Yucca Mountain and (2) build confidence in models and codes through combined experimental and numerical studies of thermohydrologic behavior at different scales and conditions. In this report, three independent studies of thermohydrologic flow processes at laboratory and field scales are presented. The experiments and field studies that are presented here were performed independently of this work. The main focus of this report was to use the numerical code TOUGH2 to simulate the non-isothermal flow behavior observed in each experiment to generate understanding of the thermohydrologic processes and to gain confidence in the code. TOUGH2 was chosen

due to its current use in calculations associated with Yucca Mountain and its capability of modeling the coupled transport of air, water, vapor, and heat in porous media.

555 (SAND–94-2038) **Summary evaluation of Yucca Mountain surface transects with implications for downhole sampling. Yucca Mountain Site Characterization Project.** Mckenna, S.A.; Rautman, C.A. Sandia National Labs., Albuquerque, NM (United States). Jun 1995. 50p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95014130. Source: OSTI; NTIS; INIS; GPO Dep.

The results of previously completed vertical outcrop sampling transacts are summarized with respect to planning downhole sampling. The summary includes statistical descriptions and descriptions of the spatial variability of the sampled parameters. Descriptions are made on each individual transect, each thermal/mechanical unit and each previously defined geohydrologic unit. Correlations between parameters indicate that saturated hydraulic conductivity is not globally correlated to porosity. The correlation between porosity and saturated hydraulic conductivity is both spatially and lithologically dependent. Currently, there are not enough saturated hydraulic conductivity and sorptivity data to define relationships between these properties and porosity on a unit by unit basis. Also, the Prow Pass member of the Crater Flat Tuff and stratigraphically lower units have gone essentially unsampled in these outcrop transacts. The vertical correlation length for hydrologic properties is not constant across the area of the transacts. The average sample spacing within the transacts ranges from 1.25 to 2.1 meters. It appears that, with the exception of the Topopah Spring member units, a comparable sample spacing will give adequate results in the downhole sampling campaign even with the nonstationarity of the vertical correlation. The properties within the thermal/mechanical units and geohydrologic units of the Topopah Spring member appear to have a spatial correlation range less than or equal to the current sample spacing within these units. For the downhole sampling, a sample spacing of less than 1.0 meters may be necessary within these units.

556 (SAND–94-2243C) **Mechanical and bulk properties of intact rock collected in the laboratory in support of the Yucca Mountain Site Characterization Project.** Price, R.H. (Sandia National Labs., Albuquerque, NM (United States)); Martin, R.J. III; Boyd, P.J.; Boinott, G.N. Sandia National Labs., Albuquerque, NM (United States). [1994]. 12p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-9409238–1: Workshop on rock mechanics, Rockville, MD (United States), 19-20 Sep 1994). Order Number DE95001883. Source: OSTI; NTIS; INIS; GPO Dep.

A comprehensive laboratory investigation is determining the mechanical properties of tuffs for the Yucca Mountain Site Characterization Project (YMP). Most recently, experiments have been performed on tuff samples from a series of drill holes along the planned alignment of the Exploratory Study Facilities (ESF) north ramp. Unconfined compression and indirect tension experiments were performed and the results are being analyzed with the help of bulk property information. The results on samples from eight of the drill holes are presented. In general, the properties vary widely, but are highly dependent on the sample porosity. The developed relationships between mechanical properties and porosity are powerful tools in the effort to model the rock mass response of Yucca Mountain to the emplacement of the potential high-level radioactive waste repository.

557 (SAND–94-2247) **Yucca Mountain thermal response: An evaluation of the effects of modeled geologic structure and thermal property descriptions.** Longenbaugh, R.; Rautman, C.A.; Ryder, E.E. Sandia National Labs., Albuquerque, NM (United States). Sep 1995. 135p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE96001803. Source: OSTI; NTIS; INIS; GPO Dep.

To assess the influence of mountain-scale thermal property model variations on predicted host-rock thermal response, a series of heat conduction calculations were run using a representative two-dimensional cross section of Yucca Mountain. The effects of modeled geologic structure were evaluated through comparisons of results from a single-material, homogeneous model with those from a uniformly layered model, a discontinuous sloping-layered model, and a geo-statistical realization of thermal properties. Comparisons indicate that assumed geologic structure can result in up to a 24°C difference in predicted temperature response. Further, thermal simulations of the method used to analyze geostatistical realizations of thermal properties shows promise as an efficient means of capturing geologic structure without the complexities of intricate finite element meshing. The functional representation of two thermal property models were also investigated. The first examines the effect of using a weighting scheme to define properties for a single, homogenous material model. The second investigates the impact of thermal property temperature dependence on predicted response. As with the investigation of geologic structure, noticeable differences in predicted temperatures (up to 29°C) were found to result.

558 (SAND–94-2283) **Preliminary geostatistical modeling of thermal conductivity for a cross section of Yucca Mountain, Nevada.** Rautman, C.A. (Sandia National Labs., Albuquerque, NM (United States). Geohydrology Dept.). Sandia National Labs., Albuquerque, NM (United States). Sep 1995. 60p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE96001763. Source: OSTI; NTIS; INIS; GPO Dep.

Two-dimensional, heterogeneous, spatially correlated models of thermal conductivity and bulk density have been created for a representative, east-west cross section of Yucca Mountain, Nevada, using geostatistical simulation. The thermal conductivity models are derived from spatially correlated, surrogate material-property models of porosity, through a multiple linear-regression equation, which expresses thermal conductivity as a function of porosity and initial temperature and saturation. Bulk-density values were obtained through a similar, linear-regression relationship with porosity. The use of a surrogate-property allows the use of spatially much-more-abundant porosity measurements to condition the simulations. Modeling was conducted in stratigraphic coordinates to represent original depositional continuity of material properties and the completed models were transformed to real-world coordinates to capture present-day tectonic tilting and faulting of the material-property units. Spatial correlation lengths required for geostatistical modeling were assumed, but are based on the results of previous transect-sampling and geostatistical-modeling work.

559 (SAND–94-2339C) **Stiffness and strength properties of natural fractures from north ramp drill holes.**

Olsson, W.A.; Price, R.H.; Brown, S.R. Sandia National Labs., Albuquerque, NM (United States). [1994]. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-9409238–2: Workshop on rock mechanics, Rockville, MD (United States), 19-20 Sep 1994). Order Number DE95001882. Source: OSTI; NTIS; INIS; GPO Dep.

Cores containing natural fractures were obtained from drillholes UE 25 NRG-4 and USW NRG-6 at Yucca Mountain, Nevada. Seven selected fractures were sheared at constant normal stress, either 5 or 10 MPa, in the air-dry condition. Detailed profilometer data were collected from each fracture surface before testing. The tests yielded the normal closure as a function of normal stress, and the shear stress and dilation as a function of shear offset. The constitutive properties resulting from the measurements were: normal stiffness, shear stiffness, shear strength and coefficient of friction, and dilation. Peak friction ranged from 0.89 to 1.11; residual friction ranged from 0.76 to 1.00. The lowest initial dilation angle was found to be 5.29° and the highest was 11.28°. The roughness characteristics of the fracture surfaces agree qualitatively with the simple mathematical model of Brown (1994) derived from fracture data in many other rock types.

560 (SAND–94-2384) **Frictional sliding in layered rock model: Preliminary experiments. Yucca Mountain Site Characterization Project.** Perry, K.E. Jr. (Idaho National Engineering Lab., Idaho Falls, ID (United States)); Buescher, B.J.; Anderson, D.; Epstein, J.S. Sandia National Labs., Albuquerque, NM (United States). Sep 1995. 15p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE96000205. Source: OSTI; NTIS; INIS; GPO Dep.

An important aspect of determining the suitability of Yucca Mountain as a possible nuclear waste repository requires understanding the mechanical behavior of jointed rockmasses. To this end we have studied the frictional sliding between simulated rock joints in the laboratory using the technique of phase shifting moire interferometry. The models were made from stacks of Lexan plates and contained a central hole to induce slip between the plates when the models were loaded in compression. These preliminary results confirm the feasibility of the approach and show a clear evolution of slip as function of load.

561 (SAND–94-2384C) **Frictional sliding in layered rock: Preliminary experiments on stacked Lexan plates.** Perry, K.E. Jr. (Idaho National Engineering Laboratory, Idaho Falls, ID (United States). Fracture Behavior Group); Epstein, J.S.; Jung, J. Sandia National Labs., Albuquerque, NM (United States). [1995]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-950655–1: 35. US symposium on rock mechanics, South Lake Tahoe, NV (United States), 4-7 Jun 1995). Order Number DE95003632. Source: OSTI; NTIS; INIS; GPO Dep.

Understanding the mechanical behavior of jointed-rock masses is of critical importance to designing and predicting the performance of a potential nuclear waste repositiry. To this end we have studied the frictional sliding between simulated rock joints using phase shifting moire interferometry. Preliminary calibration models were made from stacks of Lexan plates that were sand-blasted to provide a uniform frictional interface. Load was applied monotonically and phase shifted moire fringe patterns were recorded at three different load states. Plots of slip along the interfaces for the model are presented to demonstrate the ability of the photomechanics technique to provide precise measurements of in-plane displacement, and ultimately the slip between the plates.

562 (SAND–94-2563/1) **Performance assessment of the direct disposal in unsaturated tuff of spent nuclear fuel and high-level waste owned by U.S. Department of Energy. Volume 1: Executive summary.** Rechard, R.P. (ed.) (Sandia National Labs., Albuquerque, NM (United States). WIPP Performance Assessment Dept.). Sandia National Labs., Albuquerque, NM (United States). Mar 1995. 63p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95010511. Source: OSTI; NTIS; INIS; GPO Dep.

This assessment studied the performance of high-level radioactive waste and spent nuclear fuel in a hypothetical repository in unsaturated tuff. The results of this 10-month study are intended to help guide the Office of Environment Management of the US Department of Energy (DOE) on how to prepare its wastes for eventual permanent disposal. The waste forms comprised spent fuel and high-level waste currently stored at the Idaho National Engineering Laboratory (INEL) and the Hanford reservation. About 700 metric tons heavy metal (MTHM) of the waste under study is stored at INEL, including graphite spent nuclear fuel, highly enriched uranium spent fuel, low enriched uranium spent fuel, and calcined high-level waste. About 2,100 MTHM of weapons production fuel, currently stored on the Hanford reservation, was also included. The behavior of the waste was analyzed by waste form and also as a group of waste forms in the hypothetical tuff repository. When the waste forms were studied together, the repository was assumed also to contain about 9,200 MTHM high-level waste in borosilicate glass from three DOE sites. The addition of the borosilicate glass, which has already been proposed as a final waste form, brought the total to about 12,000 MTHM. A source term model was developed to study the wide variety of waste forms, which included radionuclides residing in 10 different matrices and up to 8 nested layers of material that might react with water. The possibility and consequences of critical conditions occurring in or near containers of highly enriched uranium spent nuclear fuel were also studied.

563 (SAND–94-2585) **Creep in Topopah Spring Member welded tuff. Yucca Mountain Site Characterization Project.** Martin, R.J. III (New England Research, Inc., White River Junction, VT (United States)); Boyd, P.J.; Noel, J.S.; Price, R.H. Sandia National Labs., Albuquerque, NM (United States). Jun 1995. 66p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95014138. Source: OSTI; NTIS; INIS; GPO Dep.

A laboratory investigation has been carried out to determine the effects of elevated temperature and stress on the creep deformation of welded tuffs recovered from Busted Butte in the vicinity of Yucca Mountain, Nevada. Water saturated specimens of tuff from thermal/mechanical unit TSw2 were tested in creep at a confining pressure of 5.0 MPa, a pore pressure of 4.5 MPa, and temperatures of 25 and 250 C. At each stress level the load was held constant for a minimum of 2.5×10^5 seconds and for as long as 1.8×10^6 seconds. One specimen was tested at a single stress of 80 MPa and a temperature of 250 C. The sample failed after a short time. Subsequent experiments were initiated with an initial differential stress of 50 or 60 MPa; the stress was then increased in 10 MPa increments until failure. The data

showed that creep deformation occurred in the form of time-dependent axial and radial strains, particularly beyond 90% of the unconfined, quasi-static fracture strength. There was little dilatancy associated with the deformation of the welded tuff at stresses below 90% of the fracture strength. Insufficient data have been collected in this preliminary study to determine the relationship between temperature, stress, creep deformation to failure, and total failure time at a fixed creep stress.

564 (SAND–94-2586) **Preliminary evaluation of techniques for transforming regional climate model output to the potential repository site in support of Yucca Mountain future climate synthesis.** Church, H.W.; Zak, B.D.; Behl, Y.K. Sandia National Labs., Albuquerque, NM (United States). Jun 1995. 15p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95013874. Source: OSTI; NTIS; INIS; GPO Dep.

The report describes a preliminary evaluation of models for transforming regional climate model output from a regional to a local scale for the Yucca Mountain area. Evaluation and analysis of both empirical and numerical modeling are discussed which is aimed at providing site-specific, climate-based information for use by interfacing activities. Two semiempirical approaches are recommended for further analysis.

565 (SAND–94-2970C) **Variability of the physical properties of tuff at Yucca Mountain, NV.** Boyd, P.J. (New England Research, Inc., White River Junction, VT (United States)); Martin, R.J. III; Price, R.H. Sandia National Labs., Albuquerque, NM (United States). [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-950655–7: 35. US symposium on rock mechanics, South Lake Tahoe, NV (United States), 4-7 Jun 1995). Order Number DE95009445. Source: OSTI; NTIS; INIS; GPO Dep.

Lateral and vertical variabilities in the bulk and mechanical properties of silicic volcanic tuff at the potential nuclear waste repository site in Yucca Mountain, NV have been evaluated. Laboratory measurements have been performed on tuff specimens recovered from boreholes located to support the design of the Exploratory Studies Facility/North Ramp. The data include dry and saturated bulk densities, average grain density, porosity, compressional and shear wave velocities, elastic moduli, and compressional and tensional fracture strengths. Data from eight boreholes aligned in a northwest-southeast direction have been collected under the required quality assurance program. Three boreholes have penetrated the potential repository horizon. The information collected provides for an accurate appraisal of the variability of rock properties in the vicinity of the boreholes. As expected, there is substantial variability in the bulk and mechanical properties of the tuff with depth (lithology). This is due to variations in gross characteristics of the tuffs (e.g., cooling units, mode of deposition, etc.), as well as smaller scale features (welding, porosity, and internal structures) that have developed as a result of depositional and post-depositional mechanisms. An evaluation of the lateral variability in bulk and mechanical properties is somewhat limited, at this time, due to a lack of borehole control to the north and south (parallel to the depositional flow direction). Initial observations indicate that there is minimal lateral variability within lithologic units. There are observable differences however, that can be related to variability in specific properties (e.g., porosity, and internal structures).

566 (SAND–94-3249C) **Can we talk? Communications management for the Waste Isolation Pilot Plant, a complex nuclear waste management project.** Goldstein, S.A.; Pullen, G.M.; Brewer, D.R. Sandia National Labs., Albuquerque, NM (United States). [1995]. 7p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-9510171–1: PMI '95: Project Management Institute conference, New Orleans, LA (United States), 13-19 Oct 1995). Order Number DE95013888. Source: OSTI; NTIS; INIS; GPO Dep.

Sandia Nuclear Waste Management Program is pursuing for DOE an option for permanently disposing radioactive waste in deep geologic repositories. Included in the Program are the Waste Isolation Pilot Plant (WIPP) Project for US defense program mixed waste the Yucca Mountain Project (YMP) for spent power reactor fuel and vitrified high-level waste, projects for other waste types, and development efforts in environmental decision support technologies. WIPP and YMP are in the public arena, of a controversial nature, and provide significant management challenges. Both projects have large project teams, multiple organization participants, large budgets, long durations, are very complex, have a high degree of programmatic risk, and operate in an extremely regulated environment requiring legal defensibility. For environmental projects like these to succeed, SNL's Program is utilizing nearly all areas in PMI's Project Management Body of Knowledge (PMBOK) to manage along multiple project dimensions such as the physical sciences (e.g., geophysics and geochemistry; performance assessment; decision analysis) management sciences (controlling the triple constraint of performance, cost and schedule), and social sciences (belief systems; public participation; institutional politics). This discussion focuses primarily on communication challenges active on WIPP. How is the WIPP team meeting the challenges of managing communications?" and "How are you approaching similar challenges?" will be questions for a dialog with the audience.

567 (SAND–95-0488/1) **Geotechnical characterization of the North Ramp of the Exploratory Studies Facility: Yucca Mountain Site Characterization Project. Volume 1, Data summary.** Brechtel, C.E. (Agapito Associates, Inc., Grand Junction, CO (United States)); Lin, Ming; Martin, E.; Kessel, D.S. Sandia National Labs., Albuquerque, NM (United States). May 1995. 304p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95015011. Source: OSTI; NTIS; INIS; GPO Dep.

This report presents the results of geological and geotechnical characterization of the Miocene volcanic tuff rocks of the Timber Mountain and Paintbrush groups that the tunnel boring machine will encounter during excavation of the Exploratory Studies Facility (ESF) North Ramp. The is being constructed by the DOE as part of the Yucca Mountain Project site characterization activities. The purpose of these activities is to evaluate the feasibility of locating a potential high-level nuclear waste repository on lands adjacent to the Nevada Test Site, Nye County, Nevada. This report was prepared as part of the Soil and Rock Properties Studies in accordance with the 8.3.1.14.2 Study Plan. This report is volume 1 of the data summary.

568 (SAND–95-0488/2) **Geotechnical characterization of the North Ramp of the Exploratory Studies Facility: Yucca Mountain Site Characterization Project. Volume 2, NRG corehole data appendices.** Brechtel, C.E. (Agapito Associates, Inc., Grand Junction, CO (United

States)); Lin, Ming; Martin, E.; Kessel, D.S. Sandia National Labs., Albuquerque, NM (United States). May 1995. 487p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95015013. Source: OSTI; NTIS; INIS; GPO Dep.

This report presents the results of the geological and geotechnical characterization of the Miocene volcanic tuff rocks of the Timber Mountain and Paintbrush groups that the tunnel boring machine will encounter during excavations of the Exploratory Studies Facility (ESF) North Ramp. The information in this report was developed to support the design of the ESF North Ramp. The ESF is being constructed by the DOE as part of the Yucca Mountain Project site characterization activities. The purpose of these activities is to evaluate the potential to locate the national high-level nuclear waste repository on land within and adjacent to the Nevada Test Site (NTS), Nye County, Nevada. This report was prepared as part of the Soil and Rock Properties Studies in accordance with the 8.3.1.14.2 Study Plan to Provide Soil and Rock Properties. This is volume 2 which contains NRG Corehole Data for each of the NRG Holes.

569 (SAND–95-0591) **Batch and column studies of adsorption of Li, Ni and Br by a reference sand for contaminant transport experiments.** Seigel, M.D. (Sandia National Labs., Albuquerque, NM (United States)); Ward, D.B.; Bryan, C.R. Sandia National Labs., Albuquerque, NM (United States); Sandia Labs., Livermore, CA (United States). Sep 1995. 200p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000 ; AC04-76DP00789. Order Number DE96001139. Source: OSTI; NTIS; INIS; GPO Dep.

A processed quartz sand (Wedron 510), mined from the St. Peter sandstone, has been characterized by a variety of chemical and physical methods for use as a reference porous media in transport model validation experiments. Wedron 510 sand was used in an intermediate-scale experiment involving migration of Ni, Li and Br through a 6-m high x 3-m diameter caisson. Ni and Li adsorption/desorption, and Li/Ni site-competition experiments yielded information on the importance of the trace mineral phases to adsorption of Li and Ni by the sand. The presence of an iron hydroxide coating similar to goethite on the sand grains is suggested by visual observation and leaching experiments. Kaolinite was identified by SEM and XRD as a significant trace mineral phase in the sand and occurs as small particles coating the sand grains. Quartz, the predominant constituent of the sand by weight, does not appear to contribute significantly to the adsorption properties of the sand. Qualitatively, the adsorption properties of the sand can be adequately modeled as a two-mineral system (goethite and kaolinite). The studies described in this report should provide a basis for understanding transport of Ni, Li and Br through porous media similar to the reference sand. Techniques were developed for obtaining parameter values for surface complexation and kinetic adsorption models for the sand and its mineral components. These constants can be used directly in coupled hydrogeochemical transport codes. The techniques should be useful for characterization of other natural materials and elements in high-level nuclear waste in support of coupled hydrogeochemical transport calculations for Yucca Mountain.

570 (SAND–95-0857) **Unsaturated-zone fast-path flow calculations for Yucca Mountain groundwater travel time analyses (GWTT-94).** Arnold, B.W. (Sandia National Labs., Albuquerque, NM (United States)); Altman, S.J.; Robey, T.H. Sandia National Labs., Albuquerque, NM (United States). Aug 1995. 150p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE96002221. Source: OSTI; NTIS; INIS; GPO Dep.

Evaluation of groundwater travel time (GWTT) is required as part of the investigation of the suitability of Yucca Mountain as a potential high-level nuclear-waste repository site. The Nuclear Regulatory Commission's GWTT regulation is considered to be a measure of the intrinsic ability of the site to contain radionuclide releases from the repository. The work reported here is the first step in a program to provide an estimate of GWTT at the Yucca Mountain site in support of the DOE's Technical Site Suitability and as a component of a license application. Preliminary estimation of the GWTT distribution in the unsaturated zone was accomplished using a numerical model of the physical processes of groundwater flow in the fractured, porous medium of the bedrock. Based on prior investigations of groundwater flow at the site, fractures are thought to provide the fastest paths for groundwater flow; conditions that lead to flow in fractures were investigated and simulated. Uncertainty in the geologic interpretation of Yucca Mountain was incorporated through the use of geostatistical simulations, while variability of hydrogeologic parameters within each unit was accounted for by the random sampling of parameter probability density functions. The composite-porosity formulation of groundwater flow was employed to simulate flow in both the matrix and fracture domains. In this conceptualization, the occurrence of locally saturated conditions within the unsaturated zone is responsible for the initiation of fast-path flow through fractures. The results of the GWTT-94 study show that heterogeneity in the hydraulic properties of the model domain is an important factor in simulating local regions of high groundwater saturation. Capillary-pressure conditions at the surface boundary influence the extent of the local saturation simulated.

571 (SAND–95-0917) **Repository thermal response: A preliminary evaluation of the effects of modeled waste stream resolution.** Ryder, E.E.; Dunn, E. Sandia National Labs., Albuquerque, NM (United States). Sep 1995. 65p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE96001862. Source: OSTI; NTIS; INIS; GPO Dep.

One of the primary factors that influences our predictions of host-rock thermal response within a high level waste repository is how the waste stream's represented in the models. In the context of thermal modeling, waste stream refers to an itemized listing of the type (pressurized-water or boiling-water reactor), age, burnup, and enrichment of the spent nuclear fuel assemblies entering the repository over the 25-year emplacement phase. The effect of package-by-package variations in spent fuel characteristics on predicted repository thermal response is the focus of this report. A three-year portion of the emplacement period was modeled using three approaches to waste stream resolution. The first assumes that each package type emplaced in a given year is adequately represented by average characteristics. For comparison, two models that explicitly account for each waste package's individual characteristics were run; the first assuming a random selection of packages and the second an ordered approach aimed at locating the higher power output packages toward the center of the emplacement area. Results indicate that the explicit representation of packages results in hot and cold spots that could have performance assessment and design implications. Furthermore,

questions are raised regarding the representativeness of average characteristics with respect to integrated energy output and the possible implications of a mass-based repository loading approach.

572 (SAND–95-1546) **Alternative conceptual models and codes for unsaturated flow in fractured tuff: Preliminary assessments for GWTT-95.** Ho, C.K.; Altman, S.J.; Arnold, B.W. Sandia National Labs., Albuquerque, NM (United States). Sep 1995. 150p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE96001440. Source: OSTI; NTIS; INIS; GPO Dep.

Groundwater travel time (GWTT) calculations will play an important role in addressing site-suitability criteria for the potential high-level nuclear waste repository at Yucca Mountain,Nevada. In support of these calculations, Preliminary assessments of the candidate codes and models are presented in this report. A series of benchmark studies have been designed to address important aspects of modeling flow through fractured media representative of flow at Yucca Mountain. Three codes (DUAL, FEHMN, and TOUGH 2) are compared in these benchmark studies. DUAL is a single-phase, isothermal, two-dimensional flow simulator based on the dual mixed finite element method. FEHMN is a non-isothermal, multiphase, multidimensional simulator based primarily on the finite element method. TOUGH2 is anon isothermal, multiphase, multidimensional simulator based on the integral finite difference method. Alternative conceptual models of fracture flow consisting of the equivalent continuum model (ECM) and the dual permeability (DK) model are used in the different codes.

573 **A preliminary total-system performance assessment for the potential repository site Yucca Mountain.** Wilson, M.L. (Sandia National Labs., Albuquerque, NM (United States)); Barnard, R.W.; Dockerey, H.A.; Gauthier, J.H. *Radioactive Waste Management and Environmental Restoration;* 19(1-3): 45-72 (1994).

Special issue Yucca Mountain.

We present a preliminary performance assessment of Yucca Mountain, Nevada, U.S.A., as a potential site for a radioactive-waste repository. Models and results are discussed for four basic categories of processes and events: groundwater flow and aqueous transport, gas flow and gaseous transport, human intrusion, and basaltic volcanism. Calculated releases of radioactivity to the accessible environment are compared with U.S. Environmental Protection Agency requirements. The preliminary results show releases from human intrusion and volcanisms to fall well below the regulatory limits, though not all aspects of those categories have yet been considered. Calculated releases for nominal gaseous transport (of $^{14}CO_2$) are closest to the limits, indicating that models and data relating to gaseous releases may need to receive higher priority. (author) 15 figs., 33 refs.

574 **Analysis of releases due to drilling at the potential Yucca Mountain repository.** Barnard, R.W. (Sandia National Labs., Albuquerque, NM (United States)). *Transactions of the American Nuclear Society;* 69: 128-130 (1993). (CONF-931160–: American Nuclear Society (ANS) winter meeting, San Francisco, CA (United States), 14-18 Nov 1993).

Human intrusion into the potential repository at Yucca Mountain, Nevada, was modeled in the Total-System Performance Assessment (TSPA-91) recently completed for the Yucca Mountain Site Characterization Project Office of the U.S. Department of Energy. The scenario modeled assumed that the repository would be penetrated at random locations by a number of boreholes drilled using 20th-century rotary drilling techniques. The probabilities of this scenario occurring depend on several factors. For these analyses, it was assumed that there was a probability of 1.0 that people would be drilling at the site for 10,000 yr.

575 **The influence of strain rate and sample inhomogeneity on the moduli and strength of welded tuff.** Martin, R.J. III (New England Research Inc., White River Junction, VT (United States)); Boyd, P.J.; Noel, J.S.; Price, R.H. *International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts;* 30(7): 1507-1510 (1993). Contract DE-AC04-76DP00789. (CONF-930644–: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993).

A series of constant strain rate, unconfined compression experiments was performed on saturated welded tuff specimens collected from Busted Butte near Yucca Mountain, Nevada. Twenty specimens were loaded to failure at strain rates ranging from 10^{-9} s^{-1} to 10^{-3} s^{-1}, under ambient pressure and temperature conditions. The strength of the specimens showed a continuous decrease with decreasing strain rate between 10^{-9} s^{-1} and 10^{-5} s^{-1}. At the highest strain rate, 10^{-3} s^{-1}, strengths were less than those observed at 10^{-5} s^{-1}, likely due to hydrofracturing within the specimen at rapid loading rates. Reduction in strength, corresponding to the decrease in strain rate, is explained in terms of stress corrosion cracking. A detailed examination of six specimens tested at a strain rate of 10^{-9} s^{-1}, using acoustic wave velocities and CT scans, shows a correlation between the nature of the microstructure of the specimens and the observed strengths and elastic moduli. (Author).

576 **Simulation of the arid climate of the southern great basin using a regional climate model.** Giorgi, F. (National Center for Atmospheric Research, Boulder, CO (United States)); Bates, G.T.; Nieman, S.J. *Bulletin of the American Meteorological Society;* 73(11): 1807-1822 (Nov 1992).

As part of the development effort of a regional climate model (RCM) for the southern Great Basin, this paper presents a validation analysis of the climatology generated by a high-resolution RCM driven by observations. Two multi-year simulations were performed over the western United States with the RCM driven by European Centre for Medium-Range Weather Forecasts analyses of observations. This validation analysis is the first phase of a project to produce simulations of future climate scenarios over a region surrounding Yucca Mountain, Nevada, the only location currently being considered as a potential high-level nuclear-waste repository site. Model-produced surface air temperatures and precipitation were compared with observations from five southern Nevada stations located in the vicinity of Yucca Mountain. The seasonal cycles of temperature and precipitation were simulated well. Monthly and seasonal temperature biases were generally negative and largely explained by differences in elevation between the observing stations and the model topography. The model-simulated precipitation captured the extreme dryness of the Great Basin. Average yearly precipitation biases were mostly negative in the summer and positive in the winter. The number of simulated daily precipitation events for various precipitation intervals was within factors of 1.5-3.5 of observed. Overall, the model tended to overestimate the

number of light precipitation events and underestimate the number of heavy precipitation events. At Yucca Mountain, simulated precipitation, soil moisture content, and water infiltration below the root zone (top 1 m) were maximized in the winter. Evaporation peaked in the spring after temperatures began to increase. The conclusion drawn from this validation analysis is that this high-resolution RCM simulates the regional surface climatology of the southern Great Basin reasonably well when driven by meteorological fields derived from observations. 26 refs., 9 figs., 4 tabs.

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577 **Modeling of strongly heat-driven flow processes at a potential high-level nuclear waste repository at Yucca Mountain, Nevada.** Pruess, K. (Lawrence Berkeley Lab., CA (United States)); Tsang, Y. pp. 568-575 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC03-76SF00098. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Two complementary numerical models for analyzing high-level nuclear waste emplacement at Yucca Mountain have been developed. A vertical cross-sectional (X-Z) model permits a realistic representation of hydrogeologic features, such as alternating tilting layers of welded and non-welded tuffs, fault zones, and surface topography. An alternative radially symmetric (R-Z) model is more limited in its ability to describe the hydrogeology of the site, but is better suited to model heat transfer in the host rock. Our models include a comprehensive description of multiphase fluid and heat flow processes, including strong enhancements of vapor diffusion from pore-level phase change effects. The neighborhood of the repository is found to partially dry out from the waste heat. A condensation halo of large liquid saturation forms around the drying zone, from which liquid flows downward at large rates. System response to infiltration from the surface and to ventilation of mined openings is evaluated. The impact of the various flow processes on the waste isolation capabilities of the site is discussed.

578 **The role of fault zone in affecting multiphase flow at Yucca Mountain.** Tsang, Y.W. (Lawrence Berkeley Lab., CA (United States)); Pruess, K.; Wang, J.S.Y. pp. 660-666 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC03-76SF00098. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Within Yucca Mountain, the potential High Level Nuclear-Waste Repository site, there are large scale fault zones, most notably the Ghost Dance Fault. The effect of such high-permeability, large-scale discontinuities on the flow and transport is a question of concern in assessing the ability of the site to isolate radio-nuclides from the biosphere. In this paper, we present a numerical study to investigate the role of the fault in affecting both the liquid and gas phase flows in the natural state at Yucca Mountain prior to waste emplacement, as well as after the waste emplacement when the fluid flow is strongly heat-driven. Our study shows that if the characteristic curves of the Ghost Dance Fault obey the same relationship between saturated permeability and capillary scaling parameter, is as observed from the measured data of Yucca Mountain welded and non[redacted] tuffs, Apache Leap tuffs, and Las Cruces soil, then a large saturated permeability of the Ghost Dance Fault will play little role in channeling water into the fault, or in enhancing the flow of water down the fault. However, the Fault may greatly enhance the upward gas flow after emplacement of waste. This may have implications on the transport of gaseous radio-nuclides such as C^{14}. The results of this study also focus attention on the need for field measurements of fluid flow in the fault zones.

579 **Studies of the role of fault zones on fluid flow using the site-scale numerical model of Yucca Mountain.** Wittwer, C.S. (Lawrence Berkeley Lab., CA (United States)); Chen, G.; Bodvarsson, G.S. pp. 667-674 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC03-76SF00098. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The three-dimensional grid of the site-scale model developed for the unsaturated zone at Yucca Mountain was used to perform two-dimensional simulations with the TOUGH2 computer program. The grid geometry consists of seventeen non-uniform layers which represent the lithological variations within the four main welded and non-welded hydrogeological units. The fault zones are explicitely modeled as porous medium using various assumptions regarding their permeabilities and characteristic curves. Matrix flow is approximated using the van Genuchten model, and the equivalent continuum approximation is used to account for fracture flow in the welded units. Steady state simulations are performed with various uniform infiltration rates. The results are interpreted in terms of the effect of the fault characteristics on the moisture flow distribution, and on the location and formation of preferential pathways.

580 **Geohydrologic data and models of Rainier Mesa and their implications to Yucca Mountain.** Wang, J.S.Y. (Lawrence Berkeley Lab., CA (United States)); Cook, N.G.W.; Wollenberg, H.A.; Carnahan, C.L.; Javandel, I.; Tsang, C.F. pp. 675-681 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC03-76SF00098. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The geohydrologic data collected at Rainier Mesa provide the only extensive observations in tunnels presently available on flow and transport in tuff units similar to those of a potential nuclear waste repository at Yucca Mountain. This information can, therefore, be of great value in planning the Exploratory Studies Facility (ESF) testing in underground drifts at Yucca Mountain. In this paper, we compare the geohydrologic characteristics of tuff units of these two sites and summarize the hydrochemical data indicating the presence of nearly meteoric water in Rainier Mesa tunnels. A simple analytic model is used to evaluate the possibility of propagating transient pulses of water along fractures or faults through the Paintbrush nonwelded tuff unit to reach the tunnel beds below. The results suggest that fast flow could occur without significant mixing between meteoric fracture

water and matrix pore water. The implications of these findings on planning for the ESF Calico Hills study at Yucca Mountain are discussed.

581 **An inverse procedure for estimating the unsaturated hydraulic conductivities of volcanic tuffs.** Zimmerman, R.W. (Lawrence Berkeley Lab., CA (United States)); Bodvarsson, G.S.; Flint, A.L.; Flint, L.E. pp. 1052-1058 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 DOE Contract AC03-76SF00098. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

A procedure is developed for estimating the hydraulic conductivity function of unsaturated volcanic tuff, using measurements of the sorptivity and capillary pressure functions. The method assumes that the sorptivity is a linear function of the initial saturation, as is suggested by experimental data. The procedure is tested on a vitrified tuff from the Calico Hills unit at Yucca Mountain, and the predicted conductivities are in reasonable agreement with measured values. Further tests of this method are needed to establish whether or not it can be routinely used for conductivity predictions.

582 **Flow and transport in hierarchically fractured systems.** Karasaki, K. (Lawrence Berkeley Laboratory, CA (United States)). pp. 1106-1111 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC03-76SF00098. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Preliminary results indicate that flow in the saturated zone at Yucca Mountain is controlled by fractures. A current conceptual model assumes that the flow in the fracture system can be approximated by a three-dimensionally interconnected network of linear conduits. The overall flow system of rocks at Yucca Mountain is considered to consist of hierarchically structured heterogeneous fracture systems of multiple scales. A case study suggests that it is more appropriate to use the flow parameters of the large fracture system for predicting the first arrival time, rather than using the bulk average parameters of the total system.

583 **Radionuclide solubility and speciation studies for the Yucca Mountain site characterization project.** Nitsche, H. (Lawrence Berkeley Laboratory, CA (United States)); Roberts, K.; Prussin, T.; Keeney, D.; Carpenter, S.A.; Becraft, K.; Gatti, R.C. pp. 1490-1495 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Yucca Mountain, Nevada, U.S.A., is being investigated for its suitability as a potential site for a geologic nuclear waste repository. As part of the site characterization studies, actinide solubilities and speciations were studied at pH 6, 7, and 8.5 at 25° and 60°C in two different groundwaters from the vicinity of Yucca Mountain. The groundwaters differ substantially in total dissolved carbonate concentration, and to a lesser extent in ionic strength. In the waters with higher carbonate content, the solubilities of neptunium(V) decreased, whereas those of americium (III) increased at 25°C and decreased at 60°C. The solids formed were sodium neptunium carbonates and americium hydroxycarbonates. Plutonium solubilities did not significantly change with changing water composition because the solubility-controlling solids were mostly amorphous Pu(IV) polymers that contained only small amounts of carbonate.

584 **Flow visualization and relative permeability measurements in rough-walled fractures.** Persoff, P. (Lawrence Berkeley Laboratory, CA (United States)); Pruess, K. pp. 2033-2041 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC03-76SF00098. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Two-phase flow conditions are likely to exist in the rock formations surrounding high level nuclear waste repositories such as Yucca Mountain and WIPP. Two-phase (gas-liquid) flow experiments were done in a natural rock fracture and transparent replicas of natural fractures. Liquid was injected at constant volume flow rate, and gas was injected at either constant mass flow rate or constant pressure. When gas was injected at constant mass flow rate, the gas inlet pressure, and inlet and outlet capillary pressures, generally did not reach steady state by cycled irregularly. Flow visualization showed that this cycling was due to repeated blocking and unblocking of gas flow paths by liquid. Relative permeabilities calculated from flow rate and pressure data show that the sum of the relative permeabilities of the two phases is much less than 1, indicating that each phase interferes strongly with the flow of the other. Comparison of the relative permeability curves with typical curves for porous media (Corey curves) show that the phase interference is stronger in fractures than in typical porous media.

585 **Single fracture aperture patterns: Characterization by slit-island fractal analysis.** Cox, B.L. (Lawrence Berkeley Laboratory, CA (United States)); Wang, S.Y. pp. 2053-2060 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC03-76SF00098. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Fracture aperture surfaces from two different fractures (one crack and one fault) are characterized and compared using geostatistical and fractal methods. Slit-island fractal dimensions of 1.3 and 1.4 are very similar. Cutoff patterns ('indicator maps') are not similar: the crack has a radial pattern and the fault has elongated patterns in the faulting direction. The cuttoff patterns could be used to test the significance of these two different patterns for single fracture fluid flow models. This research has applications for and funding from the Yucca Mountain Site Characterization Project.

586 **Photothermal deflection spectroscopy investigations of uranium electrochemistry - II.** Rudnicki, J.D. (Lawrence Berkeley Lab., CA (United States)); Russo, R.E. pp. 431-436 of Scientific basis for nuclear waste management XVII. Barkatt, A. (ed.); Van Konynenburg, R.A. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1994). pp. 964 From Fall meeting of the Materials Research Society (MRS); Boston, MA (United States); 29 Nov - 3 dec 1993.

Photothermal Deflection Spectroscopy (PDS) has been applied to the study of uranium oxide electrochemistry. PDS measures the optical absorption of the sample surface and

concentration gradients formed in the electrolyte. Both of these measurements are performed in situ under dynamic conditions. The combination of these two measurements provides information that can be used to infer the mechanism of the UO_2 surface chemistry. These studies of the uranium dissolution mechanism are performed in pH 10.5 sodium sulfate electrolytes at 22°C. The electrolytes are free from oxygen, and complexing species. Our results suggest that dissolution of UO_2 can occur at oxidizing potentials as low as -300 mV vs. saturated calomel electrode (SCE). The optical absorption and concentration gradient results provide evidence for a substantial surface change that occurs at an oxidation potential of +300 mV. The results show that the surface layer formed by this change dissolves slowly by a non-electrochemical reaction.

587 **Analysis of flow along anisotropic fractures in partially saturated media.** Wang, J.S.Y. (Lawrence Berkeley Lab., CA (United States)); Cox, B.L. pp. 1915-1921 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Potential fast flow paths could exist along fractures and faults below washes or other localized recharge areas. When a finite amount of water percolates downward, the imbibition process will remove water from the fracture into the unsaturated tuff matrix, especially in nonwelded units with large porosity and high sorptivity. The anisotropic characteristics of a fault sample, the flow path distribution, and the matrix imbibition effect on fracture flows are analyzed. For the Paintbrush nonwelded bedded tuff unit, the saturation in the middle of a wash is higher than the values measured in boreholes on the side-slopes. The implications of calculated results for the interpretation of saturation distribution in the wash are discussed.

588 **Approximating the imbibition and absorption behavior of a distribution of matrix blocks by an equivalent spherical block.** Zimmerman, R.W. (Lawrence Berkeley Lab., CA (United States)); Bodvarsson, G.S. pp. 2030-2037 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AC03-76SF00098. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The matrix blocks in the fractured unites at Yucca Mountain are the regions of rock material that are formed by the sets of intersecting fractures. A theoretical study is presented of the effect of matrix block shape and matrix block size distribution on liquid inbibition and solute absorption in a fractured rock mass. It is shown that the behavior of an individual irregularly-shaped matrix block can be modeled with reasonable accuracy by using the results for a spherical matrix block, if one uses an effective radius $\bar{a} = 3V/a$, where V is the volume of the block and A is its surface area. In the early-time regime of matrix imbibition, it is shown that a collection of blocks of different sizes can be modeled by a single equivalent block, with an equivalent radius of $\langle a^{-1} \rangle^{-1}$, where the average is taken on a volumetrically-weighted basis. In an intermediate time regime, it is shown for the case where the radii are normally distributed that the equivalent radius is reasonably well approximated by the mean radius <a>. In the long-time limit, where no equivalent radius can be rigorously defined, an asymptotic expression is derived for the cumulative diffusion as a function of the mean and the standard deviation of the radius distribution function.

589 **Preliminary analysis of three-dimensional moisture flow within Yucca Mountain, Nevada.** Bodvarsson, G. (Lawrence Berkeley Lab., CA (United States)); Chen, Gang; Wittwer, C. pp. 2038-2047 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AC03-76SF00098. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The continuous development of the three-dimensional site-scale model of Yucca Mountain, Nevada is described. Three-dimensional moisture flow simulations are conducted, that show how the stratigraphic units and faults offsets and properties at Yucca Mountain created complex three-dimensional flow patterns. Even for areally uniform infiltration rates, these geological complexities result in large lateral flow components and often concentrated flow into the water table. When the major faults are assumed to act as capillary barriers, moisture buildup occurs close to the faults. Conversely, when the faults are assumed to readily absorb water and allow for vertical migration, lateral flow is greatly enhanced and relatively dry conditions are found in the rock matrix adjacent to the faults. These results suggest that careful observations of saturations and rock matrix conditions in rock masses near major faults may help determine the hydrological characteristics of the faults. The site-scale model has been used to predict conditions in wells UZ-16 and other wells, in order to investigate the predictive capabilities of the model. Gas flow and the geothermal gradient have been incorporated into the model.

590 **A study of two phase flow in fracture networks.** Karasaki, K. (Lawrence Berkeley Labs., CA (United States)); Pruess, K.; Vomvoris, S.; Segan, S. pp. 2633-2638 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AC03-76SF00098. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Accurate characterization of the two-phase flow behavior of the fractured rock mass is vital to the safety of a potential high level nuclear waste repository in the unsaturated, fractured welded tuff at Yucca Mountain, NV. A tool for studying the two-phase flow properties of a fracture networks was developed. It is based on a simple mechanistic model in which the capillary pressure of a fracture is a unique function of the aperture. Whether a particular fracture element is occupied by wetting fluid or non-wetting fluid is determined by allowability and accessibility criteria. Relative permeability characteristics of a simulated fracture network were investigated using the model. Different assumptions are examined regarding the interactions between phases. In all cases, strong phase interference was observed. Hysteresis effects and irreducible saturation were also explained based on the model.

591 **Phenomenological studies of two-phase flow processes for nuclear waste isolation.** Pruess, K. (Lawrence Berkeley Lab., CA (United States)); Finsterle, S.;

Persoff, P.; Oldenburg, C. pp. 2639-2647 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The U.S. civilian radioactive waste management program is unique in its focus on a site in the unsaturated zone, at Yucca Mountain, Nevada. Two-phase flow phenomena can also play an important role in repositories beneath the water table where gas is generated by corrosion, hydrolysis, and biological degradation of the waste packages. An integrated program has been initiated to enhance our understanding of two-phase flow behavior in fractured rock masses. The studies include two-phase (gas-liquid) flow experiments in laboratory specimens of natural rock fractures, analysis and modeling of heterogeneity and instability effects in two-phase flow, and design and interpretation of field experiments by means of numerical simulation. We present results that identify important aspects of two-phase flow behavior on different space and time scales which are relevant to nuclear waste disposal in both unsaturated and saturated formations.

592 **Micro-scale studies of unsaturated flow in fractured media.** Wan, J. (Lawrence Berkeley Lab., CA (United States)); Tokunaga, T.K.; Tsang, Chin-Fu. pp. 14-16 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AC03-76SF00098. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Transport of water and solutes through fractured porous media is influenced by a wide variety of complex phenomena including preferential flow, fracture-matrix interactions, and entrapment of the air phase. We have developed a new method for constructing glass fracture-matrix micromodels which provide direct visualization and quantification of the aforementioned phenomena in fracture systems. In the fracture-matrix micromodels, sequential etching provides the necessary contrast between matrix pore-sizes and fracture apertures. Direct visualization of pore-scale flow fields and measurements of local velocity profiles were made possible through tracing trajectories of suspended fluorescent microspheres under a microscope. Results obtained thus far include direct measurements of parabolic velocity profiles in water-saturated fractures, details of flowlines associated with trapped air-water interfaces in partially-saturated fractures, and evidence for preferential unsaturated wedge flow along lines of contact between blocks. In general, micromodel experiments are useful for testing conceptual models concerning transport, and for detecting previously unobservable pore-scale phenomena.

593 **Experimental and numerical aqueous flow through a partially saturated fracture.** Cox, B.L. (Lawrence Berkeley Lab., CA (United States)); Finsterle, S.; Wang, J.S.Y. pp. 20-22 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AC03-76SF00098. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Partially-saturated aqueous flow through rough-walled fractures is studied by means of physical experiments and numerical simulations. Experiments are performed with epoxy replicas of the fractures. The rate of fluid advance through the fracture is measured and fluid patterns are visualized. Permeability and capillary pressure fields are generated from measured aperture distributions. Capillary pressure boundary conditions of varying strength are applied, and both transient and steady-state flow of water are simulated. The anisotropy ratio is calculated as a function of average liquid saturation. Resulting water content distributions, as well as flow fields, are compared with those obtained from physical experiments.

594 **On water infiltration in rough-walled fractures.** Geller, J.T. (Lawrence Berkeley Lab., CA (United States)); Pruess, K. pp. 23-25 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AC03-76SF00098. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

A serious concern regarding the suitability of Yucca Mountain for nuclear waste isolation is the potential for rapid transport of dissolved radionuclides along localized preferential flow paths in fractures. Hydrogeologic and geochemical studies at Rainier Mesa have provided strong evidence for fast water flow through unsaturated fractured rock. These observations cannot be reconciled with conceptual models of uniform infiltration or models that postulate strong capillary imbibition effects from the rock matrix on water flowing in fractures. Alternative concepts have been proposed such as the 'weeps model', which is supported by observations of gravitationally unstable flow (fingering) in heterogeneous fractures. In an effort to explore the conditions and characteristics of preferential flow we have performed physical and numerical experiments in rough-walled fractures.

595 **Spatial resolution in hydrologic characterization.** Vasco, D.W. (Lawrence Berkeley Lab., CA (United States)); Long, J.C.S.; Gupta, A.D. pp. 61-63 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AC03-76SF00098. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

An important component of modeling subsurface fluid flow involves characterizing the spatial variations in hydrologic parameters. One of the key problems in characterization is determining how well it is possible to resolve this heterogeneity based upon well and tracer tests. The variations in hydrological properties may be quite abrupt, reflecting many small scale features such as faults and fractures. So hydrologic parameters are most accurately described as a continuous variation in space. Characterizing heterogeneity involves trying to specify an infinite number of parameters from a finite number of observations, an inverse problem. In this paper we utilize geophysical inverse techniques in the treatment of both transient pressure and tracer data for heterogeneity characterization. Specifically, we evaluate a proposed experimental configuration at the Aspo Hard Rock Laboratory, Sweden to see what the proposed tests might resolve about the heterogeneity. We intend to apply the techniques in the evaluation and analysis of experiments at the C-holes at Yucca Mountain.

596 **Reactive transport studies at the Raymond Field Site.** Freifeld, B. (Lawrence Berkeley Lab., CA (United States)); Karasaki, K.; Solbau, R.; Cohen, A. pp. 91-93 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AC03-76SF00098. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

To ensure the safety of a nuclear waste repository, an understanding of the transport of radionuclides from the repository nearfield to the biosphere is necessary. At the Raymond Field Site, in Raymond, California, tracer tests are being conducted to test characterization methods for fractured media and to evaluate the equipment and tracers that will be used for Yucca Mountain's fracture characterization. Recent tracer tests at Raymond have used reactive cations to demonstrate transport with sorption. A convective-dispersive model was used to simulate a two-well recirculating test with reasonable results. However, when the same model was used to simulate a radially convergent tracer test, the model poorly predicted the actual test data.

597 **Neptunium, plutonium, and americium solubility and speciation studies in a neutral electrolyte with a total carbonate concentration simulating UE-25P No. 1 well water.** Becraft, K.A. (Lawrence Berkeley Lab., CA (United States)); Torretto, P.C.; Nitsche, H. pp. 137-138 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AC03-76SF00098. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

In these experiments we have approached the solubility equilibrium from oversaturation. Results are given for solubility and speciation experiments of $^{237}NpO_2^+$, $^{239}Pu^{4+}$, and $^{241}Am^{3+}$ in a neutral electrolyte (0.1 M $NaClO_4$) containing a total carbonate concentration similar to UE-25p No. 1 groundwater (0.015 M) at 25° C and at three pH values (6, 7, and 8.5). In these experiments, the solubility-controlling solids were identified and the speciation and/or oxidation states present in the supernatant solutions were determined. Trivalent neodymium was used as an oxidation state analog for $^{241}Am(III)$ in order to reduce the radiolysis effects in the solutions. The $^{241}Am(III)$ was included as a tracer for radioanalytical counting of samples.

598 **Recent development of the LBL/USGS site-scale model of Yucca Mountain, Nevada.** Bodvarsson, G.S. (Lawrence Berkeley Lab., CA (United States)); Aunzo, Z.; Chen, Gang. pp. 157-159 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AC03-76SF00098. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The three-dimensional site-scale model of Yucca Mountain has been under development by Lawrence Berkeley Laboratory and U.S. Geological Survey (LBL/USGS) over the last four years. The model has been used to evaluate moisture flow within Yucca Mountain for different assumed infiltration patterns and for various assumed hydrological conditions and properties of faults. This model is under constant development as new data may require grid modifications or extensions as new wells are drilled and information from the Exploratory Studies Facility (ESF) become available. Recent development of the model include calibrations against observed gas and temperature data, incorporation of the ESF into the numerical grid, and the areal extension of the model in all directions to include data from nearby wells and for studies of water infiltration into nearby faults such as the Solitario Canyon fault. This paper summarizes these recent developments of the LBL/USGS site-scale model.

599 **Assuring 'end-game' integrity: Testbed approach to deployment of detector systems.** Carpenter, S.A. (Lawrence Berkeley Lab., CA (United States)); Gatti, R.C.; Becraft, K.A. pp. 685-687 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AC03-76SF00098. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Engineered and natural barriers can limit, and possibly eliminate, radionuclide migration to the far field and accessible environment over geologic time scales. Nevertheless, proper deployment of replaceable monitoring systems can inform future operators (1) if radionuclide release or migration occurs, (2) its general location and migration path, and (3) its magnitude and rate of migration. If necessary, corrective action can be taken. The time scale for these monitoring and detector-replacement activities is assumed to be from 10's to possibly 1000's of years. Detector placement would be in a phased approach depending upon the potential loss paths identified in the overall site characterization and possibly other investigations.

600 (LBL–35388) **Preliminary analysis of three-dimensional moisture flow within Yucca Mountain, Nevada.** Bodvarsson, G. (Lawrence Berkeley Lab., CA (United States)); Chen, G.; Wittwer, C. Lawrence Berkeley Lab., CA (United States). Mar 1994. 10p. Sponsored by US-DOE, Washington, DC (United States). DOE Contract AC03-76SF00098. (CONF-940553–63: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94013097. Source: OSTI; NTIS; GPO Dep.

The continuous development of the three-dimensional site-scale model of Yucca Mountain Nevada is described. Three-dimensional moisture flow simulations are conducted, that show how the stratigraphic units and fault offsets and properties at Yucca Mountain create complex three-dimensional flow patterns. Even for a really uniform infiltration rates, these geological complexities result in large lateral flow components and often concentrated flow into the water table. When the major faults are assumed to act as capillary barriers, moisture buildup occurs close to the faults. Conversely, when the faults are assumed to readily absorb water and allow for vertical migration, lateral flow is greatly enhanced and relatively dry conditions are found in the rock matrix adjacent to the faults. These results suggest that careful observations of saturations and rock matrix conditions in rock masses near major faults may help determine the hydrological characteristics of the faults. The site-scale model has been used to predict conditions in wells UZ-16 and other wells, in order to investigate the predictive capabilities of the model. Gas flow and the Geothermal gradient have been incorporated into the model.

601 (LBL–35518) **T2CG1, a package of preconditioned conjugate gradient solvers for TOUGH2.** Moridis, G. (Lawrence Berkeley Lab., CA (United States). Earth Sciences Div.); Pruess, K.; Antunez, E. Lawrence Berkeley Lab., CA (United States). Mar 1994. 18p. Sponsored by US-DOE, Washington, DC (United States). DOE Contract AC03-76SF00098. Order Number DE94015159. Source: OSTI; NTIS; INIS; GPO Dep.

Most of the computational work in the numerical simulation of fluid and heat flows in permeable media arises in the solution of large systems of linear equations. The simplest technique for solving such equations is by direct methods. However, because of large storage requirements and accumulation of roundoff errors, the application of direct solution techniques is limited, depending on matrix bandwidth, to systems of a few hundred to at most a few thousand simultaneous equations. T2CG1, a package of preconditioned conjugate gradient solvers, has been added to TOUGH2 to complement its direct solver and significantly increase the size of problems tractable on PCs. T2CG1 includes three different solvers: a Bi-Conjugate Gradient (BCG) solver, a Bi-Conjugate Gradient Squared (BCGS) solver, and a Generalized Minimum Residual (GMRES) solver. Results from six test problems with up to 30,000 equations show that T2CG1 (1) is significantly (and invariably) faster and requires far less memory than the MA28 direct solver, (2) it makes possible the solution of very large three-dimensional problems on PCs, and (3) that the BCGS solver is the fastest of the three in the tested problems. Sample problems are presented related to heat and fluid flow at Yucca Mountain and WIPP, environmental remediation by the Thermal Enhanced Vapor Extraction System, and geothermal resources.

602 (LBL–35560) **Approximating the imbibition and absorption behavior of a distribution of matrix blocks by an equivalent spherical block.** Zimmerman, R.W.; Bodvarsson, G.S. Lawrence Berkeley Lab., CA (United States). Mar 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. (CONF-940553–62: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94013105. Source: OSTI; NTIS; INIS; GPO Dep.

A theoretical study is presented of the effect of matrix block shape and matrix block size distribution on liquid imbibition and solute absorption in a fractured rock mass. It is shown that the behavior of an individual irregularly-shaped matrix block can be modeled with reasonable accuracy by using the results for a spherical matrix block, if one uses an effective radius $\bar{a} = 3V/A$, where V is the volume of the block and A is its surface area. In the early-time regime of matrix imbibition, it is shown that a collection of blocks of different sizes can be modeled by a single equivalent block, with an equivalent radius of $\langle a^{-1} \rangle^{-1}$, where the average is taken on a volumetrically-weighted basis. In an intermediate time regime, it is shown for the case where the radii are normally distributed that the equivalent radius is reasonably well approximated by the mean radius $\langle a \rangle$. In the long-time limit, where no equivalent radius can be rigorously defined, an asymptotic expression is derived for the cumulative diffusion as a function of the mean and the standard deviation of the radius distribution function.

603 (LBL–35976) **Hydraulic conductivity of rock fractures.** Zimmerman, R.W.; Bodvarsson, G.S. Lawrence Berkeley Lab., CA (United States). Oct 1994. 66p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. Order Number DE95004815. Source: OSTI; NTIS; INIS; GPO Dep.

Yucca Mountain, Nevada contains numerous geological units that are highly fractured. A clear understanding of the hydraulic conductivity of fractures has been identified as an important scientific problem that must be addressed during the site characterization process. The problem of the flow of a single-phase fluid through a rough-walled rock fracture is discussed within the context of rigorous fluid mechanics. The derivation of the cubic law is given as the solution to the Navier-Stokes equations for flow between smooth, parallel plates, the only fracture geometry that is amenable to exact treatment. The various geometric and kinetic conditions that are necessary in order for the Navier-Stokes equations to be replaced by the more tractable lubrication or Hele-Shaw equations are studied and quantified. Various analytical and numerical results are reviewed pertaining to the problem of relating the effective hydraulic aperture to the statistics of the aperture distribution. These studies all lead to the conclusion that the effective hydraulic aperture is always less than the mean aperture, by a factor that depends on the ratio of the mean value of the aperture to its standard deviation. The tortuosity effect caused by regions where the rock walls are in contact with each other is studied using the Hele-Shaw equations, leading to a simple correction factor that depends on the area fraction occupied by the contact regions. Finally, the predicted hydraulic apertures are compared to measured values for eight data sets from the literature for which aperture and conductivity data were available on the same fracture. It is found that reasonably accurate predictions of hydraulic conductivity can be made based solely on the first two moments of the aperture distribution function, and the proportion of contact area. 68 refs.

604 (LBL–36235) **Flow and transport simulations using T2CG1, a package of conjugate gradient solvers for the TOUGH2 family of codes.** Moridis, G.; Pruess, K. Lawrence Berkeley Lab., CA (United States). Apr 1995. 118p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. Order Number DE96000874. Source: OSTI; NTIS (documentation only); ESTSC (complete software package), P.O. Box 1020, Oak Ridge, TN 37831-1020 (United States); GPO Dep.

This report discusses the details of modifications made to the TOUGH2 family of codes to complement its direct solver which significantly increases the size of problems solved by the TOUGH2 code. With this modification, the TOUGH2 system is being tested in multiphase, multicomponent fluid and heat flow problems related to vadose zone hydrology, nuclear waste disposal, and environmental remediation.

605 (LBL–36467) **Combined analysis of surface reflection imaging and vertical seismic profiling at Yucca Mountain, Nevada.** Daley, T.M. (Lawrence Berkeley Lab., CA (United States). Earth Sciences Div.); Majer, E.L.; Karageorgi, E. Lawrence Berkeley Lab., CA (United States). Aug 1994. 44p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. Order Number DE95006724. Source: OSTI; NTIS; INIS; GPO Dep.

This report presents results from surface and borehole seismic profiling performed by the Lawrence Berkeley Laboratory (LBL) on Yucca Mountain. This work was performed as part of the site characterization effort for the potential high-level nuclear waste repository. Their objective was to provide seismic imaging from the near surface (200 to 300 ft. depth) to the repository horizon and below, if possible. Among the issues addressed by this seismic imaging work

are location and depth of fracturing and faulting, geologic identification of reflecting horizons, and spatial continuity of reflecting horizons. The authors believe their results are generally positive, with tome specific successes. This was the first attempt at this scale using modern seismic imaging techniques to determine geologic features on Yucca Mountain. The principle purpose of this report is to present the interpretation of the seismic reflection section in a geologic context. Three surface reflection profiles were acquired and processed as part of this study. Because of environmental concerns, all three lines were on preexisting roads. Line 1 crossed the mapped surface trace of the Ghost Dance fault and it was intended to study the dip and depth extent of the fault system. Line 2 was acquired along Drill Hole wash and was intended to help the ESF north ramp design activities. Line 3 was acquired along Yucca Crest and was designed to image geologic horizons which were thought to be less faulted along the ridge. Unfortunately, line 3 proved to have poor data quality, in part because of winds, poor field conditions and limited time. Their processing and interpretation efforts were focused on lines 1 and 2 and their associated VSP studies.

606 (LBL–36527) **Inverse modeling as a step in the calibration of the LBL-USGS site-scale model of Yucca Mountain.** Finsterle, S.; Bodvarsson, G.S.; Chen, G. Lawrence Berkeley Lab., CA (United States). May 1995. 3p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. (CONF-9504179–4: 6. annual international conference on high level radioactive waste management, Las Vegas, NV (United States), 30 Apr - 5 may 1995). Order Number DE95016455. Source: OSTI; NTIS; INIS; GPO Dep.

Calibration of the LBL-USGS site-scale model of Yucca Mountain is initiated. Inverse modeling techniques are used to match the results of simplified submodels to the observed pressure, saturation, and temperature data. Hydrologic and thermal parameters are determined and compared to the values obtained from laboratory measurements and conventional field test analysis.

607 (LBL–36614) **Progress on flow visualization and relative permeability measurement in transparent replicas of natural fractures from Yucca Mountain.** Persoff, P. (Lawrence Berkeley Lab., CA (United States). Earth Sciences Div.); Pruess, K.; Petersen, L.P. Lawrence Berkeley Lab., CA (United States). Jan 1995. 27p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. Order Number DE95006723. Source: OSTI; NTIS; INIS; GPO Dep.

Small sections (75 mm x 75 mm) of two natural rock fractures from outcrop boulders of Tiva Canyon tuff have been reproduced as transparent replicas. Aperture maps were drawn from images of the replicas filled with dye. Apertures were measured by the areas occupied by liquid drops of known volume. For both these fractures, the average aperture is about 350 μm, while the hydraulic aperture is less (72 and 130 μm). Two-phase (air-water) flow experiments have been conducted in these replicas to measure relative permeability and capillary pressures. The results obtained confirm the results of previous fracture experiments, and theoretical analysis, that the sum of relative permeabilities is much less than 1 at intermediate saturations. The welded tuffs in the vadose zone of Yucca Mountain, Nevada, are being investigated as the potential site of a geological repository for high-level nuclear wastes.

608 (LBL–36807) **Transient dual-porosity simulations of unsaturated flow in fractured rocks.** Zimmerman, R.W.; Hadgu, T.; Bodvarsson, G.S. Lawrence Berkeley Lab., CA (United States). Jan 1995. 112p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. Order Number DE95012438. Source: OSTI; NTIS; INIS; GPO Dep.

This report describes the development and use of a semi-analytical dual-porosity simulator for unsaturated flow in fractured rock masses. Fluid flow between the fracture network and the matrix blocks is described by a nonlinear equation that relates the imbibition rate to the local difference in liquid-phase pressure between the fractures and the matrix blocks. This equation is a generalization of the Warren-Root equation, but is accurate in both early and late time regimes. The fracture/matrix interflow equation has been incorporated into a computational module that acts as a source/sink term for fracture elements; this module is compatible with the unsaturated flow simulator TOUGH. Flow processes are then simulated using only fracture elements in the computational grid. This semi-analytical dual-porosity module has been tested with TOUGH on various problems involving transient flow in fractured/porous media, and compared with simulations performed using explicit discretization of the matrix blocks. The new semi-analytical dual-porosity model accurately simulates flow processes in unsaturated fractured rocks, and typically requires an order of magnitude less computational time than do simulations using fully-discretized matrix blocks.

609 (LBL–36872) **Applications of TOUGH2 to infiltration of liquids in media with strong heterogeneity.** Pruess, K.; Antunez, E. Lawrence Berkeley Lab., CA (United States). Feb 1995. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. (CONF-9503116–7: 1995 TOUGH workshop, Berkeley, CA (United States), 20-22 Mar 1995). Order Number DE95012392. Source: OSTI; NTIS; GPO Dep.

Much hydrogeological research during the last decade has focused on the heterogeneity of natural geologic media on different scales. Most of this work has dealt with flow and transport in single-phase, isothermal conditions. The present paper is concerned with multiphase and nonisothermal flows in strongly heterogeneous media. A primary driver of our studies is the hydrogeological system at Yucca Mountain, which is currently being evaluated by the Department of Energy for its suitability as the site of the first geologic repository for civilian high-level nuclear wastes in the US Yucca Mountain is located in the and Southwest, near the Nevada-California border. Going from large scale to small, formation heterogeneities at Yucca Mountain include (i) alternating tilting layers of welded and non-welded tuffs with different matrix permeability and variable degree of fracturing, (ii) major fault systems, (iii) well-connected and permeable fracture networks in low-permeability rocks, and (iv) individual fractures with highly variable apertures.

610 (LBL–37018) **The effect of rock fragments on the hydraulic properties of soils.** Zimmerman, R.W.; Bodvarsson, G.S. Lawrence Berkeley Lab., CA (United States). Apr 1995. 26p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. Order Number DE95016523. Source: OSTI; NTIS; INIS; GPO Dep.

Many soils contain rock fragments the sizes of which are much larger than the average pore size of the sieved soil. Due to the fact that these fragments are often fairly large in relation to the soil testing apparatus, it is common to remove

them before performing hydrologic tests on the soil. The question then arises as to whether or not there is a simple way to correct the laboratory-measured values to account for the fragments, so as to arrive at property values that can apply to the soil in situ. This question has arisen in the surface infiltration studies that are part of the site characterization program at Yucca Mountain, where accurate values of the hydraulic conductivities of near-surface soils are needed in order to accurately estimate infiltration rates. Although this problem has been recognized for some time, and numerous review articles have been written there are as yet no proven models to account for the effect of rock fragments on hydraulic conductivity and water retention. In this report we will develop some simple physically-based models to account for the effects of rock fragments on gross hydrological properties, and apply the resulting equations to experimental data taken from the literature. These models are intended for application to data that is currently being collected by scientists from the USGS on near-surface soils from Yucca Mountain.

611 (LBL–37200) **Proceedings of the TOUGH Workshop '95 Lawrence Berkeley Laboratory, Berkeley, California, March 20–22, 1995.** Pruess, K. (ed.). Lawrence Berkeley Lab., CA (United States). Mar 1995. 380p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. (CONF-9503110–: TOUGH 95: transport of unsaturated ground water and heat workshop, Berkeley, CA (United States), 20-22 Mar 1995). Order Number DE95014788. Source: OSTI; NTIS; GPO Dep.

The TOUGH Workshop '95 focused on applications and enhancements of the TOUGH/MULKOM family of numerical simulation programs for complex flows in permeable media, including multiphase, multicomponent, non- isothermal, and variable-density flows. There were about 100 participants from 10 countries in attendance. The topical areas covered included environmental remediation, nuclear waste isolation, geothermal and petroleum reservoir engineering, mining engineering, vadose zone hydrology, and simulation methods. This volume features the extended summaries of papers that were presented at the workshop. The technical program and lists of authors and registered participants are included in appendices. Individual papers have been processed separately for the databases.

612 (LBL–37200, pp. 14-20) **The use of TOUGH2 for the LBL/USGS 3-dimensional site-scale model of Yucca Mountain, Nevada.** Bodvarsson, G. (Lawrence Berkeley Laboratory, CA (United States)); Chen, G.; Haukwa, C. Lawrence Berkeley Lab., CA (United States). Mar 1995. DOE Contract AC03-76SF00098. (CONF-9503110–: TOUGH 95: transport of unsaturated ground water and heat workshop, Berkeley, CA (United States), 20-22 Mar 1995). In *Proceedings of the TOUGH Workshop '95 Lawrence Berkeley Laboratory, Berkeley, California, March 20–22, 1995.* 380p. Order Number DE95014788. Source: OSTI; NTIS; GPO Dep.

The three-dimensional site-scale numerical model of the unsaturated zone at Yucca Mountain is under continuous development and calibration through a collaborative effort between Lawrence Berkeley Laboratory (LBL) and the United States Geological Survey (USGS). The site-scale model covers an area of about 30 km^2 and is bounded by major fault zones to the west (Solitario Canyon Fault), east (Bow Ridge Fault) and perhaps to the north by an unconfirmed fault (Yucca Wash Fault). The model consists of about 5,000 grid blocks (elements) with nearly 20,000 connections between them the grid was designed to represent the most prevalent geological and hydro-geological features of the site including major faults, and layering and bedding of the hydro-geological units. Further information about the three-dimensional site-scale model is given by Wittwer et al. and Bodvarsson et al.

613 (LBL–37200, pp. 21) **Drift-scale thermo-hydrologic analyses for the proposed repository at Yucca Mountain, NV.** Reeves, M. (M&O/Intera, Inc., Las Vegas, NV (United States)); Lingineni, S. Lawrence Berkeley Lab., CA (United States). Mar 1995. DOE Contract AC03-76SF00098. (CONF-9503110–: TOUGH 95: transport of unsaturated ground water and heat workshop, Berkeley, CA (United States), 20-22 Mar 1995). In *Proceedings of the TOUGH Workshop '95 Lawrence Berkeley Laboratory, Berkeley, California, March 20–22, 1995.* 380p. Order Number DE95014788. Source: OSTI; NTIS; GPO Dep.

Focusing on the near field of a waste package, this paper presents results obtained from a thermo-hydrologic model. Vertically, the conceptual model extends from ground surface to a depth of 1000 m below the water table. Horizontally, it is bounded by the centerlines of two pillars. Inside an assumed circular drift, an invert (backfill) surrounds the waste package. Here, a coarse-grained crushed tuff is assumed to provide a capillary barrier against infiltrating ground water. For comparison, the invert is replaced by intact tuff, corresponding to borehole emplacement. In further examining the near-field thermo-hydrology of a waste package, the study considers several values of the areal power density together with both nonenhanced and enhanced levels of vapor diffusivity. In order to characterize drift resaturation effects deriving from the latter, the calculations extend to 100,000 years. The clarity of the coding present in LBL's integrated finite-difference model TOUGH2 has permitted us to make several code changes. For the most part, they expedite convergence on difficult applications. The paper briefly discusses these changes.

614 (LBL–37200, pp. 58-68) **Parametric analysis of a TOUGH2 model for the unsaturated zone at Yucca Mountain.** Xiang, Y. (CRWMS M&O/INTERA, Inc., Las Vegas, NV (United States)); Mishra, S.; Dunlap, B. Lawrence Berkeley Lab., CA (United States). Mar 1995. DOE Contract AC03-76SF00098. (CONF-9503110–: TOUGH 95: transport of unsaturated ground water and heat workshop, Berkeley, CA (United States), 20-22 Mar 1995). In *Proceedings of the TOUGH Workshop '95 Lawrence Berkeley Laboratory, Berkeley, California, March 20–22, 1995.* 380p. Order Number DE95014788. Source: OSTI; NTIS; GPO Dep.

Yucca Mountain in Nevada is currently being investigated for suitability as a potential site for the disposal of high-level radioactive waste and spent nuclear fuel. As the most important natural barrier against radionuclide migration to the accessible environment, the unsaturated zone at Yucca mountain is a key constituent in assessing the ambient geohydrology. A three-dimensional site-scale TOUGH2 model of the unsaturated zone is currently under development by Lawrence Berkeley Laboratory (LBL) and the United States Geological Survey (USGS) consists of six hydrogeologic units - TCw (Tiva Canyon welded), PTn (Paintbrush nonwelded), TSw (Topopah Spring welded), TSv (Topopah Spring welded-vitrophyre), CHnz (Calico Hills nonwelded-vitric), and CHnz (Calico Hills nonwelded-zeolitic), which are further subdivided into seventeen layers to represent additional lithologic detail. Based on the work of Klavetter and Peters, the fractured units TCw and TSw are treated as

equivalent continua with specified threshold saturation for triggering fracture flow.

615 (LBL–37200, pp. 335-343) **Application of TOUGH to hydrologic problems related to the unsaturated zone site investigation at Yucca Mountain, Nevada.** Kwicklis, E.M. (Geological Survey, Lakewood, CO (United States)); Healy, R.W.; Bodvarsson, G.S. Lawrence Berkeley Lab., CA (United States). Mar 1995. DOE Contract AC03-76SF00098. (CONF-9503110–: TOUGH 95: transport of unsaturated ground water and heat workshop, Berkeley, CA (United States), 20-22 Mar 1995). In *Proceedings of the TOUGH Workshop '95 Lawrence Berkeley Laboratory, Berkeley, California, March 20–22, 1995.* 380p. Order Number DE95014788. Source: OSTI; NTIS; GPO Dep.

To date, TOUGH and TOUGH2 have been the principal codes used by the U.S. Geological Survey in their investigation of the hydrology of the unsaturated zone at Yucca Mountain. Examples of some applications of the TOUGH and TOUGH2 codes to flow and transport problems related to the Yucca Mountain site investigation are presented, and the slight modifications made to the codes to implement them are discussed. These examples include: (1) The use of TOUGH in a simple fracture network model, with a discussion of an approach to calculate directional relative permeabilities at computational cells located at fracture intersections. These simulations illustrated that, under unsaturated conditions, the locations of dominant pathways for flow through fracture networks are sensitive to imposed boundary conditions; (2) The application of TOUGH to investigate the possible hydrothermal effects of waste-generated heat at Yucca Mountain using a dual-porosity, dual-permeability treatment to better characterize fracture-matrix interactions. Associated modifications to TOUGH for this application included implementation of a lookup table that can express relative permeabilities parallel and transverse to the fracture plane independently. These simulations support the continued use of an effective media approach in analyses of the hydrologic effects of waste-generated heat; and (3) An investigation of flow and tracer movement beneath a wash at Yucca Mountain in which a particle tracker was used as a post-processor. As part of this study, TOUGH2 was modified to calculate and output the x-,y- and z- sequence of tuffs overlying the potential repository site will result in the formation of capillary barriers that locally promote considerable lateral flow, thereby significantly decreasing the magnitude of fluxes form peak values at the ground surface and delaying the arrival of surface-derived moisture at the potential repository horizon.

616 (LBL–37332) **Effective transmissivity of two-dimensional fracture networks.** Zimmerman, R.W.; Bodvarsson, G.S. Lawrence Berkeley Lab., CA (United States). Apr 1995. 19p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. Order Number DE95015139. Source: OSTI; NTIS; INIS; GPO Dep.

Many of the sites that have been proposed as potential locations of underground radioactive waste repositories contain fractured rocks. For example, both the saturated and unsaturated zone at Yucca Mountain, Nevada, contains many hydrogeologic units that are extensively fractured. When modeling the hydrological behavior of these sites, for either the purpose of site characterization of performance assessment, computational grid-blocks are often used that contain large number of fractures. In order to treat these as equivalent continua, it is necessary to develop a procedure for relating the hydraulic properties of the individual fractures and he topology of the fracture network to the overall scale permeability. One aspect of this problem is that of determining the in situ hydraulic properties of the individual fractures. Another aspect is to reconstruct the three-dimensional geometry of the fracture network based on borehole or outcrop measurements. The final stage in the problem is that of taking a network of known geometry and determining it effective scale conductivity. The purpose of this paper is to describe a simple procedure for solving this latter problem,a nd to demonstrate it use in cases of both saturated and unsaturated flow. The TOUGH simulator was used.

617 (LBL–37356) **Preliminary development of the LBL/USGS three-dimensional site-scale model of Yucca Mountain, Nevada.** Wittwer, C. (Bureau de Recherches Geologiques et Minieres (BRGM), 45 - Orleans (France). Dept. Geothermie et Hydroenergie); Chen, G.; Bodvarsson, G.S.; Chornack, M.; Flint, A.; Flint, L.; Kwicklis, E.; Spengler, R. Lawrence Berkeley Lab., CA (United States). Jun 1995. 100p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098 ; AI08-78ET44802. Order Number DE96000149. Source: OSTI; NTIS; INIS; GPO Dep.

A 3-D model of moisture flow within the unsaturated zone at Yucca Mountain is being developed at LBL in cooperation with USGS. This site-scale model covers an area of about 34 km^2 and is bounded by major faults to the north, east, and west. The relatively coarse-grid model includes about 300 horizontal grid-blocks and 17 layers. Contour maps and isopach maps are presented defining different types of infiltration zones, and the spatial distribution of Tiva Canyon, Paintbrush, and Topopah Spring hydrogeological units. Matrix flow is approximated using the van Genuchten model, and the equivalent continuum approximation is used to account for fracture flow in the welded units. One-, two-, and three-dimensional simulations are conducted using the TOUGH2 computer program. Steady-state simulations are performed with various uniform and nonuniform infiltration rates; results are interpreted in terms of effect of fault characteristics on moisture flow distribution, and on the location and formation of preferential pathways.

618 (LBL–37492) **Estimation of hydraulic conductivities of Yucca Mountain tuffs from sorptivity and water retention measurements.** Zimmerman, R.W.; Bodvarsson, G.S. Lawrence Berkeley Lab., CA (United States). Jun 1995. 31p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. Order Number DE96001002. Source: OSTI; NTIS; INIS; GPO Dep.

The hydraulic conductivity functions of the matrix rocks at Yucca Mountain, Nevada, are among the most important data needed as input for the site-scale hydrological model of the unsaturated zone. The difficult and time-consuming nature of hydraulic conductivity measurements renders it infeasible to directly measure this property on large numbers of cores. Water retention and sorptivity measurements, however, can be made relatively rapidly. The sorptivity is, in principle, a unique functional of the conductivity and water retention functions. It therefore should be possible to invert sorptivity and water retention measurements in order to estimate the conductivity; the porosity is the only other parameter that is required for this inversion. In this report two methods of carrying out this inversion are presented, and are tested against a limited data set that has been collected by Flint et al. at the USGS on a set of Yucca Mountain tuffs. The absolute permeability is usually predicted by both methods to within an average error of about 0.5 - 1.0 orders of

magnitude. The discrepancy appears to be due to the fact that the water retention curves have only been measured during drainage, whereas the imbibition water retention curve is the one that is relevant to sorptivity measurements. Although the inversion methods also yield predictions of the relative permeability function, there are yet no unsaturated hydraulic conductivity data against which to test these predictions.

619 (PNC-TN-1100-94-003, pp. III/63-III/70) **Fracture characterization experiments at Raymond, California.** Karasaki, Kenzi (Lawrence Berkeley Lab., CA (United States)); Freifeld, Barry. Power Reactor and Nuclear Fuel Development Corp., Tokyo (Japan). 1994. (CONF-9311199--: International workshop on research and development of geological disposal, Tokai (Japan), 15-19 Nov 1993). In *Proceedings of technical session on research and development of geological disposal.* 379p. Order Number DE95757546. Source: OSTI; NTIS; INIS.

In the United States, the potential repository for high level radioactive waste would be built in Yucca Mountain, Nevada. The geology of the site consists of the sequences of ash flow and ash fall turfs. In general, these rocks are extensively fractured. To develop the field testing techniques and analysis methods for characterizing the flow and transport properties of fractured rocks, a dedicated field site was established near Raymond, California. In this report, the details of the site, the design and the results of geophysical and hydrological tests, as well as an approach for modeling the flow and transport in such fractured rocks are discussed. The Raymond Field Site is located in Sierra Nevada foothills, approximately 3.2 km east of Raymond, California. The site lies within Knowles Granodiorite. A cluster of nine boreholes were drilled so far. The data acquisition system is explained. The hydraulic tests including falling head slug test, pressure injection test and interference test and radially convergent tracer test were carried out. The flow in a fracture system may be approximated better by a network of three-dimensionally interconnected line segments. The modeling approach is discussed. The hierarchical fracture system of three different scales of interest is explained. (K.I.).

620 **Development of a three-dimensional site-scale model for the unsaturated zone at Yucca Mountain, Nevada.** Wittwer, C.S. (Lawrence Berkeley Laboratory, Earth Sciences Div., Berkeley (United States)); Bodvarsson, G.S.; Chornack, M.P.; Flint, A.L.; Flint, L.E.; Lewis, B.D.; Spengler, R.W.; Rautmann, C.A. *Radioactive Waste Management and Environmental Restoration;* 19(1-3): 147-164 (1994).

Special issue Yucca Mountain.

A three-dimensional model of moisture flow within the highly heterogeneous, porous and fractured tuffs of the unsaturated zone at Yucca Mountain is being developed. This site-scale model covers an area of about 30 km^2 and is bounded by major faults at the east and west. A detailed numerical grid has been developed based on the locations of boreholes, on the spatial distribution of different infiltration zones, hydrogeological units and water level data, and on the offset of the volcanic tuffs due to major faults. Hydrogeologic contour-and isopachs maps, are presented for the different infiltration zones, and for the base of the Tiva Canyon, the Paintbrush, and the Topopah Spring hydrogeological units. One- and two-dimensional simulations have been performed using the TOUGH2 computer code to test the geometry and the accuracy of the model-grid, which consists of about 5000 gridblocks distributed among 17 non-uniform vertical layers representing the four main hydrogeological units of the unsaturated zone. (author) 11 figs., 1 tab., 21 refs.

621 **Accuracy and efficiency of a semi-analytical dual-porosity simulator for flow in unsaturated fractured rock masses.** Zimmerman, R.W. (Lawrence Berkeley Laboratory, Earth Sciences Div., Berkeley (United States)); Chen, G.; Bodvarsson, G. *Radioactive Waste Management and Environmental Restoration;* 19(1-3): 193-208 (1994).

Special issue Yucca Mountain.

A semi-analytical dual-porosity simulator for unsaturated flow in fractured rock masses has been developed. Fluid flow between the fracture network and the matrix blocks is described by analytical expressions that have been derived from approximate solutions to the imbibition equation. These expressions have been programmed into an unsaturated flow simulator, TOUGH, as a source/sink term. Flow processes are then simulated using only fracture elements in the computational grid. The modified code is used to simulate flow along single fractures, and infiltration into pervasively fractured formations. Comparisons are made with simulations carried out using discretization of both the fractures and matrix blocks. The new semi-analytical code is shown to be accurate, and typically requires an order of magnitude less computational time. (author) figs., tabs., refs.

622 **Technical issues relevant to hydrological performance assessment at Yucca Mountain: a hierarchial perspective.** Narasimhan, T.N. (Lawrence Berkeley Laboratory, Earth Science Div., Berkeley (United States)); Wang, J.S.Y. *Radioactive Waste Management and Environmental Restoration;* 19(1-3): 209-229 (1994).

Special issue Yucca Mountain.

Hydrological Performance Assessment (PA) is an important component of Yucca Mountain Site Characterization Project (YMP). The goal of PA is to assess, as far quantitatively as possible, whether radioactive contaminants will be released to the groundwater and transported to the accessible environment in adverse quantities should a potential repository for high level radioactive wastes (HLW) be constructed and operated at Yucca Mountain. Ideally, it would be desirable to demonstrate with certitude, using scientific data, that the wastes could be safely contained at the site over a 10,000-year time frame. Nevertheless, the scientific issues involved are many and the necessary data cannot be gathered and interpreted over the next several years to answer all the questions. Yet, available evidence suggests that the site has many attributes favorable for long-term containment of high level radioactive wastes. Under the circumstances, phased, long-term approach to site characterization appears prudent. Integral to such an approach will be long-term data acquisition and monitoring, should construction be permitted. Considering the complex, difficult-to-access nature of earth systems, the long-term approach should provide for an open-endedness to accommodate unforeseen contingencies which may come to light during long-term monitoring. To guide data acquisition and monitoring, it is necessary to identify the various technical issues relevant to repository performance. We present these issues in a systematic, hierarchial frame-work. (author) 1 fig., 14 refs.

U.S. GEOLOGICAL SURVEY

623 **Volcanic episodes near Yucca Mountain as determined by paleomagnetic studies as Lathrop Wells, Crater Flat, and Sleeping Butte, Nevada.** Champion, D.E. (Geological Survey, Menlo Park, CA (United States)). pp. 61-67 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

It has been suggested that mafic volcanism in the vicinity of Yucca Mountain, Nevada, is both recent (20 ka) and a product of complex "polycyclic" eruptions. This pattern of volcanism, as interpreted by some workers at the Lathrop Wells volcanic complex, comprises a sequence of numerous small-volume eruptions that become more tephra-producing over time. Such sequences are thought to occur over timespans as long as 100,000 years. However, paleomagnetic studies of the tephra and lava flows from mafic volcanoes near Yucca Mountain fail to find evidence of repeated eruptive activity over timespans of 10^3 to 10^5 years, even though samples have been taken that represent approximately 95% of the products of these volcanoes. Instead, the eruptions seem to have occurred as discrete episodes at each center and thus can be considered to be "monogenetic." Dates of these episodes have been obtained by the proven radiometric-geochronometer methods of K-Ar or $^{40}Ar/^{39}Ar$ dating.

624 **$^{40}Ar/^{39}Ar$ laser fusion and K-Ar ages from Lathrop Wells, Nevada, and Cima, California: The age of the latest volcanic activity in the Yucca Mountain area.** Turrin, B.D. (Geological Survey, Menlo Park, CA (United States)); Champion, D.E. pp. 68-75 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

K-Ar and $^{40}Ar/^{39}Ar$ ages from the Lathrop Wells volcanic center, Nevada, and from the Cima volcanic field, California, indicate that the recently reported 20-ka age estimate for the Lathrop Wells volcanic center is incorrect. Instead an age of 119±11 to 141±10 ka is indicated for the Lathrop Wells volcanic center. This age corrected is concordant with the ages determined by two independent isotopic geochronometric techniques and with the stratigraphy of surficial deposits in the Yucca Mountain region. In addition, paleomagnetic data and radiometric age data indicate only two volcanic events at the Lathrop Wells volcanic center that are probably closely linked in time, not as many as five as recently reported.

625 **Assessment of fracture-sampling techniques for laboratory tests on core.** Severson, G.R. (Geological Survey, Denver, CO (United States)); Boernge, J.M. pp. 285-290 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

As part of the site characterization work to be done at Yucca Mountain in Nye County, Nevada, a candidate site for the first mined-geologic repository for high-level nuclear waste, laboratory tests are proposed to evaluate fluid flow in single fractures. Laboratory and onsite tests were conducted to develop methods for collecting rock-core samples containing single fractures for the subsequent laboratory tests. Techniques for collecting rock cores with axial (parallel to the core axis) and radial (perpendicular to the core axis) fractures are discussed.

626 **Evaluation of geographic information systems for three-dimensional ground-water modeling, Yucca Mountain, Nevada.** Turner, A.K. (Geological Survey, Denver, CO (United States)); Ervin, E.M.; Downey, J.S. pp. 520-528 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Fully three-dimensional representations of the geologic system at Yucca Mountain have been developed using a Geoscientific Information System, which is an expansion of a traditional Geographic Information System. These advanced, three dimensional, representations of Yucca Mountain are required to adequately evaluate the complex geologic and hydrologic conditions surrounding the site. This Geoscientific Information System will be used to store, analyze, and display site data. The system also will provide a link between geologic and hydrologic data and the numerical ground-water-flow model resulting in more easy testing of hypotheses concerning the conceptual model of the geohydrologic system at Yucca Mountain.

627 **Major results of gravity and magnetic studies at Yucca Mountain, Nevada.** Oliver, H.W. (Geological Survey, Menlo Park, CA (United States)); Ponce, D.A.; Sikora, R.F. pp. 787-794 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AI08-78ET44802. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

About 4,000 gravity stations have been obtained at Yucca Mountain and vicinity since the beginning of radioactive-waste studies there in 1978. These data have been integrated with data from about 29,000 stations previously obtained in the surrounding region to produce a series of Bouguer and isostatic-residual-gravity maps of the Nevada Test Site and southeastern Nevada. Yucca Mountain is characterized by a WNW-dipping gravity gradient whereby residual values of -10 mGal along the east edge of Yucca Mountain decrease to about -38 mGal over Crater Flat. Using these gravity data, two-dimensional modeling predicted the depth to pre-Cenozoic rocks near the proposed repository to be about 1,220±150 m, an estimate that was subsequently confirmed by drilling to be 1,244 m. Three-dimensional modeling of the gravity low over Crater Flat indicates the thickness of Cenozoic volcanic rocks and alluvial cover to be about 3,000 m. Gravity interpretations also

identified the Silent Canyon caldera before geologic mapping of Pahute Mesa and provided an estimate of the thickness of the volcanic section there of nearly 5 km. Considerable aeromagnetic coverage of southwestern Nevada was obtained in 1978-79 to help characterize Yucca Mountain and vicinity. One significant result is the discovery of a series of circular magnetic anomalies in Crater Flat and the northern Amargosa Desert that suggest the presence of buried volcanic centers there. If this interpretation is confirmed by drilling, the magnetic data can be used to help estimate the total volume of buried volcanic rocks, which, along with radiometric dating, could help provide a better prediction of future volcanism. Elongate magnetic highs and associated lows over Yucca Mountain correlate with mapped faults, some of which are only partially exposed. Thus, the data provide information on the extent and continuity of these faults.

628 **Geophysical borehole logging in the unsaturated zone, Yucca Mountain, Nevada.** Schimschal, U. (Geological Survey, Denver, CO (United States)); Nelson, P.H. pp. 795-801 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AI08-78ET44802. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Borehole geophysical logging for site characterization in the volcanic rocks at the proposed nuclear waste repository at Yucca Mountain, Nevada, requires data collection under rather unusual conditions. Logging tools must operate in rugose, dry holes above the water table in the unsaturated zone. Not all logging tools will operate in this environment, therefore; careful consideration must be given to selection and calibration. A sample suite of logs is presented that demonstrates correlation of geological formations from borehole to borehole, the definition of zones of altered mineralogy, and the quantitative estimates of rock properties. The authors show the results of an exploratory calculation of porosity and water saturation based upon density and epithermal neutron logs. Comparison of the results with a few core samples is encouraging, particularly because the logs can provide continuous data in boreholes where core samples are not available.

629 **An alternative method to Mariotte reservoir system for maintaining constant hydraulic pressure.** Thamir, F. (Geological Survey, Denver, CO (United States)). pp. 994-998 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Some studies being done to evaluate the suitability of the Yucca Mountain area as a potential radioactive waste repository require the application of a constant water pressure as a boundary condition to study water flow through porous media. The Mariotte reservoir system is commonly used to supply such a boundary condition. Several problems with the Mariotte reservoir system were discovered when it was used to apply a constant water pressure as a boundary condition for a prolonged period. The constant-pressure boundary condition is required for some lab. experiments to study water flow through porous media. The observed problems were caused by temperature and barometric-pressure fluctuations while the flow rates were very small and caused erroneous water flow-rate measurements. An alternative method was developed and used where the water pressure is controlled by regulating its level by using water-level sensing electrodes. The new method eliminated the effects of temperature and barometric-pressure fluctuations and maintained an acceptable accuracy of the estimated water flow rate without compromising the advantage of the Mariotte reservoir.

630 **Pore-water extraction from unsaturated tuffs using one-dimensionsal compression.** Mower, T.E. (PRC Environmental Management Inc., Denver, CO (United States)); Higgins, J.D.; Yang, I.C. pp. 999-1006 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

To support the study of the unsaturated-zone hydrochemistry at Yucca Mountain, Nevada, a one-dimensional compression system was developed and tested to extract unaltered and uncontaminated pore-water samples from unsaturated tuff. The major components of the compression system include a high strength steel-alloy corpus ring and nickel-alloy sample sleeve that confine a core sample, and a base platen and piston for application of the axial stress. The base platen and piston are fitted with drainage grooves to alloy pore water to drain during compression. Results obtained using the compression system indicate that pore-water samples could be obtained from nonwelded-tuff cores that had initial moisture contents as small as 8 percent (by weight) and from welded tuff cores that had initial moisture contents as small as 6.5 percent (by weight). For the ambient moisture conditions of tuffs present at Yucca Mountain, the one-dimensional compression system is more effective for extracting pore water than a previously tested triaxial-compression device.

631 **Isotopic discontinuities in ground water beneath Yucca Mountain, Nevada.** Stuckless, J.S. (Geological Survey, Denver, CO (United States)); Whelan, J.F.; Steinkampf, W.C. pp. 1410-1415 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Analytical data for stable isotopes in ground water from beneath Yucca Mountain, when examined in map view, show areal patterns of heterogeneity that can be interpreted in terms of mixing of at least three end members. One end member must be isotopically heavy in terms of hydrogen and oxygen and have a young apparent ^{14}C age such as water found at the north end of Yucca Mountain beneath Fortymile Wash. A second end member must contain isotopically heavy carbon and have an old apparent ^{14}C age such as water from the Paleozoic aquifer. The third end member cannot be tightly defined. It must be isotopically lighter than the first with respect of hydrogen and oxygen and be intermediate to the first and second end members with respect to both apparent ^{14}C age and $\sigma^{14}C$. The variable isotopic compositions of hydrogen and oxygen indicate

that two of the end members are waters, but the variable carbon isotopic composition could represent either a third water end member of reaction of water with a carbon-bearing solids such as calcite.

632 **Distribution of rubidium, strontium, and zirconium in tuff from two deep coreholes at Yucca Mountain, Nevada.** Spengler, R.W. (Geological Survey, Denver, CO (United States)); Peterman, Z.E. pp. 1416-1422 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Variations in concentrations of trace elements Rb, Sr, and Zr within the sequence of high-silica tuff and dacitic lava beneath Yucca Mountain reflect both primary composition and secondary alteration. Rb and K concentrations have parallel trends. Rb concentrations are significantly lower within intervals containing zeolitic nonwelded to partially welded and bedded tuffs and are higher in thick moderately to densely welded zones. Sr concentrations increase with depth from about 30 ppm in the Topopah Spring Member of the Paintbrush Tuff to almost 300 ppm in the older tuffs. Zr concentrations are about 100 ppm in the Topopah Spring Member and also increase with depth to about 150 ppm in the Lithic Ridge Tuff and upper part of the older tuffs. Conspicuous local high concentrations of Sr in the lower part of the Tram Member, in the dacite lava, and in unit c of the older tuffs in USW G-1, and in the densely welded zone of the Bullfrog Member in USW GU-3/G-3 closely correlate with high concentrations of less-mobile Zr and may reflect either primary composition or elemental redistribution resulting largely from smectitic alteration. Initial $^{87}Sr/^{86}Sr$ values from composite samples increase upward in units above the Bullfrog Member of the Crater Flat Tuff. The progressive tenfold increase in Sr with depth coupled with the similarity of initial $^{87}Sr/^{86}Sr$ values within the Bullfrog Member and older units to those of Paleozoic marine carbonates are consistent with a massive influx of Sr from water derived from a Paleozoic carbonate aquifer.

633 **Strontium isotopes in carbonate deposits at Crater Flat, Nevada.** Marshall, B.D. (Geological Survey, Denver, CO (United States)); Futa, K.; Peterman, Z.E.; Stuckless, J.S. pp. 1423-1428 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Strontium isotope studies of carbonates from soils, veins, eolian dust and Paleozoic basement sampled near Crater Flat, southwest of Yucca Mountain, provide evidence for the origins of these materials. Vein and soil carbonates have nearly identical ranges of $^{87}Sr/^{86}Sr$, and eolian material has $^{87}Sr/^{86}Sr$ ratios at the lower end of the pedogenic range. The average $^{87}Sr/^{86}Sr$ of Paleozoic basement from Black Marble Hill is similar to the $^{87}Sr/^{86}Sr$ in the eolian dust, perhaps indicating a local source for this material. Possible spring deposits have generally higher $^{87}Sr/^{86}Sr$ than the other carbonates. These data are compared with similar data from areas east of Yucca Mountain.

634 **An evaluation of evidence pertaining to the origin of vein deposits exposed in trench 14, Nevada Test Site, Nevada.** Stuckless, J.S. (Geological Survey, Denver, CO (United States)). pp. 1429-1438 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Large vein-like deposits of calcite and opaline silica that infill the Bow Ridge fault are exposed by Trench 14 at the Nevada Test Site. The origin of the deposits has been the center of considerable controversy because the deposits occur on the edge of Yucca Mountain, which is being characterized geologically as a possible site for the nation's first high level nuclear waste repository, and the various proposed modes of origin have differing implications for the performance of a geologic repository. Isotopic data for oxygen, carbon, strontium, and uranium in the carbonates preclude deposition by upwelling waters by any mechanism from either of the regionally extensive aquifers known to exist beneath Yucca Mountain. Data from the adjacent Ash Meadows flow system further suggest that the isotopic compositions of ground water in southern Nevada have not changed markedly during the last 300 to 600 ky, and that therefore, conclusions based on present-day water compositions are probably valid for at least the last 600 ky. Geologic and paleontologic data are inconsistent with a shallow perched water spring origin for the veins, but are consistent with a pedogenic origin. Mineralogic and isotopic data match well with those for pedogenic deposits with perhaps minor modification from entrained or reacted wall rock. Taken as a whole, the data show that the carbonate and opaline silica deposits exposed in Trench 14 must have formed by a pedogenic process. Preliminary results suggest that veins in the sand ramps west of Busted Butte formed by the same mechanism.

635 **Flow and transport through unsaturated rock-data from two text holes, Yucca Mountain, Nevada.** Yang, I.C. (Geological Survey, Denver, CO (United States)). pp. 732-737 of High level radioactive waste management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1992). pp. 1244 From 3. international high level radioactive waste management (IHLRWM) conference; Las Vegas, NV (United States); 12-16 Apr 1992.

Tritium data for unsaturated-zone water from test holes UE-25 UZ No. 4 and UE-25 UZ No. 5, Yucca Mountain, Nevada, indicated concentration inversions at several depths. Chemical-composition inversions and large differences in ^{14}C in the ground-water from these holes also were observed in the deeper strata. These abrupt changes are attributed to preferential flow paths.

636 **A hint of recharge at Franklin Lake playa, Inyo County, California, USA.** Czarnecki, J.B. (Geological Survey, Denver, CO (United States)); Ronen, D.; Magaritz, M.; Kroitoru, L. pp. 631-634 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

Hydrochemical and hydraulic-head data at a central study site on Franklin Lake playa imply the occurrence of localized recharge caused by intermittent stream flow. The playa is a

major discharge area of the ground-water flow system that includes Yucca Mountain, Nevada, the potential site of a high-level nuclear-waste repository. Depth to water at the study site was 1.7 meters in a fully-screened well in which a multilevel sampler was used to obtain detailed vertical hydrochemical profiles. These profiles showed the occurrence of a relatively fresher-water lens in approximately the top 10 centimeters below the water table which may have resulted from localized recharge. Hydraulic-head data from a 3-piezometer nest indicated a downward hydraulic gradient (-0.10) and a 0.83-meter; rise in the water table in a 3.20-meter-deep piezometer from 1984 to 1989. 3 refs., 4 figs.

637 **Isotopic studies of fracture coatings at Yucca Mountain, Nevada, USA.** Marshall, B.D. (Geological Survey, Denver, CO (United States)); Whelan, J.F.; Peterman, Z.E.; Futa, K.; Mahan, S.A.; Stuckless, J.S. pp. 737-740 of Water-Rock Interaction: Proceedings. Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

At Yucca Mountain, secondary calcite occurs as fracture coatings, open-space fillings, and replacement cement (in the saturated zone) and has been observed in most of the Tertiary volcanic section. In general, Sr, O and C isotope systematics as well as UV fluorescence suggest that the present depth to water table of ≈500 m is a long-lived feature. Calcite deposition probably reflects a long history of fluid/rock interaction. Calcite $^{87}Sr/^{86}Sr$ ratios and $\delta^{13}C$ values are fairly constant in the lower part of the Tertiary section, reflecting the geochemical signature of the lower carbonate aquifer. Unsaturated zone calcite $\delta^{13}C$ values indicate input of pedogenic C, and $^{87}Sr/^{86}Sr$ increases from shallow ground-water ratios near the water table to pedogenic values near the surface. Calcite $\delta^{18}O$ values are in approximate equilibrium with current ground waters at the present geothermal gradient. 9 refs., 3 figs., 1 tab.

638 **A preliminary study of the chemistry of pore water extracted from tuff by one-dimensional compression.** Peters, C.A. (Geological Survey, Denver, CO (United States)); Yang, I.C.; Higgins, J.D.; Burger, P.A. pp. 741-745 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

A specially designed and fabricated one-dimensional compression cell is being used to extract water from nonwelded and densely welded tuffs having degrees of saturation greater than 16 and 37 percent respectively. Chemical analyses of pore water obtained at increasing pressures are used to evaluate possible changes in chemistry caused by compression. The extracted pore water varies from a calcium chloride type to a sodium bicarbonate type. The mean concentration of dissolved ions generally decreases during compression. The relative abundance of the major cations varies little with increasing pressure. The relative abundance of the major anion varies moderately with increasing pressure. Possible causes of the pore-water-chemistry changes include: (1) dilution of pore water by low ionic strength adsorbed water from zeolites and clays; (2) dissolution reactions caused by the increase in dissolved carbon dioxide concentrations that may result from pressurization; (3) membrane filtration by zeolites and clays; and (4) ion exchange with the zeolites and clays. 11 refs., 5 figs., 3 tabs.

639 **Strontium isotope characterization of the Ash Meadows ground-water system, southern Nevada, USA.** Peterman, Z.E. (Geological Survey, Denver, CO (United States)); Stuckless, J.S.; Mahan, S.A.; Marshall, B.D.; Gutentag, E.D.; Downey, J.S. pp. 825-829 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 DOE Contract AI08-78ET44802. From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

The regional $\delta^{87}Sr$ variation in ground water of the Ash Meadows flow system is consistent with previous work which identifies the Spring Mountains as a major recharge area. $\delta^{87}Sr$ values between -1.06 and 0.79 in water from high springs are indistinguishable from the $\delta^{87}Sr$ values of the Paleozoic carbonate rocks which compose most of the Spring Mountains. The bulk of the discharge at Ash Meadows carries strontium with $\delta^{87}Sr$ values between 4.43 and 4.99. These discharge values require recharge to the system with $\delta^{87}Sr$ values substantially greater than 5. Such waters are identified in the west-central part of the flow system, reflecting a northerly source, and in one spring form the Pahranagat Valley at the northeastern limit of the system. The ultimate source of these large $\delta^{87}Sr$ values may include Tertiary felsic tuffs, Upper Devonian and Mississippian Eleana Formation, or Precambrian clastic rocks. 14 refs., 3 figs.

640 **The influence of seasonal climatic variability on shallow infiltration at Yucca Mountain.** Hevesi, J.A. (Geological Survey, Mercury, NV (United States)); Flint, A.L. pp. 122-131 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Yucca Mountain, Nevada, is currently being evaluated as a potential location for an underground high-level nuclear waste repository, and the characterization of natural infiltration at this arid site is required. To analyze infiltration and the redistribution of moisture in alluvial deposits at Yucca Mountain, water content profiles at a 13.5 meter deep borehole were measured at monthly intervals using a neutron moisture probe. Measured profiles for the period 1/11/90 to 10/07/92 indicated increases in water content to a maximum depth of 1.8 meters in response to winter-season precipitation events, followed by a more gradual drying of the wetted zone due to evapotranspiration and possible downward percolation. Below a depth of 1.8 meters, a gradual drying trend was indicated for the entire measurement period by a small but consistent decrease in water contents throughout the profile. To analyze the influence of a longer climatic record on the water content profile, a one dimensional numerical model of unsaturated flow was calibrated to the measured water content profiles using measured daily precipitation and estimated potential evapotranspiration. The use of a 7.1 meter deep root-zone and a moisture dependent evapotranspiration function in the model provided a close agreement between the simulated and measured profiles for the 990 day calibration period. A 15 year record of daily precipitation and air temperatures at Desert Rock Airport, approximately 30 miles southeast of the study site, was used to provide a hypothetical climatic record for Yucca Mountains. Multiplying daily precipitation by factors of 0.5, 1.0, 1.5, 2.0, and 2.5 provided variations of the hypothetical record for investigating the influence of climatic variability on the moisture

profile. Results indicated a maximum penetration of the simulated wetting front to a depth of 6.9 meters in response to the occurrence of two consecutive anomalously wet years.

641 **The influence of long term climate change on net infiltration at Yucca Mountain, Nevada.** Flint, A.L. (Geological Survey, Mercury, NV (United States)); Hevesi, J.A.; Flint, L.E. pp. 152-159 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Net infiltration and recharge at Yucca Mountain, Nevada, a potential site for a high level nuclear waste repository, are determined both by the rock properties and past and future changes in climate. A 1-dimensional model was constructed to represent a borehole being drilled through the unsaturated zone. The rock properties were matched to the lithologies expected to be encountered in the borehole. As current paleoclimate theory assumes that ^{18}O increases with wetter and cooler global climates, a past climate scenario, built on depletion of ^{18}O from ocean sediments was used as a basis for climate change over the past 700,000 years. The climate change was simulated by assigning net infiltration values as a linear function of ^{18}O. Assuming the rock properties, lithologies, and climate scenarios are correct, simulations indicated that Yucca Mountain is not in steady state equilibrium at the surface (<75 meters) when compared to measured data, but that the system could be at steady state conditions at depths of >250 meters. Based on the cyclic climate inputs, the near surface is currently in a long term drying trend (for the last 3,000 years) yet recharge into the water table is continuing to occur at an average rate equivalent to the average input rate of the climate model, indicating that conditions at depth are damped out over very long time periods. The Paintbrush Tuff nonwelded units, positioned between the Tiva Canyon and Topopah Spring welded tuff Members, do not appear to act as a capillary barrier and therefore would not perch water. The low porosity vitric caprock and basal vitrophyre of the Topopah Spring Member, however, act as restrictive layers. The higher porosity rock directly above the caprock reduces the potential for the caprock to perch water leaving the basal vitrophyre as the most likely location for perched water to develop.

642 **Geophysical investigation of concealed faults near Yucca Mountain, southwest Nevada.** Ponce, D.A. (Geological Survey, Menlo Park, CA (United States)). pp. 168-174 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Detailed gravity and ground magnetic data collected along surveyed traverses across Midway Valley, on the eastern flank of Yucca Mountain, Nevada reveal that these methods can be used to delineate concealed faults. These studies are part of an effort to evaluate faulting in the vicinity of the proposed surface facilities for a potential nuclear waste repository at Yucca Mountain. The largest gravity and magnetic anomaly in the vicinity of Midway Valley is associated with the Paintbrush fault on the west flank of Alice Ridge. Geophysical data infer a vertical offset of about 200 m (650 ft). Another prominent gravity and magnetic anomaly is associated with the Bow Ridge fault in the western part of Midway Valley.

643 **Carbon isotopic data from test hole USW UZ-1, Yucca Mountain, Nevada.** Yang, I.C. (Geological Survey, Denver, CO (United States)); Peters, C.A.; Thorstenson, D.C. pp. 401-406 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Rock-CO_2-gas analyses in test hole USW UZ-1 at Yucca Mountain indicate that gas movement in the unsaturated zone is likely through a dry-fracture system with little porewater or caliche-calcite interaction. This is because near-surface $\sigma^{13}C$ values are of biogenic origin and have changed little throughout the total depth. Post-bomb ^{14}C activity is observed to the depth of about 12 m. An abrupt change in plotted ^{14}C/depth slope is seen at 61 m. The less steep upper segment corresponds to the zone with greater porosity and moisture content, and consequently more tortuosity, with an estimated traveltime of 1.27 cm/yr; the steeper sloped zone corresponding to the lower segment has smaller porosity and moisture content but larger fracture density for gas transport, with an estimated traveltime of 3.26 cm/yr.

644 **Structural character of the Ghost Dance Fault, Yucca Mountain, Nevada.** Spengler, R.W. (Geological Survey, Denver, CO (United States)); Braun, C.A.; Linden, R.M.; Martin, L.G.; Ross-Brown, D.M.; Blackburn, R.L. pp. 653-659 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Detailed structural mapping of an area that straddles the southern part of the Ghost Dance Fault has revealed the presence of several additional subparallel to anastomosing faults. These faults, mapped at a scale of 1:240, are: (1) dominantly north-trending, (2) present on both the upthrown and downthrown sides of the surface trace of the Ghost Dance fault, (3) near-vertical features that commonly offset strata down to the west by 3 to 6 m (10 to 20 ft), and (4) commonly spaced 15 to 46 m (50 to 150 ft) apart. The zone also exhibits a structural fabric, containing an abundance of northwest-trending fractures. The width of the zone appears to be at least 213 m (700 ft) near the southernmost boundary of the study area but remains unknown near the northern extent of the study area, where the width of the study area is only 183 m (600 ft).

645 **Development of 3-D lithostratigraphic and confidence models at Yucca Mountain, Nevada.** Beusch, D.C. (Geological Survey, Las Vegas, NV (United States)); Nelson, J.E.; Dickerson, R.P.; Spengler, R.W. pp. 943-948 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Computerized three-dimensional geologic models of potential high-level nuclear waste repositories such as Yucca Mountain, Nevada, are important for visualizing the complex interplay of (1) thickness and facies variations in lithostratigraphic units and (2) the disruption of these units by faults. The concept of a "model of confidence" in the lithostratigraphic model is introduced to show where data are located versus regions where interpolations are included. Models of

confidence can be based on (1) expert judgment, (2) geostatistical analysis, or (3) a simplified combination of these two methods. Linking of lithostratigraphic models and models of confidence provide guidelines for future characterization and modeling activities, as well as for design and construction of the Exploratory Studies Facility.

646 Estimation of water-filled and air-filled porosity in the unsaturated zone, Yucca Mountain, Nevada. Nelson, P.H. (Geological Survey, Denver, CO (United States)). pp. 949-954 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Water content and porosity vary considerably within the unsaturated zone at Yucca Mountain. Measurement of these quantities has been based on core samples. A log-based approach offers the advantage of in-situ measurements, continuous throughout the borehole. This paper describes an algorithm which determines the air-filled and water-filled porosities from density and dielectric logs. The responses of density and dielectric logs are formulated in terms of the matrix properties, air-filled porosity and water-filled porosity. Porosity values obtained from logs from borehole USW G-2 are in reasonable agreement with estimates from core determinations.

647 Effects of core sealing methods on the preservation of pore water. Striffler, P. (Geological Survey, Denver, CO (United States)); Peters, C.A. pp. 960-966 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Five general core sealing methods (using Protecore, Lexan, wax, Protecore with wax, and Protecore with Lexan) were studied over a two year period to determine their moisture retention capabilities. Results indicate that the multibarrier methods (Protecore with wax and Protecore with Lexan) and the single barrier methods (Protecore and wax) provide successful means of retaining moisture in cores. Additional testing indicated that a tight wrap of Saran is effective in: (1) protecting the outer vapor barriers from puncture, (2) containing any condensate in close proximity to where it was condensed, and (3) retarding condensation. Tests conducted to determine the moisture adsorption potential of wax and the use of applying a positive or negative pressure to Protecore packets proved inconclusive, but warrant further investigation. The importance of proper and timely handling of core samples in the field, including refrigeration and weighing of samples, can not be overstated.

648 Characterizing the hydrogeologic framework of the Death Valley region, southern Nevada and California. Faunt, C. (Geological Survey, Denver, CO (United States)); D'Agnese, F.; Downey, J.S.; Turner, A.K. pp. 1194-1199 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Three-dimensional (3-D) hydrogeologic modeling of the complex geology of the Death Valley region requires the application of a number of Geoscientific Information System (GSIS) techniques. This study, funded by United States Department of Energy as a part of the Yucca Mountain Project, focuses on an area of approximately 100,000 square kilometers (three degrees of latitude by three degrees of longitude) and extends up to ten kilometers in depth. The geologic conditions are typical of the Basin and Range province; a variety of sedimentary and igneous intrusive and extrusive rocks have been subjected to both compressional and extensional deformation. GSIS techniques allow the synthesis of geologic, hydrologic and climatic information gathered from many sources, including satellite imagery and published maps and cross-sections. Construction of a 3-D hydrogeologic model is possible with the combined use of software products available from several vendors, including traditional GIS products and sophisticated contouring, interpolation, visualization, and numerical modeling packages.

649 Summary of revised potentiometric-surface map for Yucca Mountain and Vicinity, Nevada. Ervin, E.M. (Geological Survey, Denver, CO (United States)); Luckey, R.R.; Burkhardt, D.J. pp. 1554-1558 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The revised map for the potentiometric surface of the uppermost saturated zone in Tertiary volcanic rocks at Yucca Mountain, Nevada, is based mainly on 1988 water levels. Refinement of the water-level corrections has increased understanding of the area immediately east-southeast and hydrologically downgradient of Yucca Mountain. This small-gradient area is a nearly horizontal surface which corresponds to the likely direction of ground-water flow from Yucca Mountain–east southeast. To the west of Yucca Mountain water levels are approximately 300 m higher than those in the small-gradient area. Water levels are higher to the west of Yucca Mountain apparently because of a barrier to ground-water flow formed by the Solitario Canyon fault and a splay of the fault, and water levels are higher to the north apparently because of a semi-perched ground-water system.

650 Isotopic evidence of complex ground-water flow at Yucca Mountain, Nevada, USA. Peterman, Z.E. (Geological Survey, Denver, CO (United States)); Stuckless, J.S. pp. 1559-1566 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Strontium isotopes (expressed as per mil deviation from mean sea water, $\delta^{87}Sr$) reflect interaction between ground water and the aquifer of the Yucca Mountain region, $\delta^{87}Sr$ values increase from north to south downgradient in the flow system. The largest $\delta^{87}Sr$ values occur in the Amargosa Desert where ground water probably encounters alluvial basin fill derived from Precambrian rocks in the Funeral Range. Similarly, large $\delta^{87}Sr$ values for ground water in the Paleozoic aquifer at the western end of the Spring Mountains also probably reflect an encounter with Precambrian rocks. In several wells into the volcanic rocks, apparent isotopic disequilibrium between ground water and the producing units suggest that the ground water probably integrates over a substantial part of the saturated section in attaining its strontium isotope signature.

651 Late quaternary history and uranium isotopic compositions of ground water discharge deposits, Crater Flat, Nevada. Paces, J.B. (Geological Survey, Denver, CO (United States)); Taylor, E.M.; Bush, C. pp. 1573-1580 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Three carbonate-rich spring deposits are present near the southern end of Crater Flat, NV, approximately 18 km southwest of the potential high-level waste repository at Yucca Mountain. We have analyzed five samples of carbonate-rich material from two of the deposits for U and Th isotopic compositions. Resulting U-series disequilibrium ages indicate that springs were active at 18 ± 1, 30 ± 3, 45 ± 4 and >70 ka. These ages are consistent with a crude internal stratigraphy at one site. Identical ages for two samples at two separate sites suggest that springs were contemporaneous, at least in part, and were most likely part of the same hydrodynamic system. In addition, initial U isotopic compositions range from 2.8 to 3.8 and strongly suggest that ground water from the regional Tertiary-volcanic aquifer provided the source for these hydrogenic deposits. This interpretation, along with water level data from near-by wells suggest that the water table rose approximately 80 to 115 m above present levels during the late Quaternary and may have fluctuated repeatedly. Current data are insufficient to allow reconstruction of a detailed depositional history, however geochronological data are in a good agreement with other paleoclimatic proxy records preserved throughout the region. Since these deposits are down gradient from the potential repository site, the possibility of higher ground water levels in the future dramatically shortens both vertical and lateral ground water pathways and reduces travel times of transported radionuclides to potential discharge sites.

652 Structure of Crater Flat and Yucca Mountain, southeastern Nevada, as inferred from gravity data. Oliver, H.W. (Geological Survey, Menlo Park, CA (United States)); Fox, K.F. pp. 1812-1817 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Existing gravity data in the vicinity of Yucca Mountain and Crater Flat have been examined to determine if these data support only the caldera model or if they support other geologic models such as for a high-angle graben or detachment fault. The west to east isostatic gravity profile reduced for a density of 2.0 g/cm shows a gravity low of about 20 mGal centered only 2 km from the eastern edge of Crater Flat relative to a gravity high over the eastern boundary of Yucca Mountain. In the western part of Crater Flat, isostatic anomalies rise about 50 mGal across the flat, reaching a maximum gradient of 9 mGal/km about 3 km east of the Bare Mountain range-front fault. Computer modeling of these data indicate that a model that consists of a detachment fault that dips to the west at 12° under Yucca Mountain and interacts a 27° east-dipping Bare Mountain fault fits the observed gravity data generally as well as the caldera model.

653 Seismic reflection profiling: Essential geophysical data for Yucca Mountain, Nevada. Hunter, W.C. (Geological Survey, Denver, CO (United States)); Spengler, R.W.; Brocher, T.M. pp. 1835-1839 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Yucca Mountain, Nevada, consists of a thick sequence of ash-flow tuffs and lavas fractured into intact blocks with east-dipping strata, marginal broken zones characterized by dense faulting and brecciation, and intervening down-to-the-west fault zones with locally a typical west-dipping strata. Uncertainty in the structural setting of Yucca Mountain has resulted in multiple interpretations of the role and style of faulting. One interpretation describes steep normal faulting extending to seismogenic depth (10 to 15 km), and an alternate explanation suggests listric faults and a major low-angle detachment between the Tertiary volcanic sequence and the underlying Paleozoic rocks. Resolution of the deep geology is critical to evaluations of the potential tectonic and hydrologic hazards of the site. Seismic reflection profiling will provide essential data for defining the subsurface geometry of Yucca Mountain and for distinguishing between alternate interpretations of the structure of the mountain.

654 Geophysical investigations of buried volcanic centers near Yucca Mountain, Southwest Nevada. Langenheim, V.E. (Geological Survey, Menlo Park, CA (United States)); Kirchoff-Stein, K.S.; Oliver, H.W. pp. 1840-1846 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Several aeromagnetic dipolar anomalies occur over flat, alluvial areas near Yucca Mountain that resemble anomalies typically associated with subaerial basaltic volcanic centers. Detailed gravity and ground magnetic data were collected along a surveyed traverse across an aeromagnetic anomaly in Amargosa Valley, south of Yucca Mountain, Nevada. Modeling of the ground magnetic data collected over the largest of these anomalies, the Lathrop Wells aeromagnetic anomaly, indicates that the top of the causative body, most likely basalt, is less than 250 m below the surface. Gravity data indicate an apparent lack of an associated gravity anomaly and suggest that either the causative body may be tuff rather than basalt, or the volume of the body is small. Both drilling and collection of more magnetic and gravity data are necessary because ages and volumes of buried volcanic centers are important constraints for estimating the probability of potential volcanism near the proposed nuclear waste repository at Yucca Mountain.

655 Isotopic and trace element variability in altered and unaltered tuffs at Yucca Mountain, Nevada. Peterman, Z.E. (Geological Survey, Denver, CO (United States)); Spengler, R.W.; Singer, F.R.; Dickerson, R.P. pp. 1940-1947 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Reference stratigraphic sections near Yucca Mountain, Nevada were established and sampled in outcrop areas where the volcanic rocks have been minimally altered. Isotopic and trace element analysis obtained for these reference sections are baseline data for assessing the degree

and extent of element mobility attendant with past zonal alteration of the rock mass. In agreement with earlier studies, zeolitization is shown to have occurred under wholesale open-system conditions. Calcium was increased by two to three times the baseline values and strontium up to twenty times. In contrast, barium displays less variability, and the high-field strength elements zirconium and titanium were the least mobile during zeolitization. The data reported here establish the usefulness of reference sections for assessing past element mobility. The information gained will be helpful in predicting possible future element mobility induced by thermally activated fluids in the near field of a potential repository.

656 **Strontium isotopic evidence for a higher water table at Yucca Mountain.** Marshall, B.D. (Geological Survey, Denver, CO (United States)); Peterman, Z.E.; Stuckless, J.S. pp. 1948-1952 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

At Yucca Mountain, calcite occurs as open-space fillings and coatings on fractures within much of the host volcanic rocks in both the saturated and unsaturated zones. Strontium isotope analysis of these calcites divide the samples into two groups corresponding to their location in either the saturated or unsaturated zones. The group of samples from the unsaturated zone corresponds very well with pedogenic carbonate samples, indicating that the strontium came from the surface during infiltration events. However, four samples from the unsaturated zone show strontium isotopic ratios similar to present-day ground water. Since these samples are closest to the water table, they are interpreted as the result of a higher water-table stand (≈85 m higher than present-day) in the past.

657 **Lead isotopic composition of paleozoic and late proterozoic marine carbonate rocks in the vicinity of Yucca Mountains, Nevada.** Zartman, R.E. (Geological Survey, Denver, CO (United States)); Kwak, L.M. pp. 1953-1959 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Paleozoic and Late Proterozoic marine carbonate rocks (limestones, dolomites, and their metamorphic equivalents) cropping out in the vicinity of Yucca Mountain contain lead with an isotopic composition strongly suggesting them to be a major source of the lead observed at Trench 14 in the carbonate phase of carbonate-silica veins and nearby surficial calcrete deposits. Six whole-rock samples of marine carbonate rocks yield $^{206}Pb/^{204}Pb$ = 19.21-29.06, $^{207}Pb/^{204}Pb$ = 15.74-16.01, and $^{208}Pb/^{204}Pb$ = 37.90-39.25, and leachate and residue fractions of the rocks reveal additional isotopic heterogeneity within individual samples. Two samples of eolian dust also have isotopic compositions lying along a 'carbonate' to 'silicate' mixing trend that appears to arise entirely from pedeogenic processes. The tendency for the marine carbonate rocks to evolve highly uranogenic, but not thorogenic, lead results in a distinctive isotopic composition that serves as a tracer in eolian dust and secondary carbonate minerals derived from the marine carbonate rocks.

658 **Laboratory study of water infiltration into a block of welded tuff.** Thamir, F. (Geological Survey, Denver, CO (United States)); Kwicklis, E.M.; Anderton, S. pp. 2071-2080 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

A laboratory water infiltration experiment through a block of fractured welded tuff measuring 47.5 cm long x 54.3 cm wide x 80.6 cm high was conducted. The purpose of the laboratory experiment was to design an instrumentation and monitoring scheme for an in situ field test to be conducted at Yucca Mountain. The instrumentation design included thermocouple psychrometers and tensiometers to measure water and matrix potentials in fractures or matrix. An infiltrometer was designed to apply constant boundary conditions (pressure or flow rate). The block was drilled with 18 small diameter (12.7 mm) boreholes into which the thermocouple psychrometers and tensiometers were installed. The block was encased in plexiglas to minimize fluctuations in boundary conditions and water evaporation. Sand layers were placed below and above the block. Initial hydraulic testing involved saturating the overlying sand layer and monitoring the redistribution of water from the sand into the block. The final stage of testing involved the application of water to the top sand layer at a constant pressure. Water flow rates into the block at different applied pressures were measured. No outflow of water from the bottom of the block was observed. The instruments and infiltrometer proved to be adequate to make the desired measurements in both matrix and fractures.

659 (CONF-9309228–10) **Estimation of unsaturated zone liquid water flux at boreholes UZ No. 4, UZ No. 5, UZ No. 7, and UZ No. 13, Yucca Mountain, Nevada, from saturation and water potential profiles.** Kwicklis, E.M. (Geological Survey, Lakewood, CO (United States)); Healy, R.W.; Flint, A.L. Geological Survey, Denver, CO (United States). [1993]. 19p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From Focus 93: site characterization and model validation; Las Vegas, NV (United States); 26-29 Sep 1993. Order Number DE94014223. Source: OSTI; NTIS; INIS; GPO Dep.

The unsaturated zone at Yucca Mountain, Nevada, is being investigated as a potential location for a high-level nuclear waste repository. Characterization of the liquid water flux and its spatial distribution under natural conditions provides estimates of the amount of water that could potentially contact the waste canisters and transport soluble radionuclides to the accessible environment. Estimates of ambient water flux may affect design requirements by indicating the degree to which reliance must be placed on engineered barriers or the waste-generated heat to keep the waste canisters dry.

660 (CONF-9309228–11) **Three-dimensional lithostratigraphic model at Yucca Mountain, Nevada: A framework for fluid transport modeling and engineering design.** Buesch, D.C. (Geological Survey, Las Vegas, NV (United States)); Spengler, R.W.; Nelson, J.E.; Dickerson, R.P. Geological Survey, Las Vegas, NV (United States). [1993]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From Focus 93: site characterization and model validation; Las Vegas, NV (United States); 26-29 Sep 1993. Order Number DE94014850. Source: OSTI; NTIS; INIS; GPO Dep.

A three-dimensional lithostratigraphic model of the central block of Yucca MounEain. Nevada, illustrates how some activities can serve both site characterization and dcsign and construction of the Exploratory Studies Facility (ESF). Site-characterization activities supported bv this model include characterizing the three-dimensional geometry of lithologic units and faults, and providing boundary conditions for geostatistical models and site-scale fluid flow modeling. The model supports the conceptual design as construction efforts for the proposed ramps of the ESF and potential high-level nuclear waste repository.

661 (CONF-940553–67) **Saturation levels and trends in the unsaturated zone, Yucca Mountain, Nevada.** Nelson, P.H. Geological Survey, Denver, CO (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE94013978. Source: OSTI; NTIS; INIS; GPO Dep.

The unsaturated zone at Yucca Mountain, Nevada, consists of interstratified nonwelded tuffs, which are locally altered to zeolites and clays, and welded tuffs which have laterally extensive lithophysal and nonlithophysal zones. The vertical heterogeneity and lateral homogeneity in rock types control the physical and hydrological properties. Water content and porosity within the unsaturated zone at Yucca Mountain can be quantified using geophysical logs. A log-based approach offers the advantage of in-situ measurements, continuous throughout a borehole. Water content and porosity can be determined with a pair of geophysical logs, such as the density and dielectric logs, as outlined in this paper.

662 (CONF-940553–85) **Ground-water recharge in Fortymile Wash near Yucca Mountain, Nevada, 1992–1993.** Savard, C.S. Geological Survey, Mercury, NV (United States). [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001451. Source: OSTI; NTIS; INIS; GPO Dep.

Quantification of the ground-water recharge from streamflow in the Fortymile Wash watershed will contribute to regional ground-water studies. Regional ground-water studies are an important component in the studies evaluating the ground-water flow system as a barrier to the potential migration of radionuclides from the potential underground high-level nuclear waste repository. Knowledge gained in understanding the ground-water recharge mechanisms and pathways in the Pah Canyon area, which is 10 km to the northeast of Yucca Mountain, may transfer to Yucca site specific studies. The current data collection network in Fortymile Canyon does not permit quantification of ground-water recharge, however a qualitative understanding of ground-water recharge was developed from these data.

663 (CONF-940553–86) **Observations of water movement in a block of fractured welded Tuff.** Thamir, F. (Geological Survey, Denver, CO (United States)); Kwicklis, E.M.; Hampson, D.; Anderton, S. Geological Survey, Denver, CO (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001452. Source: OSTI; NTIS; INIS; GPO Dep.

A laboratory water infiltration experiment through a block of fractured, moderately welded volcanic tuff was conducted at different boundary pressures. The block measured 47.5 cm long × 54.3 cm wide × 80.6 cm high. The purpose of the experiment was: (a) to test an instrumentation scheme for a field test, and (b) to make flow measurements through a fractured network at different boundary pressures to understand mechanisms that affect fracture flow. The upper boundary water pressure was decreased in steps; each step lasted several weeks where the pressure was kept steady. Water inflow and outflow rates were measured for each boundary condition. Entrapped air was found to impede water movement. The gas phase in the fracture network was found to not be continuous; its pressure within the network was not known. The matric potential values could not be measured with tensiometers alone since a known gas pressure is required. Long-term input and output flow rates were equal. Outflow rate did not stabilize during the test period; it continued to decrease, even when the upper boundary water pressure was kept steady. No relation between boundary pressure and flow rate was established. Bacteria, which was found in the outflow, possibly caused variations in the behavior. Trapped air caused the outflow to periodically decrease or stop; however, outflow rates following the interruptions did not change long-term flow trends.

664 (CONF-940553–87) **Characterization of a desert soil sequence at Yucca Mountain, NV.** Guertal, W.R. (Foothill Engineering, Inc., Mercury, NV (United States)); Hofmann, L.L. Hudson, D.B.; Flint, A.L. Geological Survey, Denver, CO (United States). [1994]. 7p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001453. Source: OSTI; NTIS; INIS; GPO Dep.

Yucca Mountain, Nevada, is currently being evaluated as a potential site for a geologic repository for high level radioactive waste. Hydrologic evaluation of the unsaturated zone of Yucca Mountain is being conducted as an integrated set of surface and subsurface-based activities with a common objective to characterize the temporal and spatial distribution of water flux through the potential repository. Yucca Mountain is covered with a thin to thick layer of colluvial/alluvial materials, where there are not bedrock outcrops. It is across this surface boundary that all infiltration and all exfiltration occurs. This surface boundary effects water movement through the unsaturated zone. Characterization of the hydrologic properties of surficial materials is then a necessary step for short term characterization goals and for long term modeling.

665 (CONF-940553–88) **Verification of a 1-dimensional model for predicting shallow infiltration at Yucca Mountain.** Hevesi, J.A. (Geological Survey, Mercury, NV (United States)); Flint, A.L.; Flint, L.E. Geological Survey, Denver, CO (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001454. Source: OSTI; NTIS; INIS; GPO Dep.

A characterization of net infiltration rates is needed for site-scale evaluation of groundwater flow at Yucca Mountain, Nevada. Shallow infiltration caused by precipitation

may be a potential source of net infiltration. A 1-dimensional finite difference model of shallow infiltration with a moisture-dependant evapotranspiration function and a hypothetical root-zone was calibrated and verified using measured water content profiles, measured precipitation, and estimated potential evapotranspiration. Monthly water content profiles obtained from January 1990 through October 1993 were measured by geophysical logging of 3 boreholes located in the alluvium channel of Pagany Wash on Yucca Mountain. The profiles indicated seasonal wetting and drying of the alluvium in response to winter season precipitation and summer season evapotranspiration above a depth of 2.5 meters. A gradual drying trend below a depth of 2.5 meters was interpreted as long-term redistribution and/or evapotranspiration following a deep infiltration event caused by runoff in Pagany Wash during 1984. An initial model, calibrated using the 1990 to 1 992 record, did not provide a satisfactory prediction of water content profiles measured in 1993 following a relatively wet winter season. A recalibrated model using a modified, seasonally-dependent evapotranspiration function provided an improved fit to the total record. The new model provided a satisfactory verification using water content changes measured at a distance of 6 meters from the calibration site, but was less satisfactory in predicting changes at a distance of 18 meters.

666 (CONF-940553–89) **A borehole instrumentation program for characterization of unsaturated-zone percolation.** Kume, J.; Rousseau, J.P. Geological Survey, Denver, CO (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001455. Source: OSTI; NTIS; INIS; GPO Dep.

A borehole instrumentation and monitoring program has been designed by the US Geological Survey to support site characterization of unsaturated-zone percolation at Yucca Mountain, Nye County, Nevada. This program provides a means of defining the unsaturated-zone fluid flow (liquid and gas) potential field in a setting that incorporates large-scale stratigraphic and structural features, and the influences of geothermal heat flow and atmospheric pressure changes. Data derived from this program will be used to evaluate the suitability of Yucca Mountain as a mined geologic-repository for the storage of high-level, radioactive waste. These data include in-situ temperature, pneumatic pressure, and water potential. In addition, the instrumentation program provides facilities for gas-sampling, gas-tracer diffusion testing, water-injection testing, water-level monitoring, neutron moisture-meter monitoring, temperature profiling, and in-situ recalibration of the downhole sensors. The program included testing and development of: (1) precision sensors for measurement; (2) a downhole instrumentation-station-apparatus to house the sensors, recalibrate sensors in-situ, and allow access to instrument stations for other testing purposes; and (3) surface-based support and instrumentation facilities.

667 (CONF-940553–90) **Hydrologic property alterations due to elevated temperatures at Yucca Mountain.** Flint, A.L. (Geological Survey, Mercury, NV (United States)); Nash, M.H.; Nash, M.S. Geological Survey, Denver, CO (United States). [1994]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001456. Source: OSTI; NTIS; INIS; GPO Dep.

Yucca Mountain is currently being evaluated as a potential site for a high level nuclear waste repository. The pre-emplacement hydrologic properties of the rock are important in determining the suitability of the site; however, post emplacement thermal loads and associated drying may permanently alter the character of the rock. A preliminary study was undertaken to determine the effects of elevated temperatures on hydrologic properties of the welded Topopah Spring member of the Paintbrush Tuff and a zeolitic, nonwelded tuff from the Tuffaceous Beds of Calico Hills. Rock outcrop samples were collected and dried in the laboratory at different temperatures (up to 400 degrees C). Hydrologic and physical properties -were tested before and after each of the drying cycles.

668 (CONF-940553–91) **Shallow infiltration processes in arid watersheds at Yucca Mountain, Nevada.** Flint, L.E. (Geological Survey, Mercury, NV (United States)); Flint, A.L. Hevesi, J.A. Geological Survey, Denver, CO (United States). [1994]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001457. Source: OSTI; NTIS; INIS; GPO Dep.

A conceptual model of shallow infiltration processes at Yucca Mountain, Nevada, was developed for use in hydrologic flow models to characterize net infiltration (the penetration of the wetting front below the zone influenced by evapotranspiration). The model categorizes the surface of the site into four infiltration zones. These zones were identified as ridgetops, sideslopes, terraces, and active channels on the basis of water-content changes with depth and time. The maximum depth of measured water-content change at a specific site is a function of surface storage capacity, the timing and magnitude of precipitation, evapotranspiration, and the degree of saturation of surficial materials overlying fractured bedrock. Measured water-content profiles for the four zones indicated that the potential for net infiltration is higher when evapotranspiration is low (i.e winter, cloudy periods), where surface concentration of water is likely to occur (i.e. depressions, channels), where surface storage capacity is low, and where fractured bedrock is close to the surface.

669 (CONF-940553–92) **Late glacial climate estimates for southern Nevada: The ostracode fossil record.** Forester, R.M. (Geological Survey, Denver, CO (United States)); Smith, A.J. Firestone Tire and Rubber Co., Akron, OH (United States). [1995]. 9p. Sponsored by USDOE, Washington, DC (United States). U.S. Geological Survey, Global Climate Change and Climate Histor From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001458. Source: OSTI; NTIS; GPO Dep.

Climate change plays an important role in determining as possible long term hydrological performance of the potential high level nuclear waste repository within Yucca Mountain, Nevada. Present-day global circulation results in this region having an arid to semi-arid climate characterized by hot and relatively dry summers. Global circulation during the late glacial (about 14 to 20 ka) was very different from the present-day. Preliminary study of late-glacial fossil ostracodes from "marsh deposits" in the upper Las Vegas Valley suggests mean annual precipitation may have been four

times higher, while mean annual temperature may have been about 10°C cooler than today. A major difference between present-day and late-glacial climate was likely the existence of cooler, cloudier, and wetter summers in the past.

670 (CONF-940553–93) **Simulation of flow in the unsaturated zone beneath Pagany Wash, Yucca Mountain.** Thamir, F. (Geological Survey, Denver, CO (United States)); Kwicklis, E.M.; Hampson, D.; Anderton, S. Geological Survey, Denver, CO (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001459. Source: OSTI; NTIS; INIS; GPO Dep.

A one-dimensional numerical model was created simulate water movement beneath Pagany Wash, Yucca Mountain, Nevada. Model stratigraphy and properties were on data obtained from boreholes UE-25 UZ #4 UE-25 UZ #5, which were drilled in the alluvial channel and bedrock sideslope of Pagany Wash. Although unable to account for multidimensional or preferential flowpaths beneath the wash, the model proved a useful conceptual tool with which to develop hypotheses and, in some cases, provide bounding calculations. The model indicated that liquid flux decreases with depth in the upper 120 m beneath the wash, with fluxes of several tens mm/yr in the nonwelded base of the Tiva Canyon Member and fluxes on the order of a tenth mm/yr in the upper Topopah Spring Member. Capillary barrier effects were indicated by the model to significantly delay the entry of large fluxes into the potential repository horizon during periods of increasing net infiltration, and to inhibit rapid drainage of water from the nonwelded and bedded intervals into the potential repository horizon during periods of moisture redistribution. Lateral moisture redistribution can be expected to be promoted by these effects.

671 (CONF-940553–95) **Fluid inclusion studies of calcite veins from Yucca Mountain, Nevada, Tuffs: Environment of formation.** Roedder, E. (Harvard Univ., Cambridge, MA (United States)); Whelan, J.F.; Vaniman, D.T. Geological Survey, Denver, CO (United States). [1994]. 4p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001461. Source: OSTI; NTIS; INIS; GPO Dep.

Calcite vein and vug fillings at four depths (130-314m), all above the present water table in USW G-1 bore hole at Yucca Mountain, Nevada, contain primary fluid inclusions with variable vapor/liquid raitos: Most of these inclusions are either full of liquid or full of vapor. The liquid-filled inclusions show that most of the host calcite crystallized from fluids at <100°C. The vapor-filled inclusions provide evidence that a separate vapor phase was present in the fluid during crystallization. Studies of these vapor-filled inclusions on the microscope crushing stage were interpreted in an earlier paper as indicating trapping of an air-water-CO_2 vapor phase at "<100°C". Our new studies reveal the additional presence of major methane in the vapor-filled inclusion, indicating even lower temperatures of trapping, perhaps at near-surface temperatures. They also show that the host calcite crystals grew from a flowing film of water on the walls of fractures open to the atmosphere, the vapor-filled inclusions representing bubbles that exsolved from this film onto the crystal surface.

672 (CONF-940553–96) **Isotopic studies of Yucca Mountain soil fluids and carbonate pedogenesis.** McConnaughey, T.A.; Whelan, J.F.; Wickland, K.P.; Moscati, R.J. Geological Survey, Denver, CO (United States). [1994]. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001462. Source: OSTI; NTIS; INIS; GPO Dep.

Secondary carbonates occurring within the soils, faults, and subsurface fractures of Yucca Mountain contain some of the best available records of paleoclimate and palehydrology for the potential radioactive waste repository site. This article discusses conceptual and analytical advances being made with regard to the interpretation of stable isotope data from pedogenic carbonates, specifically related to the ^{13}C content of soil CO_2, $CaCO_3$, precipitation mechanisms, and isotopic fractionations between parent fluids and precipitating carbonates. The ^{13}C content of soil carbon dioxide from Yucca Mountain and vicinity shows most of the usual patterns expected in such contexts: Decreasing ^{13}C content with depth decreasing ^{13}C with altitude and reduced ^{13}C during spring. These patterns exist within the domain of a noisy data set; soil and vegetational heterogeneities, weather, and other factors apparently contribute to isotopic variability in the system. Several soil calcification mechanisms appear to be important, involving characteristic physical and chemical environments and isotopic fractionations. When CO_2 loss from thin soil solutions is an important driving factor, carbonates may contain excess heavy isotopes, compared to equilibrium precipitation with soil fluids. When root calcification serves as a proton generator for plant absorption of soil nutrients, heavy isotope deficiencies are likely. Successive cycles of dissolution and reprecipitation mix and redistribute pedogenic carbonates, and tend to isotopically homogenize and equilibrate pedogenic carbonates with soil fluids.

673 (CONF-940553–97) **Modeling a ponded infiltration experiment at Yucca Mountain, NV.** Hudson, D.B. (Foothill Engineering, Inc., Mercury, NV (United States)); Guertal, W.R.; Flint, A.L. Geological Survey, Denver, CO (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001463. Source: OSTI; NTIS; INIS; GPO Dep.

Yucca Mountain, Nevada is being evaluated as a potential site for a geologic repository for high level radioactive waste. As part of the site characterization activities at Yucca Mountain, a field-scale ponded infiltration experiment was done to help characterize the hydraulic and infiltration properties of a layered dessert alluvium deposit. Calcium carbonate accumulation and cementation, heterogeneous layered profiles, high evapotranspiration, low precipitation, and rocky soil make the surface difficult to characterize.The effects of the strong morphological horizonation on the infiltration processes, the suitability of measured hydraulic properties, and the usefulness of ponded infiltration experiments in site characterization work were of interest. One-dimensional and two-dimensional radial flow numerical models were used to help interpret the results of the ponding experiment. The objective of this study was to evaluate the results of a ponded infiltration experiment done around borehole UE25 UZN #85 (N85) at Yucca Mountain, NV. The effects of morphological

horizons on the infiltration processes, lateral flow, and measured soil hydaulic properties were studied. The evaluation was done by numerically modeling the results of a field ponded infiltration experiment. A comparison the experimental results and the modeled results was used to qualitatively indicate the degree to which infiltration processes and the hydaulic properties are understood. Results of the field characterization, soil characterization, borehole geophysics, and the ponding experiment are presented in a companion paper.

674 (CONF-940553–98) **Strontium isotope geochemistry of soil and playa deposits near Yucca Mountain, Nevada.** Marshall, B.D.; Mahan, S.A. Geological Survey, Denver, CO (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001464. Source: OSTI; NTIS; INIS; GPO Dep.

The isotopic composition of strontium contained in the carbonate fractions of soils provides an excellent tracer which can be used to test models for their origin. This paper reports data on surface coatings and cements, eolian sediments, playas and alluvial fan soils which help to constrain a model for formation of the extensive calcretes and fault infilling in the Yucca Mountain region. The playas contain carbonate with a wide range of strontium compositions; further work will be required to fully understand their possible contributions to the pedogenic carbonate system. Soils from an alluvial fan to the west of Yucca Mountain show that only small amounts of strontium are derived from weathering of silicate detritus. However, calcretes from a fan draining a carbonate terrane have strontium compositions dominated locally by the limestone strontium component. Although much evidence points to an eolian source for at least some of the strontium in the pedogenic carbonates near Yucca Mountain, an additional component or past variation of strontium composition in the eolian source is required to model the pedogenic carbonate system.

675 (CONF-940553–99) **Spatial distribution of potential near surface moisture flux at Yucca Mountain.** Flint, A.L.; Flint, L.E. Geological Survey, Mercury, NV (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001465. Source: OSTI; NTIS; INIS; GPO Dep.

An estimate of the areal distribution of present-day surface liquid moisture flux at Yucca Mountain was made using field measured water contents and laboratory measured rock properties. Using available data for physical and hydrologic properties (porosity, saturated hydraulic conductivity moisture retention functions) of the volcanic rocks, surface lithologic units that are hydrologically similar were delineated. Moisture retention and relative permeability functions were assigned to each surface unit based on the similarity of the mean porosity and saturated hydraulic conductivity of the surface unit to laboratory samples of the same lithology. The potential flux into the mountain was estimated for each surface hydrologic unit using the mean saturated hydraulic conductivity for each unit and assuming all matrix flow. Using measured moisture profiles for each of the surface units, estimates were made of the depth at which seasonal fluctuations diminish and steady state downward flux conditions are likely to exist. The hydrologic properties at that depth were used with the current relative saturation of the tuff, to estimate flux as the unsaturated hydraulic conductivity. This method assumes a unit gradient. The range in estimated flux was 0.02 mm/yr for the welded Tiva Canyon to 13.4 mm/yr for the nonwelded Paintbrush Tuff. The areally averaged flux was 1.4 mm/yr. The major zones of high flux occur to the north of the potential repository boundary where the nonwelded tuffs are exposed in the major drainages.

676 (CONF-940553–100) **Evidence for a welded tuff in the Rhyolite of Calico Hills.** Dickerson, R.P. (Science Applications International Corp., Golden, CO (United States)); Hunter, W.C. Geological Survey, Denver, CO (United States). [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001466. Source: OSTI; NTIS; INIS; GPO Dep.

A welded pyroclastic deposit has been identified in the Rhyolite of Calico Hills near Yucca Mountain, Nevada, where only lava flows and nonwelded pyroclastic deposits were previously described. Field data from Fortymile Wash show that nonwelded, bedded tuff grades upward into partially welded massive ruff, and thence into densely welded vitrophyre. Petrographic data show a progressive decrease in inter- and intragranular porosity and amount of vapor-phase minerals, with increasing welding. Pumice fragments are first deformed, then develop diffuse boundaries which become increasingly obscure with progressive welding. The most densely welded rock is a perlitic vitrophyre. The origin of this welded tuff is not clear, as it could represent an ignimbrite or a tuff fused beneath a thick lava flow.

677 (CONF-940553–101) **Evaluation of a 6-wire thermocouple psychrometer for determination of in-situ water potentials.** Loskot, C.L. (Geological Survey, Denver, CO (United States)); Rousseau, J.P.; Kurzmack, M.A. Geological Survey, Denver, CO (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE96001467. Source: OSTI; NTIS; INIS; GPO Dep.

The US Geological Survey has been conducting investigations at Yucca Mountain, Nevada, to provide information about the hydrologic and geologic suitability of this site for storing high-level nuclear wastes in an underground mined repository. Test drilling and instrumentation are a principal method of investigation. The main objectives of the deep unsaturated-zone testhole program are: (1) to determine the flux of water moving through the unsaturated welded and nonwelded tuff units, (2) to determine the vertical and lateral distribution of moisture content, water potential, and other important geohydrologic characteristics in the rock units penetrated, and (3) to monitor stability and changes in in-situ fluid potentials with time. Thermocouple psychrometers will be used to monitor in-situ water potentials.

678 **Integrated geology and preliminary cross section along the north ramp of the exploratory studies facility, Yucca Mountain.** Buesch, D.C. (Geological Survey, Las Vegas, NV (United States)); Dickerson, R.P.; Drake, R.M.; Spengler, R.W. pp. 1055-1065 of High Level Radioactive Waste Management: Proceedings of the fifth annual

international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The Exploratory Studies Facility is a major part of the site characterization activities at Yucca Mountain, Nevada, and the north ramp is the first phase of construction. The N61W trending north ramp will transect the Bow Ridge and Drill Hole Wash faults and numerous minor faults, and traverses two thick welded tuffs and several nonwelded tuff units. A preliminary cross section along the north ramp was created by integration of geologic map relations, lithostratigraphic data from core collected from boreholes, and surface and borehole geophysical data. The Bow Ridge fault is a west-dipping normal fault with about 410 feet of dip-slip separation. East-dipping strata in the hanging wall adjacent to the fault is contrary to early structural interpretations. West of the Bow Ridge fault the ramp might traverse about 220 ± 65 feet of nonlithified tuffaceous material. Geometry of the Drill Hole Wash fault is not known, but is modeled in part as two strands that juxtapose different thicknesses and facies of formations with a complex sense of movement.

679 Oil and gas exploration near Yucca Mountain, southern Nevada. Grow, J.A. (Geological Survey, Denver, CO (United States)); Barker, C.E.; Harris, A.G. pp. 1298-1315 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Three oil exploration wells were drilled within 20 km of Yucca Mountain in 1991. Conodont samples from two of these new wells and 190 locations near Yucca Mountain and have been analyzed for color alteration indices (CAI), which can be correlated to thermal maturity and petroleum generation. Cambrian through Triassic rocks in the vicinity of Yucca Mountain have experienced temperatures too high to be capable of generating oil, except for a narrow zone (20 x 100 km) northeast of Yucca Mountain, where Mississippian through Triassic rocks are just within the upper limit of the oil generating window. Organic geochemical samples from the Mississippian Eleana Formation in this zone have low total organic carbon and low hydrogen indices, which, combined with overall pattern of CAI values, indicates that the entire Cambrian through Triassic sedimentary column is unfavorable as oil source rocks. While much of the Cambrian through Triassic rocks have thermal potential for gas, extensive Late Tertiary faulting at Yucca Mountain suggest that seals might be inadequate for retaining gas. No commercial gas fields have been found to date in Nevada or adjacent parts of California. Organic geochemistry on samples from a few Tertiary lacustrine deposits do show high carbon and hydrogen indices. However, the lacustrine deposits in these basin and range type valleys lack long range continuity and none of the present Nevada oil fields produce from such Tertiary valley-fill.

680 Isotopic tracers of gold deposition in paleozoic limestones, southern Nevada. Peterman, Z.E. (Geological Survey, Denver, CO (United States)); Widmann, B.L.; Marshall, B.D.; Aleinikoff, J.N.; Futa, K.; Mahan, S.A. pp. 1316-1323 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Strontium isotopic analyses of barren and mineralized Paleozoic carbonate rocks show that hydrothermal fluids added radiogenic strontium (^{87}Sr) to the mineralized zones. At Bare Mountain, samples collected from mineralized areas have $\delta^{87}Sr_t$ values (per mil deviation from primary marine values) ranging from +3.0 to +23.0 (mean of this log-normal distribution is +7.0), whereas unmineralized carbonate rocks have $\delta^{87}Sr_t$ values of -0.6 to +2.9 (mean of +1.07±1.03). In other ranges (Striped Hills, Spring Mountains, and ranges in the vicinity of Indian Springs Valley), $\delta^{87}Sr_t$ values of the unmineralized carbonate rocks are even lower and virtually indistinguishable from primary marine values. This correlation of elevated $\delta^{87}Sr_t$ values with mineralized zones provides a useful technique for assessing the mineral potential of the Paleozoic basement beneath Yucca Mountain, and may find broader use in mineral exploration in the Basin and Range province as a whole.

681 Ground-water recharge in Fortymile Wash near Yucca Mountain, Nevada, 1992-93. Savard, C.S. (Geological Survey, Mercury, NV (United States)). pp. 1805-1813 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Ground-water recharge occurred after five separate streamflow event periods in the Pah Canyon area of Fortymile Wash approximately 10 kilometers from Yucca Mountain, Nevada during 1992-93. Ground-water levels rose in two wells, UE-29 a No.1 and UE-29 a No.2, and one neutron-access borehole, UE-29 UZN-91, after each streamflow event period. A maximum rise of 2.9 meters occurred at UE-29 a No.1 thirteen days after the largest streamflow event where depth to water changed from 27.3 to 24.4 meters. Water levels fluctuated 3.89 meters in UE-29 a No.1, 2.92 meters in UE-29 a No.2, and 2.10 meters in UE-29 UZN-91 during the period January, 1992 to September, 1993. During two of the streamflow event periods, one in 1992 and one in 1993, there was flow around the neutron-access borehole located in the Fortymile Wash channel. Three other streamflow event periods were documented in Pah Canyon Wash but the streamflow infiltrated prior to reaching the neutron-access borehole location. Volumetric-water-content profiles were measured periodically in the neutron-access borehole. After the 1992 streamflow event period, water content increased in the upper six meters of the unsaturated zone. After the 1993 streamflow event period, water content increased in the entire unsaturated section, approximately 16 meters thick at the neutron-access borehole. Water levels in the neutron-access borehole rose even when there was no apparent water movement through the unsaturated zone as inferred by changes in the volumetric-water contents. This rise is attributed to ground-water recharge from nearby infiltration of Pah Canyon Wash streamflow. A groundwater mound probably formed beneath Pah Canyon Wash and spread laterally as evidence by larger rises in water levels in UE-29 a No.1 and UE-29 a No.2, which are closer to Pah Canyon Wash than UE-29 UZN-91.

682 Fluid inclusion studies of calcite veins from Yucca Mountain, Nevada, Tuffs: Environment of formation. Roedder, E. (Harvard Univ., Cambridge, MA (United States)); Whelan, J.F.; Vaniman, D.T. pp. 1854-1860 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Calcite vein and vug fillings at fourth depths (130-314m), all above the present water table in USW G-1 bore hole at Yucca Mountain, Nevada, contain primary fluid inclusions with variable vapor/liquid ratios: most of these inclusions are either full of liquid or full of vapor. The liquid-filled inclusions show that most of the host calcite crystallized from fluids at <100°C. The vapor-filled inclusions provide evidence that a separate vapor phase was present in the fluid during crystallization. Studies of these vapor-filled inclusions on the microscope crushing stage were interpreted in an earlier paper as indicating trapping of an air-water-CO_2 vapor phase at "100°C". Our new studies reveal the additional presence of major methane in the vapor-filled inclusion, indicating even lower temperatures of trapping, perhaps at near-surface temperatures. They also show that the host calcite crystals grew from a flowing film of water on the walls of fractures open to the atmosphere, the vapor-filled inclusions representing bubbles that exsolved from this film onto the crystal surface.

683 Evidence for a welded tuff in the rhyolite of Calico Hills. Dickerson, R.P. (Science Applications International Corp., Golden, CO (United States)); Hunter, W.C. pp. 1861-1868 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A welded pyroclastic deposit has been identified in the Rhyolite of Calico Hills near Yucca Mountain, Nevada, where only lava flows and nonwelded pyroclastic deposits were previously described. Field data from Fortymile Wash show that nonwelded, bedded tuff grades upward into partially welded massive tuff, and thence into densely welded vitrophyre. Petrographic data show a progressive decrease in inter- and intragranular porosity and amount of vapor-phase minerals, with increasing welding. Pumice fragments are first deformed, then develop diffuse boundaries which become increasingly obscure with progressive welding. The most densely welded rock is a perlitic vitrophyre. The origin of this welded tuff is not clear, as it could represent an ignimbrite or a tuff fused beneath a thick lava flow.

684 Petrographic and geochemical characteristics of a section through the Tiva Canyon Tuff at Antler Ridge, Yucca Mountain, Nevada. Singer, F.R. (Science Applications International Corp., Golden, CO (United States)); Widmann, B.L.; Dickerson, R.P.; Byers, F.M. Jr. pp. 1869-1879 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The Tiva Canyon Tuff of the Paintbrush Group of Miocene age caps much of Yucca Mountain, Nevada and is a compositionally zoned, compound cooling, pyroclastic flow that ranges from a dominantly high-silica rhyolitic base to a quartz-latitic caprock. Petrographic and geochemical studies have focused on rigorously defining the internal stratigraphy of this unit to support the detailed mapping of the Ghost Dance fault and other structures in the central fault block of Yucca Mountain. This study shows that devitrification textures and vapor phase mineralogy, in addition to other physical attributes such as pumice variability (flattening) and crystal content, can be used as distinguishing criteria to better define lithologic zones within the Tiva Canyon Tuff. In addition, the study also shows that the petrographic textures and chemistry of the groundmass vary systematically within recognizable lithologic zones and may be used to characterize and vertically divide litho-stratigraphic zones within the Tiva Canyon Tuff.

685 Observations of water movement in a block of fractured welded tuff. Thamir, F. (Geological Survey, Denver, CO (United States)); Kwicklis, E.M.; Hampson, D.; Anderton, S. pp. 2020-2029 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A laboratory water infiltration experiment through a block of fractured, moderately welded volcanic tuff was conducted at different boundary pressures. The block measured 47.5 cm long × 54.3 cm wide × 80.6 cm high. The purpose of the experiment was: (a) to test an instrumentation scheme for a field test, and (b) to make flow measurements through a fractured network at different boundary pressures to understand mechanisms that affect fracture flow. The upper boundary water pressure was decreased in steps; each step lasted several weeks where the pressure was kept steady. Water inflow and outflow rates were measured for each boundary condition. Entrapped air was found to impede water movement. The gas phase in the fracture network was found to not be continuous; its pressure within the network was not known. The matric potential values could not be measured with tensionmeters alone since a known gas pressure is required. Long-term input and output flow rates were equal. Outflow rate did not stabilize during the test period; it continued to decrease, even when the upper boundary water pressure was kept steady. No relation between boundary pressure and flow rate was established. Bacteria, which was found in the outflow, possibly caused variations in the behavior. Trapped air caused the outflow to periodically decrease or stop; however, outflow rates following the interruptions did not change long-term trends.

686 A borehole instrumentation program for characterization of unsaturated-zone percolation. Kume, J. (Geological Survey, Denver, CO (United States)); Rousseau, J.P. pp. 2076-2083 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A borehole instrumentation and monitoring program has been designed by the U.S. Geological Survey to support site characterization of unsaturated-zone percolation at Yucca

Mountain, Nye County, Nevada. This program provides a means of defining the unsaturated-zone fluid flow (liquid and gas) potential field in a setting that incorporates large-scale stratigraphic and structural features, and the influences of geothermal heat flow and atmospheric pressure changes. Data derived from this program will be used to evaluate the suitability of Yucca Mountain as a mined geologic-repository for the storage of high-level, radioactive waste. These data include in-situ temperature, pneumatic pressure, and water potential. In addition, the instrumentation program provides facilities for gas-sampling, gas-tracer diffusion testing, water-injection testing, water-level monitoring, neutron moisture-meter monitoring, temperature profiling, and in-situ recalibration of the downhole sensors. The program included testing and development of: (1) precision sensors for measurement, (2) a downhole instrumentation-station-apparatus to hose the sensors, recalibrate sensors in-situ, and allow access to instrument stations for other testing purposes, and (3) surface-based support and instrumentation facilities.

687 **Evaluation of a 6-wire thermocouple psychrometer for determination of in-situ water potentials.** Loskot, C.L. (Geological Survey, Denver, CO (United States)); Rousseau, J.P.; Kurzmack, M.A. pp. 2084-2091 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A 6-wire, Peltier-type thermocouple psychrometer was designed and evaluated by the U.S. Geological Survey for monitoring in-situ water potentials in dry-drilled boreholes in the unsaturated zone at Yucca Mountain, Nye County, Nevada. The psychrometer consists of a wet-bulb, chromel-constantan, sensing junction and a separate dry-bulb, copper-constantan, reference junction. Two additional reference junctions are formed where the chromel and constantan wires of the wet-bulb sensing junction are soldered to separate, paired, copper, lead wires. In contrast, in the standard 3-wire thermocouple psychrometer, both the wet bulb and dry bulb share a common wire. The new design has resulted in a psychrometer that has an expanded range and greater reliability, sensitivity, and accuracy compared to the standard model.

688 **Hydrologic property alterations due to elevated temperatures at Yucca Mountain.** Flint, A.L. (Geological Survey, Mercury, NV (United States)); Nash, M.H.; Nash, M.S. pp. 2101-2105 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Drying experiments were conducted on fifty core samples of welded tuff and fifty core samples of zeolitic, nonwelded tuff. Initially, all core samples were vacuum saturated, and weights and volumes were measured. The samples were dried in a relative humidity oven at 60 degrees C and 45 percent relative humidity. Sorptivity was measured to obtain information on flow properties. The samples from each type of tuff were divided into five sets of ten samples with similar mean porosities. Each sample set was subjected to a different drying temperature; 60, 105, 200, 300 or 400 degrees C with the fifth group left as a control. After drying, the samples were resaturated and all the measurements repeated. Calculated porosity, particle density, and sorptivity increased; and bulk density decreased with increasing temperature. Air and water permeability increased on the nonwelded tuff samples, however air permeability was unchanged for the welded tuff. All bulk properties recovered to the original values following drying, while the flow properties (sorptivity and air and water permeability) were permanently altered. At the completion of the flow measurements, one core from each temperature treatment, was cut into small disks. Water retention curves were measured on these disks (subsamples). There were no differences in measured water retention curves due to drying at different temperatures.

689 **Late cenozoic evolution of Fortymile Ash: Major change in drainage pattern in the Yucca Mountain, Nevada region during late miocene volcanism.** Lundstrom, S.C. (Geological Survey, Las Vegas, NV (United States)); Warren, R.G. pp. 2121-2130 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Analysis of sedimentary provenance and altitude distribution of volcanic strata along Fortymile Wash, the primary desert wash east of Yucca Mountain, NV, indicates a major change in surface drainage basins related to late Miocene volcanic disruption. This event resulted in the establishment of the modern Fortymile Wash basin before 3 Ma, and probably by latest Miocene time. An understanding of this event is useful for evaluation of extensive alluviation east of Yucca Mountain and its relation to paleoclimate, hydrology and tectonics. To the northeast of Yucca Mountain, Fortymile Wash provides southward surface drainage from 60% of the area of the 11 Ma Timber Mountain caldera via Fortymile Canyon, a major breach in the caldera wall. In the southeast caldera moat, the distribution of volcanic units that predate and include the 9.4 Ma Thirsty Canyon Group and the characteristics of intercalated sediments indicate a northward paleoslope and sediment transport from a major drainage divide near Dome Mountain, a shield volcano now deeply incised by Fortymile Canyon. Eruption of the Thirsty Canyon Group from the Black Mountain area, 10 km northwest of the Timber Mountain caldera, is likely to have dammed a counterclockwise drainage system of the east moat. Following drainage disruption, the east moat filled with sediment up to the level of a new southward outlet at the saddle between Dome Mountain and the onlapping rhyolite of Shoshone Mountain. An older canyon south of this saddle received the overflow from the east moat and became the throughgoing Fortymile Canyon, integrating the east moat basin with a lower base level in Jackass Flats. Well-integrated southward drainage existed by the time the trachybasalt flows of Buckboard Mesa (2.8 Ma) were emplaced, because basal elevations of these flows slope southward about 100 m above modern Fortymile Wash.

690 **A gas sampling system for withdrawing humid gases from deep boreholes.** Rousseau, J.P. (Geological Survey, Denver, CO (United States)); Thordarson, W.; Kurzmack, M.A. pp. 2139-2145 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE

Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A gas sampling system, designed to withdraw nearly vapor-saturated gases (93 to 100% relative humidity) from deep, unsaturated zone boreholes, was developed by the U.S. Geological Survey for use in the unsaturated zone borehole instrumentation and monitoring program at Yucca Mountain, Nye County, Nevada. This gas sampling system will be used to: (1) sample formation rock gases in support of the unsaturated zone hydrochemical characterization program; and (2) verify downhole, thermocouple psychrometer measurements of water potential in support of the unsaturated zone borehole instrumentation and monitoring program. Using this sampling system, nearly vapor-saturated formation rock-gases can be withdrawn from deep boreholes without condensing water vapor in the sampling tubes, and fractionating heavy isotopes of oxygen, hydrogen, and carbon. The sampling system described in this paper uses a dry carrier-gas (nitrogen) to lower the dew point temperature of the formation rock-gas at its source. Mixing of the dry carrier gas with the source gas takes place inside a specially designed downhole instrument station apparatus (DISA). Nitrogen inflow is regulated in a manner that lowers the dew point temperature of the source gas to a temperature that is colder than the coldest temperature that the mixed gas will experience in moving from warmer, deeper depths, to colder, shallower depths near the land surface. A test of this gas sampling system was conducted in December, 1992, in a 12.2 meter deep borehole that was instrumented in October, 1991. The water potential calculated using this system reproduced in-situ measurements of water potential to within five percent of the average value, as recorded by two thermocouple psychrometers that had been in operation for over 12 months.

691 **Gravity and magnetic investigations of Yucca Wash, southwest Nevada.** Langenheim, V.E. (Geological Survey, Menlo Park, CA (United States)); Ponce, D.A. pp. 2272-2278 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Gravity and ground magnetic data collected across Yucca Wash do not indicate major vertical offsets along the inferred Yucca Wash fault. A 300- to 600-nT magnetic high whose source is buried at shallow depth coincides geographically with the relatively abrupt change in the elevation of the water table north of a proposed high-level radioactive waste repository site at Yucca Mountain.

692 **Shallow infiltration processes in arid watersheds at Yucca Mountain, Nevada.** Flint, L.E. (Geological Survey, Mercury, NV (United States)); Flint, A.L.; Hevesi, J.A. pp. 2315-2322 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A conceptual model of shallow infiltration processes at Yucca Mountain, Nevada, was developed for use in hydrologic flow models to characterize net infiltration (the penetration of the wetting front below the zone influenced by evapotranspiration). The model categorizes the surface of the site into four infiltration zones. These zones were identified as ridgetops, sideslopes, terraces, and active channels on the basis of water-content changes with depth and time. The maximum depth of measured water-content change at a specific site is a function of surface storage capacity, the timing and magnitude of precipitation, evapotranspiration, and the degree of saturation of surficial materials overlying fractured bedrock. Measured water-content profiles for the four zones indicated that the potential for net infiltration is higher when evapotranspiration is low (i.e. winter, cloudy periods), where surface concentration of water is likely to occur (i.e. depressions, channels), where surface storage capacity is low, and where fractured bedrock is close to the surface.

693 **Verification of a 1-dimensional model for predicting shallow infiltration at Yucca Mountain.** Hevesi, J. (Geological Survey, Mercury, NV (United States)); Flint, A.L.; Flint, L.E. pp. 2323-2332 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A characterization of net infiltration rates is needed for site-scale evaluation of groundwater flow at Yucca Mountain, Nevada. Shallow infiltration caused by precipitation may be a potential source of net infiltration. A 1-dimensional finite difference model of shallow infiltration with a moisture-dependent evapotranspiration function and a hypothetical root-zone was calibrated and verified using measured water content profiles, measured precipitation, and estimated potential evapotranspiration. Monthly water content profiles obtained from January 1990 through October 1993 were measured by geophysical logging of 3 boreholes located in the alluvium channel of Pagany Wash on Yucca Mountain. The profiles indicated seasonal wetting and drying of the alluvium in response to winter season precipitation and summer season evapotranspiration above a depth of 2.5 meters. A gradual drying trend below a depth of 2.5 meters was interpreted as long-term redistribution and/or evapotranspiration following a deep infiltration event caused by runoff in Pagany Wash during 1984. An initial model, calibrated using the 1990 to 1992 record, did not provide a satisfactory prediction of water content profiles measured in 1993 following a relatively wet winter season. A recalibrated model using a modified, seasonally-dependent evapotranspiration function provided an improved fit to the total record. The new model provided a satisfactory verification using water content changes measured at a distance of 6 meters from the calibration site, but was less satisfactory in predicting changes at a distance of 18 meters.

694 **Simulation of flow in the unsaturated zone beneath Pagany Wash, Yucca Mountain.** Kwicklis, E.M. (Geological Survey, Lakewood, CO (United States)); Healy, R.W.; Flint, A.L. pp. 2341-2351 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A one-dimensional numerical model was created to simulate water movement beneath Pagany Wash, Yucca Mountain, Nevada. Model stratigraphy and properties were based on data obtained from boreholes UE-25 UZ No. 4 and UE-25 UZ No. 5, which was drilled in the alluvial channel and bedrock sideslope of Pagany Wash. Although

unable to account for multidimensional or preferential flowpaths beneath the wash, the model proved a useful conceptual tool with which to develop hypotheses and, in some cases, provide bounding calculations. The model indicated that liquid flux decreases with depth in the upper 120 m beneath the wash, with fluxes of several tens mm/yr in the nonwelded base of the Tiva Canyon Member and fluxes on the order of a tenth mm/yr in the upper Topopah Spring Member. Capillary barrier effects were indicated by the model to significantly delay the entry of large fluxes into the potential repository horizon during periods of increasing net infiltration, and to inhibit rapid drainage of water from the nonwelded and bedded intervals into the potential repository horizon during periods of moisture redistribution. Lateral moisture redistribution can be expected to be promoted by these effects.

695 **Spatial distribution of potential near surface moisture flux at Yucca Mountain.** Flint, A.L. (Geologic Survey, Mercury, NV (United States)); Flint, L.E. pp. 2352-2358 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

An estimate of the areal distribution of present-day surface liquid moisture flux at Yucca Mountain was made using field measured water contents and laboratory measured rock properties. Using available data for physical and hydrologic properties (porosity, saturated hydraulic conductivity, moisture retention functions) of the volcanic rocks, surface lithologic units that are hydrologically similar were delineated. Moisture retention and relative permeability functions were assigned to each surface unit based on the similarity of the mean porosity and saturated hydraulic conductivity of the surface unit to laboratory samples of the same lithology. The potential flux into the mountain was estimated for each surface hydrologic unit using the mean saturated hydraulic conductivity for each unit and assuming all matrix flow. Using measured moisture profiles for each of the surface units, estimates were made of the depth at which seasonal fluctuations diminish and steady state downward flux conditions are likely to exist. The hydrologic properties at that depth were used with the current relative saturation of the tuff, to estimate flux as the unsaturated hydraulic conductivity. This method assumes a unit gradient. The range in estimated flux was 0.02 mm/yr for the welded Tiva Canyon to 13.4 mm/yr for the nonwelded Paintbrush Tuff. The areally averaged flux was 1.4 mm/yr. The major zones of high flux occur to the north of the potential repository boundary where the nonwelded tuffs are exposed in the major drainages.

696 **The Sundance fault: A newly recognized shear zone at Yucca Mountain, Nevada.** Spengler, R.W. (Geological Survey, Denver, CO (United States)); Braun, C.A.; Martin, L.G.; Weisenberg, C.W. pp. 2359-2366 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Ongoing detailed mapping at a scale of 1:240 of structural features within the potential repository area indicates the presence of several previously unrecognized structural features. Minor north-trending west-side-down faults occur east and west of the Ghost Dance fault and suggest a total width of the Ghost Dance fault system of nearly 366 m (1200 ft). A zone of near-vertical N30°-40° W-trending faults, at least 274 m (900 ft) wide, has been identified in the northern part of our study area and may traverse across the potential repository area. On the basis of a preliminary analysis of available data, we propose to name this zone the "Sundance fault system" and the dominant structure, occurring near the middle of the zone, the "Sundance fault". Some field relations suggest left-stepping deflections of north-trending faults along a pre-existing northwest-trending structural fabric. Other field observations suggest that the "Sundance fault system" offsets the Ghost Dance fault system in an apparent right lateral sense by at least 52 m (170 ft). Additional detailed field studies are needed to better understand structural complexities at Yucca Mountain.

697 **Structural character of the northern segment of the Paintbrush Canyon fault, Yucca Mountain, Nevada.** Dickerson, R.P. (Science Applications International Corp., Golden, CO (United States)); Spengler, R.W. pp. 2367-2372 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Detailed mapping of exposed features along the northern part of the Paintbrush Canyon fault was initiated to aid in construction of the computer-assisted three-dimensional lithostratigraphic model of Yucca Mountain, to contribute to kinematic reconstruction of the tectonic history of the Paintbrush Canyon fault, and to assist in the interpretation of geophysical data from Midway Valley. Yucca Mountain is segmented into relatively intact blocks of east-dipping Miocene volcanic strata, bounded by north-striking, west-dipping high-angle normal faults. The Paintbrush Canyon fault, representing the easternmost block-bounding normal fault, separates Fran Ridge from Midway Valley and continues northward across Yucca Wash to at least the southern margin of the Timber Mountain Caldera complex. South of Yucca Wash, the Paintbrush Canyon Fault is largely concealed beneath thick Quaternary deposits. Bedrock exposures to the north reveal a complex fault, zone, displaying local north- and west-trending grabens, and rhombic pull-apart features. The fault scarp, discontinuously exposed along a mapped length of 8 km north of Yucca Wash, dips westward by 41° to 74°. Maximum vertical offset of the Rhyolite of Comb Peak along the fault measures about 210 m in Paintbrush Canyon and, on the basis of drill hole information, vertical offset of the Topopoah Spring Tuff is about 360 m near the northern part of Fran Ridge. Observed displacement along the fault in Paintbrush Canyon is down to the west with a component of left-lateral oblique slip. Unlike previously proposed tectonic models, strata adjacent to the fault dip to the east. Quaternary deposits do not appear displaced along the fault scarp north of Yucca Wash, but are displaced in trenches south of Yucca Wash.

698 **Preliminary results of paleoseismic investigations of Quaternary faults on eastern Yucca Mountain, Nye County, Nevada.** Menges, C.M. (Geological Survey, Denver, CO (United States)); Oswald, J.A.; Coe, J.A.; Whitney, J.W.; Swan, F.H.; Wesling, J.R.; Thomas, A.P. pp. 2373-2390 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL

(United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Site characterization of the potential nuclear waste repository at Yucca Mountain, Nevada, requires detailed knowledge of the displacement histories of nearby Quaternary faults. Ongoing paleoseismic studies provide data on the amount and rates of Quaternary activity on the Paintbrush Canyon, Bow Ridge, and Stagecoach Road faults along the eastern margin of the mountain over varying time spans of 0-700 ka to perhaps 0-30 ka, depending on the site. Preliminary stratigraphic interpretations of deposits and deformation at many logged trenches and natural exposures indicate that each of these faults have experienced from 3 to 8 surface-rupturing earthquakes associated with variable dip-slip displacements per event ranging from 5 to 115 cm, and commonly in the range of 20 to 85 cm. Cumulative dip-slip offsets of units with broadly assigned ages of 100-200 ka are typically less than 200 cm, although accounting for the effects of possible left normal-oblique slip could increase these displacements by factors of 1.1 to 1.7. Current age constraints indicate recurrence intervals of 10^4 to 10^5 years (commonly between 30 and 80 k.y.) and slip rates of 0.001 to 0.08 mm/yr (typically 0.01-0.02 mm/yr). Based on available timing data, the ages of the most recent ruptures among the faults; they appear younger on the Stagecoach Road Fault (~ 5.20 ka) relative to the southern Paintbrush Canyon and Bow Ridge faults (~ 30-100 ka).

699 Preliminary U-series disequilibrium and thermoluminescence ages of surficial deposits and paleosols associated with Quaternary faults, eastern Yucca Mountain. Paces, J.B. (Geological Survey, Denver, CO (United States)); Menges, C.M.; Bush, C.A.; Futa, K.; Millard, H.T.; Maat, P.B.; Whitney, J.W.; Widmann, B.; Wesling, J.R. pp. 2391-2401 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Geochronological control is an essential component of paleoseismic evaluation of faults in the Yucca Mountain region. New U-series disequilibrium and thermoluminescence age estimates for pedogenic deposits that bracket surface-rupture events are presented from four sites exposing the Paintbrush Canyon, Bow Ridge and Stagecoach Road faults. Ages show an internal consistency with stratigraphic relationships as well as an overall concordancy between the two independent geochronometers. Age estimates are therefore interpreted to date depositional events or episodes of pedogenic carbonate mobility that can be used to establish a paleoseismic fault chronology. Ultimately, this type of chronological information will be used to evaluate seismic hazards at Yucca Mountain.

700 Use of an analog site near Raymond, California, to develop equipment and methods for characterizing a potential high-level, nuclear waste repository site at Yucca Mountain, Nevada. Umari, A.M.J. (Geological Survey, Denver, CO (United States)); Geldon, A.; Patterson, G.; Gemmell, J.; Earle, J.; Darnell, J. pp. 2413-2422 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Yucca Mountain, Nevada, currently is being investigated by the U.S. Geological Survey as a potential site for a high-level nuclear waste repository. Planned hydraulic-stress and tracer tests in fractured, tuffaceous rocks below the water table at Yucca Mountain will require work at depths in excess of 1,300 feet. To facilitate prototype testing of equipment and methods to be used in aquifer tests at Yucca Mountain, an analog site was selected in the foothills of the Sierra Nevada near Raymond, California. Two of nine 250- to 300-feet deep wells drilled into fractured, granitic rocks at the Raymond site have been instrumented with packers, pressure transducers, and other equipment that will be used at Yucca Mountain. Aquifer tests conducted at the Raymond site to date have demonstrated a need to modify some of the equipment and methods conceived for use at Yucca Mountain.

701 A preliminary characterization of the spatial variability of precipitation at Yucca Mountain, Nevada. Hevesi, J.A. (Geological Survey, Mercury, NV (United States)); Flint, A.L.; Ambos, D.S. pp. 2520-2529 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Isohyetal maps of precipitation and numerical models for simulating precipitation are needed to help characterize natural infiltration at Yucca Mountain, Nevada. A geostatistical analysis of measured precipitation accumulated from storm periods. Precipitation was measured during a 3.8 year period from January 1990 to October, 1993 using a network of precipitation gages. A total of 34 winter-type storms and 12 summer-type storm, categorized using synoptic weather records, were analyzed using the 1st and 2nd statistical moments and sample variograms. Average standardized variograms indicated good spatial correlation for both storm types with only slight differences in the general spatial structure. Coefficients of variation and average relative variograms indicated that summer storms are characterized by greater variability as compared to winter storms. Models were fitted to the average summer and winter standarized variograms for each storm using the mean storm depth and the coefficient of variation as scaling parameters. Isohyetal maps of 4 representative storms were created using the standarized models. Results indicate that standarized models can be used to simulate the spatial distribution of precipitation depth, provided that the 1st and 2nd moments are known or can be estimated, and that identifiable deterministic trends can be included in the models. A single, fixed model representing the spatial variability of precipitation at Yucca Mountain is not recommended.

702 Molluscs as climate indicators: Preliminary stable isotope and community analysis. Sharpe, S.E. (Desert Research Institute, Reno, NV (United States)); Forester, R.M.; Whelan, J.F.; McConnaughey, T. pp. 2538-2544 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Gastropods (snails) live in many terrestrial environments where sufficient humid shelter exists to protect them from desiccation. We have found gastropods living on the mountains of southern Nevada above 1800 m, but not below, to about 2700 m, the highest elevation collected. The $\delta^{18}O$ value of terrestrial snail shells provides a way to estimate the $\delta^{18}O$ value of precipitation and from that the source of the water. Comparisons of modern and fossil snail shell $\delta^{18}O$ values provide a way to identify changes in source waters during summer, the season of active growth. Our modern snail $\delta^{18}O$ values show a rough inverse correlation with elevation suggesting that snails do record a climate signal. All modern $\delta^{18}O$ values are much higher than those from the late Pleistocene fossil record suggesting that the Pleistocene summers were variously colder and wetter than today or less evaporative (more humid). Cooler and wetter summers would be consistent with other lines of evidence including models of past global circulation.

703 Estimating past precipitation and temperature from fossil ostracodes. Smith, A.J. (Kent State Univ., OH (United States)); Forester, R.M. pp. 2545-2552 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 Grant EAR-9210832. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The fossil records of certain aquatic organisms provide a way of obtaining meaningful estimates of past temperature and precipitation. These estimates of past environmental conditions are derived from multivariate statistical methods that are in turn based on the modern biogeographic distributions and environmental tolerances of the biota of interest. These estimates are helpful in conducting slimate studies as part of the Yucca Mountain site characterization. Ostracodes are microscopic crustaceans that produce bivalved calcite shells which are easily fossilized in the sediments of the lakes and wetlands in which the animals lived. The modern biogeographic distribution and environmental conditions of living ostracodes are the basis for the interpretation of the past environmental conditions of the fossil ostracodes. The major assumption in this method of interpretation is that the environmental tolerances of ostracodes have not changed substantially over thousands of years. Two methods using these modern analogs to determine past environmental conditions are the modern analog method and the range method. The range method also considers the information provided by fossil ostracode assemblages that have no modern analog in today's world.

704 Late glacial climate estimates for southern Nevada the ostracode fossil record. Forester, R.M. (Geological Survey, Denver, CO (United States)); Smith, A.J. pp. 2553-2561 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Climate change plays an important role in determining the possible long term hydrological performance of the potential high level nuclear waste repository within Yucca Mountain, Nevada. Present-day global circulation results in this region having an arid to semi-arid climate characterized by hot and relatively dry summers. Global circulation during the late glacial (about 14 to 20 ka) was very different from the present-day. Preliminary study of late-glacial fossil ostracodes from "marsh deposits" in the upper Las Vegas Valley suggests mean annual precipitation may have been four times higher, while mean annual temperature may have been about 10°C cooler than today. A major difference between present-day and late-glacial climate was likely the existence of cooler, cloudier, and wetter summers in the past.

705 Isotopic studies of Yucca Mountain soil fluids and carbonate pedogenesis. McConnaughey, T.A. (Geological Survey, Denver, CO (United States)); Whelan, J.F.; Wickland, K.P.; Moscati, R.J. pp. 2584-2589 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Secondary carbonates occurring within the soils, faults, and subsurface fractures of Yucca Mountain contain some of the best available records of paleoclimate and paleohydrology for the potential radioactive waste repository site. This article discusses conceptual and analytical advances being made with regard to the interpretation of stable isotope data from pedogenic carbonates, specifically related to the ^{13}C content of soil CO_2, $CaCO_3$ precipitation mechanisms, and isotopic fractionations between parent fluids and precipitating carbonates. The ^{13}C content of soil carbon dioxide from Yucca Mountain and vicinity shows most of the usual patterns expected in such contexts: decreasing ^{13}C content with depth (due mainly to increased importance of respired CO_2), decreasing ^{13}C with altitude (partially due to relatively more C-3 vegetation), and reduced ^{13}C during spring (due again to higher rates of respiration, and reduced gas permeability of wet soils). These patterns exist within the domain of a noisy data set; soil and vegetational heterogeneities, weather, and other factors apparently contribute to isotopic variability in the system. Several soil calcification mechanisms appear to be important, involving characteristic physical and chemical environments and isotopic fractionations. When CO_2 loss from thin soil solutions is an important driving factor, carbonates may contain excess heavy isotopes, compared to equilibrium precipitation with soil fluids. When root calcification serves as a proton generator for plant absorption of soil nutrients, heavy isotope deficiencies are likely. Successive cycles of dissolution and reprecipitation mix and redistribute pedogenic carbonates, and tend to isotopically homogenize and equilibrate pedogenic carbonates with soil fluids.

706 Strontium isotope geochemistry of soil and playa deposits near Yucca Mountain, Nevada. Marshall, B.D. (Geological Survey, Denver, CO (United States)); Mahan, S.A. pp. 2685-2691 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The isotopic composition of strontium contained in the carbonate fractions of soils provides an excellent tracer which can be used to test models for their origin. This paper reports data on surface coatings and cements, eolian sediments, playas and alluvial fan soils which help to constrain a

model for formation of the extensive calcretes and fault infillings in the Yucca Mountain region. The playas contain carbonate with a wide range of strontium compositions; further work will be required to fully understand their possible contributions to the pedogenic carbonate system. Soils from an alluvial fan to the west of Yucca Mountain show that only small amounts of strontium are derived from a fan draining a carbonate terrane have strontium component. Although much evidence points to an eolian source for at least some of the strontium in the pedogenic carbonates near Yucca Mountain, an additional component or past variation of strontium composition in the eolian source is required to model the pedogenic carbonate system.

707 Paleoclimatic and paleohydrologic records from secondary calcite: Yucca Mountain, Nevada. Whelan, J.F. (Geological Survey, Denver, CO (United States)); Stuckless, J.S.; Moscati, R.J.; Vaniman, D.T. pp. 2738-2745 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Stable isotope analyses of calcite and opal, fluid inclusion formation conditions and gas compositions, Sr isotope ratios, and REE compositions all support formation of secondary calcite in the unsaturated zone of Yucca Mountain from infiltration of surface-derived (and soil zone buffered) waters of meteoric origin. Detailed sampling of growth-banding preserved by the secondary calcite should provide a record of past variations in the stable isotope chemistry of these infiltrating waters, and, hence, of precipitation at Yucca Mountain, i.e., a proxy of past climate at Yucca Mountain. The precision of this record depends on how well it can be dated. The distribution and texture of secondary calcite occurrences, if mapped in careful detail from existing bore hole samples and underground workings (as exposures become accessible), could provide a time/space map of fracture and fault unsaturated-zone ground water flowpaths during past wetter climates which might prevail in the future with change in climate.

708 Late glacial to modern climate near Yucca Mountain, Nevada. Forester, R.M. (Geological Survey, Denver, CO (United States)). pp. 2750-2754 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Climate plays an important role in evaluating the suitability of Yucca Mountain, Nevada, as a potential high-level nuclear waste repository. Present-day global atmospheric circulation patterns are responsible for the semi-arid climate in the southwestern USA that result in limited winter precipitation and hot, relatively dry summers. Changes in global circulation may produce dramatic climate change resulting in colder average annual air temperatures and much higher average annual precipitation. Preliminary estimates from fossil plant and animal records suggest that during the last glacial (14 to 25 ka) mean annual precipitation may have been as much as five times modern, while mean annual temperatures were 8-10°C lower than today. Such conditions may have been responsible for past percolation through the mountain recorded by the secondary carbonate and silica fracture mineralization within the unsaturated zone.

709 Characterization of a desert soil sequence at Yucca Mountain, NV. Guertal, W.R. (Foothill Engineering, Inc., Mercury, NV (United States)); Hofmann, L.L.; Hudson, D.B.; Flint, A.L. pp. 2755-2763 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Morphological descriptions, borehole geophysics, hydraulic properties from samples, and a ponding experiment were used to characterize a layered, heterogeneous, desert soil sequence at Yucca Mountain, Nevada. Nine major horizon units were identified using standard morphologic techniques and borehole geophysics. The borehole geophysical logging data correlated well with the observed horizons from the exposure and/or the corresponding washout zones. In addition, the geophysical logs provide a quantitative estimate of porosity for the horizons with porosity ranging from 25 to 55 percent. As part of an infiltration experiment, over 50,000 liters of water were applied to a 3.5 m diameter ring during a 14 day period. The final wetting depth was 5 meters. When water application was stopped, redistribution allowed water to continue downward to a maximum depth of 7.4 meters in the next several months. Water content measurements made over time indicate that the horizons had a major influence on the flow of water in the soil and may have caused over 80 percent of the water applied to move laterally.

710 Results of prototype borehole instrumentation at the Hydrologic Research Facility, area 25, NTS. Rousseau, J.P. (Geological Survey, Denver, CO (United States)); Kurzmack, M.; Greengard, A. pp. 2764-2773 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Two 12+ meter (40 feet) deep, dry-augured boreholes, located adjacent to the Hydrologic Research Facility (HRF) calibration laboratory in Area 25, Nevada Test Site (NTS), were instrumented in October, 1991, and a third in February, 1992. Four instrument stations located at depths of 3.0, 6.1, 9.1, and 12.2 meters (m) were established in each borehole in order to evaluate instrumentation that will be used in the deep unsaturated-zone borehole-instrumentation program at Yucca Mountain, Nye County, Nevada. Yucca Mountain is being evaluated as a potential site for the storage of high-level radioactive waste. The Yucca Mountain borehole-instrumentation program is designed to measure and monitor the unsaturated-zone fluid (liquid and gas) flow potential gradients and flow processes in the unsaturated-zone. To date, results of the HRF prototype borehole instrumentation program indicate that the stability and operational reliability of the sensors selected for use at Yucca Mountain will be adequate to sustain a long-term, in-situ monitoring program; one that is expected to last from three to five years. Data from the HRF borehole instrumentation experiment also indicate that sensor accuracy and precision are sufficient to measure the state variables (pneumatic pressure, temperature, vapor pressure and water potential)

needed to quantify water, water vapor, gas, and heat flux in the unsaturated zone at Yucca Mountain.

711 Saturation levels and trends in the unsaturated zone, Yucca Mountain, Nevada. Nelson, P.H. (Geological Survey, Denver, CO (United States)). pp. 2774-2781 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Water content and porosity within the unsaturated zone at Yucca Mountain are computered from the caliper, density, and epithermal neutron logs obtained in 15 WT-boreholes. Separation between the water content and porosity logs clearly demarcate the lithophysal zones within the Topopah Spring Member of the Paintbrush Tuff. Lithophysal and non-lithophysal zones constitute regionally correlatable intervals across the area penetrated by the WT-boreholes. Lithophysal abundance appears to be nearly zero in the lower lithophysal zone in the southernmost borehole. Total porosity increases as lithophysal abundance increases, and water saturation decreases in the zones with high lithophysal abundance. Averages of water content for two lithophysal zones in the Topopah Spring Member of the Paintbrush Tuff show that water content decreases with height above the static water level; the trends in water content versus elevation are a function of geological zone. Thus, the pore size distribution spectrum appears to be preserved in the lithophysal zones.

712 Results of air-permeability testing in a vertical borehole at Yucca Mountain, Nevada. LeCain, G.D. (Geological Survey, Denver, CO (United States)); Walker, J.N. pp. 2782-2788 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Air-injection testing to determine air permeabilities was conducted in borehole UE-25 UZ No.16 as part of the Yucca Mountain Surface-Based Borehole Investigations Project. Air permeabilities of the rocks tested are: (1) Tiva Canyon Member; 2.0 E-13 m^2 to 88.0 E-13 m^2; (2) Topopah Spring Member; 1.1 E-13 m^2 to 12.0 E-13 m^2. Based on the moisture observed on the downhole equipment, the borehole wall is dry down to 268.3 meters below surface level and wet below this depth. Testing above 268.3 meters showed no wellbore storage or skin effects. Tests conducted below 268.3 meters showed both wellbore storage and skin effects. Tests that forced water out of the rock exhibited a characteristic pressure drop in the arithmetic pressure plots. The stabilization pressure of the steady-state testing following this pressure drop provides an estimate of the test interval in-situ capillary pressure. Permeabilities calculated from the steady-state period following the pressure drop were less than those calculated from the transient tests, because the steady-state analysis did not account for skin effects.

713 Applications of multi-mode imaging to multiple offset VSP data. Balch, A.H. (Colorado School of Mines, Golden, CO (United States)); Erdemir, C.; Rousseau, J.P. pp. 2797-2803 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A multiple offset, "9-component" vertical seismic profile (VSP) has been designed in order to obtain subsurface hydro-geologic information at the Yucca Mountain, Nevada, proposed high level radioactive waste repository site. Approximately 96 closely spaced three-component geophones will be grouted in the UE-25 UZ No.16 borehole. In the vicinity of the borehole several hundred three-component seismic source locations will be occupied, and an attempt will be made to use all four once-reflected seismic modes to produce images of the reflecting horizons. Shear wave anisotropy, if present, will be detected and the parameter correlated to the presence and orientation of the fractures. Physical elastic models were used to demonstrate the viability of the concept and to develop imaging computer software. These models were also used to locate the optimum position of UE-25 UZ No.16 in order to image the Ghost Dance fault in the center of Yucca Mountain yet retain the capability to image the imbricate fault structures along the eastern flank of Yucca Mountain. A preliminary VSP, using a single 3-component wall-locking seismometer, was run in August, 1993, to establish that coherent seismic signals can be obtained at depth, and at large offset distances, in the volcanic rocks present at Yucca Mountain. This survey was run in the UE-25 UZ No.16 borehole.

714 Geophysical expression of the Ghost Dance Fault, Yucca Mountain, Nevada. Ponce, D.A. (Geological Survey, Menlo Park, CA (United States)); Langenheim, V.E. pp. 123-125 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AI08-92NV10874. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Gravity and ground magnetic data collected along surveyed traverses across Antler and Live Yucca Ridges, on the eastern flank of Yucca Mountain, Nevada, reveal small-scale faulting associated with the Ghost Dance and possibly other faults. These studies are part of an effort to evaluate faulting in the vicinity of a potential nuclear waste repository at Yucca Mountain.

715 Discrete fracture modeling-ESF north portal area, Yucca Mountain, Nevada. Anna, L.O. (Geological Survey, Lakewood, CO (United States)). pp. 126-128 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The purpose of this project is to develop an understanding of fluid flow in partially saturated fractured rock. The Exploratory Studies Facility north portal area (east of Yucca Mountain) was chosen to develop the initial conceptual and flow models. The project will develop statistical parameters from the three-dimensional fracture network and hydraulic parameters that will be used in site scale models. The approach will use geometric fracture models and assess their impact on flow characteristics and parameters. Laboratory

and field testing data will be integrated to calibrate the flow models and to determine sensitivities of the system.

716 **Depth to pre-cenozoic basement in Southwest Nevada.** Langenheim, V.E. (Geological Survey, Menlo Park, CA (United States)); Ponce, D.A. pp. 129-131 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AI08-92NV10874. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

An iterative procedure based on gravity data, surface geology, and an estimated density-depth function was used to estimate the depth to pre-Cenozoic basement at Yucca Mountain and vicinity.

717 (CONF-9509121--1) **Potentially disruptive hydrologic features, events and processes at the Yucca Mountain Site, Nevada.** Hoxie, D.T. Geological Survey, Las Vegas, NV (United States). [1995]. 15p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From Characterizations of long term geological changes being considered for disposal sites; Paris (France); 19-21 Sep 1995. Order Number DE95009558. Source: OSTI; NTIS; INIS; GPO Dep.

Yucca Mountain, Nevada, has been selected by the United States to be evaluated as a potential site for the development of a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. If the site is determined to be suitable for repository development and construction is authorized, the repository at the Yucca Mountain site is planned to be constructed in unsaturated tuff at a depth of about 250 meters below land surface and at a distance of about 250 meters above the water table. The intent of locating a repository in a thick unsaturated-zone geohydrologic setting, such as occurs at Yucca Mountain under the arid to semi-arid climatic conditions that currently prevail in the region, is to provide a natural setting for the repository system in which little ground water will be available to contact emplaced waste or to transport radioactive material from the repository to the biosphere. In principle, an unsaturated-zone repository will be vulnerable to water entry from both above and below. Consequently, a major effort within the site-characterization program at the Yucca Mountain site is concerned with identifying and evaluating those features, events, and processes, such as increased net infiltration or water-table rise, whose presence or future occurrence could introduce water into a potential repository at the site in quantities sufficient to compromise the waste-isolation capability of the repository system.

718 (DOE/NV/10874--T1) **Nevada Test Site flood inundation study: Part of US Geological Survey flood potential and debris hazard study, Yucca Mountain Site for USDOE, Office of Civilian Radioactive Waste Management.** Blanton, J.O. III. Bureau of Reclamation, Denver, CO (United States). [1992]. 50p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94017188. Source: OSTI; NTIS; INIS; GPO Dep.

The Geological Survey (GS), as part of the Yucca Mountain Project (YMP), is conducting studies at Yucca Mountain, Nevada. The purposes of these studies are to provide hydrologic and geologic information to evaluate the suitability of Yucca Mountain for development as a high-level nuclear waste repository, and to evaluate the ability of the mined geologic disposal system (MGDS) to isolate the waste in compliance with regulatory requirements. The Bureau of Reclamation was selected by the GS as a contractor to provide probable maximum flood (PMF) magnitudes and associated inundation maps for preliminary engineering design of the surface facilities at Yucca Mountain. These PMF peak flow estimates and associated inundation maps are necessary for successful waste repository design and construction. The standard step method for backwater computations, incorporating the Bernouli energy equation and the results of the PMF study were chosen as the basis for defining the areal extent of flooding.

719 (DOE/NV/10874--T2) **Nevada Test Site probable maximum flood study, part of US Geological Survey flood potential and debris hazard study, Yucca Mountain Site for US Department of Energy, Office of Civilian Radioactive Waste Management.** Bullard, K.L. Bureau of Reclamation, Denver, CO (United States). [1994]. 114p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94017189. Source: OSTI; NTIS; INIS; GPO Dep.

The US Geological Survey (USGS), as part of the Yucca Mountain Project (YMP), is conducting studies at Yucca Mountain, Nevada. The purposes of these studies are to provide hydrologic and geologic information to evaluate the suitability of Yucca Mountain for development as a high-level nuclear waste repository, and to evaluate the ability of the mined geologic disposal system (MGDS) to isolate the waste in compliance with regulatory requirements. In particular, the project is designed to acquire information necessary for the Department of Energy (DOE) to demonstrate in its environmental impact statement (EIS) and license application whether the MGDS will meet the requirements of federal regulations 10 CFR Part 60, 10 CFR Part 960, and 40 CFR Part 191. Complete study plans for this part of the project were prepared by the USGS and approved by the DOE in August and September of 1990. The US Bureau of Reclamation (Reclamation) was selected by the USGS as a contractor to provide probable maximum flood (PMF) magnitudes and associated inundation maps for preliminary engineering design of the surface facilities at Yucca Mountain. These PMF peak flow estimates are necessary for successful waste repository design and construction. The PMF technique was chosen for two reasons: (1) this technique complies with ANSI requirements that PMF technology be used in the design of nuclear related facilities (ANSI/ANS, 1981), and (2) the PMF analysis has become a commonly used technology to predict a "worst possible case" flood scenario. For this PMF study, probable maximum precipitation (PMP) values were obtained for a local storm (thunderstorm) PMP event. These values were determined from the National Weather Services's Hydrometeorological Report No. 49 (HMR 49).

720 (IFE/KR/E--93/007, pp. 83) **Strontium isotope characterization of ground water flow systems at Yucca Mountain, Nevada, USA.** Peterman, Z.E. (U.S. Geological Survey, Denver, CO (United States)); Stuckless, J.S. Institutt for Energiteknikk, Kjeller (Norway). Sep 1993. (CONF-9308236--: 1. international symposium on applied isotope geochemistry (AIG-1), Geiranger (Norway), 29 Aug - 3 sep 1993). In *Proceedings of 1. international symposium on applied isotope geochemistry (AIG-1): Program and abstracts.* 133p. Order Number DE94627117. Source: OSTI; NTIS; INIS.

Short communication. GROUND WATER/isotope ratio; GROUND WATER/rock-fluid interactions; USA/ground water; AQUIFERS; HYDROLOGY; STRONTIUM 86; STRONTIUM 87; TRACER TECHNIQUES; USA

721 (USGS/MAP/I–2201) **Geological map of Bare Mountain, Nye County, Nevada.** Miscellaneous Investigations Series. Monsen, S.A.; Carr, M.D.; Reheis, M.C.; Orkild, P.P. Geological Survey, Denver, CO (United States). Map Div. 1992. 31p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-78ET44802. Source: U.S. Geological Survey, Map Division, Box 25286, Denver Federal Center, Denver, CO 80225.

Bare Mountain comprises the isolated complex of mountain peaks southeast of the town of Beatty in southern Nye County, Nevada. This small mountain range lies between the alluvial basins of Crater Flat to the east and the northern Amargosa Desert to the southwest. The northern boundary of the range is less well defined, but for this report, the terrane of faulted Miocene volcanic rocks underlying Beatty Mountain and the unnamed hills to the east are considered to be the northernmost part of Bare Mountain. The southern tip of the mountain range is at Black Marble; the isolated hill at the southeast corner of the map. The main body of the range, between Fluorspar Canyon and Black Marble, is a folded and complexly faulted, but generally northward-dipping (or southward-dipping and northward-overturned), sequence of weakly to moderately metamorphosed upper Proterozoic and Paleozoic marine strata, mostly miogeoclinal (continental shelf) rocks. The geology of Bare Mountain is mapped at a scale of 1:24,000.

722 (USGS-OFR–92-201) **Water permeability and related rock properties measured on core samples from the Yucca Mountain USW GU-3/G-3 and USW G-4 boreholes, Nevada Test Site, Nevada.** Anderson, L.A. Geological Survey, Denver, CO (United States). 1994. 36p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94017959. Source: OSTI; NTIS; INIS; GPO Dep.

Core samples were measured for bulk density, grain density, porosity, resistivity, and water permeability as part of a comprehensive geologic investigation designed to determine the suitability of Yucca Mountain as a site for the containment of high-level radioactive waste products. The cores were selected at the drill sites so as to be representative of the major lithologic variations observed within stratigraphic units of the Paintbrush Tuff, Calico Hills Tuff, Crater Flat Tuff, Lithic Ridge Tuff, and Older Tuffs. Dry and saturated bulk density, grain density, and porosity measurements were made on the core samples principally to establish that a reasonable uniformity exists in the textural and mineral character of the sample pairs. Electrical resistivity measured on sample pairs tended to be lower along the plane transverse to the vertical axis of the drill core herein referred to as the horizontal plane. Permeability values, ranging from virtually zero (<.02 microdarcies) to over 200 millidarcies, also indicate a preferential flow direction along the horizontal plane of the individual tuff units. Permeability decreases with flow duration in all but the non-welded tuffs as unconsolidated particles within the pore network are repositioned so as to impede the continued flow of water through the rock. Reversing flow direction initially restores the permeability of the rock to its original or maximum value.

723 (USGS-OFR–92-450) **Geodetic leveling data used to define historical height changes between Tonopah Junction and Las Vegas, Nevada.** Gilmore, T.D. Geological Survey, Menlo Park, CA (United States). 1992. 133p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94003605. Source: OSTI; NTIS; INIS; GPO Dep.

This report documents geodetic leveling data for a survey route following US Highway 95 from Tonopah Junction, approximately 50 km west of Tonopah, Nevada, to Las Vegas, Nevada. The survey route passes immediately south of the potential site for a high-level nuclear waste repository at Yucca Mountain in southern Nevada. Comparisons among the results of the several repeated levelings along this survey route provide a partial basis for evaluating contemporary crustal deformation patterns in the vicinity of the Yucca Mountain site and the relation between any such deformation and geologic structures known or suspected to have been active during Quaternary time.

724 (USGS-OFR–92-458) **Evidence of prehistoric flooding and the potential for future extreme flooding at Coyote Wash, Yucca Mountain, Nye County, Nevada.** Glancy, P.A. USDOE Nevada Operations Office, Las Vegas, NV (United States). 1994. 46p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94018347. Source: OSTI; NTIS; INIS; GPO; GPO Dep.

Coyote Wash, an approximately 0.3-square-mile drainage on the eastern flank of Yucca Mountain, is the potential location for an exploratory shaft to evaluate the suitability of Yucca Mountain for construction of an underground repository for the storage of high-level radioactive wastes. An ongoing investigation is addressing the potential for hazards to the site and surrounding areas from flooding and related fluvial-debris movement. Unconsolidated sediments in and adjacent to the channel of North Fork Coyote Wash were examined for evidence of past floods. Trenches excavated across and along the valley bottom exposed multiple flood deposits, including debris-flow deposits containing boulders as large as 2 to 3 feet in diameter. Most of the alluvial deposition probably occurred during the late Quaternary. Deposits at the base of the deepest trench overlie bedrock and underlie stream terraces adjacent to the channel; these sediments are moderately indurated and probably were deposited during the late Pleistocene. Overlying nonindurated deposits clearly are younger and may be of Holocene age. This evidence of intense flooding during the past indicates that severe flooding and debris movement are possible in the future. Empirical estimates of large floods of the past range from 900 to 2,600 cubic feet per second from the 0.094-square-mile drainage area of North Fork Coyote Wash drainage at two proposed shaft sites. Current knowledge indicates that mixtures of water and debris are likely to flow from North Fork Coyote Wash at rates up to 2,500 cubic feet per second. South Fork Coyote Wash, which has similar basin area and hydraulic characteristics, probably will have concurrent floods of similar magnitudes. The peak flow of the two tributaries probably would combine near the potential sites for the exploratory shaft to produce future flow of water and accompanying debris potentially as large as 5,000 cubic feet per second.

725 (USGS-OFR–92-657) **Geohydrologic data collected from shallow neutron-access boreholes and resultant-preliminary geohydrologic evaluations, Yucca Mountain area, Nye County, Nevada.** Blout, D.O. (Raytheon Services Nevada, Las Vegas, NV (United States)); Hammermeister, D.P.; Loskot, C.L.; Chornack,

M.P. Geological Survey, Denver, CO (United States). 1994. 147p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95005995. Source: OSTI; NTIS; INIS; U.S. Geological Survey, Earth Science Information Center, Open-File Reports Section, Box 25286, MS 517, Denver Federal Center, Denver, CO 80225; GPO Dep.

In cooperation with the US Department of Energy, 74 neutron-access boreholes were drilled in and near the southwestern part of the Nevada Test Site, Nye County, Nevada. Drilling, coring, sample collection and handling, and lithologic and preliminary geohydrologic data are presented in this report. The boreholes were drilled in a combination of alluvium/colluvium, ash-flow tuff, ash-fall tuff, or bedded tuff to depths of 4.6 to 36.6 meters. Air was used as a drilling medium to minimize disturbance of the water content and water potential of drill cuttings, core, and formation rock. Drill cuttings were collected at approximately 0.6-meter intervals. Core was taken at selected intervals from the alluvium/colluvium using drive-coring methods and from tuff using rotary-coring methods. Nonwelded and bedded tuffs were continuously cored using rotary-coring methods. Gravimetric water-content and water-potential values of core generally were greater than those of corresponding drill cuttings. Gravimetric water-content, porosity, and water-potential values of samples generally decreased, and bulk density values increased, as the degree of welding increased. Grain-density values remained fairly constant with changes in the degree of welding. A high degree of spatial variability in water-content and water-potential profiles was noted in closely spaced boreholes that penetrate similar lithologic subunits and was also noted in adjacent boreholes located in different topographic positions. Variability within a thick lithologic unit usually was small. 18 refs., 21 figs., 17 tabs.

726 (USGS-OFR-93-44) **Status of aeromagnetic survey coverage of Yucca Mountain and vicinity to a radius of about 140 kilometers, southwestern Nevada and southeastern California, 1992.** Sikora, R.F.; Ponce, D.A.; Oliver, H.W. Department of the Interior, Denver, CO (United States). 1993. 15p. Sponsored by USDOE, Washington, DC (United States);Department of the Interior, Washington, DC (United States). DOE Contract AI08-78ET44802. Order Number DE96001884. Source: OSTI; NTIS; INIS; U.S. Geological Survey, Books and Open-File Reports Section, Box 25425, Federal Center, Denver, CO 80225; GPO Dep.

Fifty aeromagnetic surveys in the southwestern part of Nevada and the southeastern part of California have been evaluated to assess the quality and coverage of aeromagnetic data within 140 kilometers (km) of a potential nuclear waste repository at Yucca Mountain, Nevada. The compilation shows that all the study area is covered by aeromagnetic surveys, but in some areas, particularly in the Death Valley region, new surveys flown with closer flight line spacing and lower elevations than the existing coverage are needed. In addition, the California part of the study area needs to be analytically continued downward to 305 meters (m) above ground level to provide a consistent data set for interpretation of subsurface geologic structures.

727 (USGS-OFR-93-60) **Geohydrologic data from test hole USW UZ-6s, Yucca Mountain, Nye County, Nevada.** Loskot, C.L. Geological Survey, Denver, CO (United States). 1993. 25p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94008084. Source: OSTI; NTIS; INIS; GPO Dep.

As part of the investigation of Yucca Mountain, Nevada, as a potential site for storing high-level radioactive wastes in an underground mined geologic repository, the US Geological Survey, in cooperation with the US Department of Energy, in 1982, began drilling a series of test holes in and near the southwestern part of the Nevada Test Site to determine the geologic and hydrologic characteristics of the area. Test hole USW UZ-6s is part of that series of test holes, and this report presents data obtained from test hole USW UZ-6s. The data includes those from drilling operations, lithology, coring, and laboratory analyses of hydrologic properties, which include gravimetric water content, water potential, and bulk- and grain-density values. The gravimetric water content of the densely welded section of the Tiva Canyon Member of the Paintbrush Tuff averages 0.027 gram per gram for test hole USW UZ-6s; water potential averages −7,200 kilo-pascals; gravimetric water content of the moderately to densely welded tuffs range from 0.054 gram per gram for the Tiva Canyon Member of the Paintbrush Tuff to 0.027 gram per gram for the Topopah Spring Member of the Paintbrush Tuff; and water potentials range from −6,700 to −3,400 kilopascals. Gravimetric water content for the partially welded to unnamed bedded tuffs average 0.123, 0.106, and 0.085 gram per gram for the Tiva Canyon Member, the unnamed bedded tuffs, and the Topopah Spring Member in test hole USW UZ-6s; average water potentials for these units are −1,700, −480, and −820 kilopascals.

728 (USGS-OFR-93-89) **Ground-water altitudes and well data, Nye County, Nevada, and Inyo County, California.** Ciesnik, M.S. Geological Survey, Denver, CO (United States). 1995. 61p. Sponsored by USDOE, Washington, DC (United States);Department of the Interior, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95011964. Source: OSTI; NTIS; INIS; U.S. Geological Survey, Earth Science Information Center, Box 25286, MS 517, Denver Federal Center, Denver, CO 80225(United States); GPO Dep.

This report contains ground-water altitudes and well data for wells located in Nye County, Nevada, and Inyo County, California, south of Yucca Mountain, Nevada, the potential site for a high-level nuclear waste repository. Data are from wells whose coordinates are within the Beatty and Death Valley Junction, California-Nevada maps from the US Geological Survey, scale 1:100,000 (30-minute × 60-minute quadrangle). Compilation of these data was made to provide a reference for numerical models of ground-water flow at Yucca Mountain and its vicinity. Water-level measurements were obtained from the US Geological Survey National Water Information System (NWIS) data base, and span the period of October 1951 to May 1991; most measurements were made from 1980 to 1990.

729 (USGS-OFR-93-098) **Water levels in continuously monitored wells in the Yucca Mountain Area, Nevada, 1989.** Lobmeyer, D.H.; Luckey, R.R.; O'Brien, G.M.; Burkhardt, D.J. Geological Survey, Denver, CO (United States). 1995. 173p. Sponsored by USDOE, Washington, DC (United States);Geological Survey, Reston, VA (United States). DOE Contract AI08-92NV10874. Order Number DE95007251. Source: OSTI; NTIS; INIS; GPO Dep.

Water levels have been monitored hourly in 16 wells representing 24 intervals in the Yucca Mountain area, Nevada. Water levels were monitored using pressure transducers and were recorded by data loggers. The pressure transducers were periodically calibrated by raising and lowering them in the wells. The water levels were normally measured at

approximately the same time that the transducers were calibrated. Where the transducer output appeared reasonable, it was converted to water levels using the calibrations and manual water-level measurements. The amount of transducer output that was converted to water levels ranged from zero for one interval to 100 percent for one interval. Fifteen of the wells were completed in Tertiary volcanic rocks and one well was completed in Paleozoic carbonate rocks. Each well monitored from one to four depth intervals. Water-level fluctuation caused by barometric pressure changes and earth tides were observed. Transducer output is presented in graphic form and, where appropriate, water-level altitude is presented in graphical and tabular form.

730 (USGS-OFR–93-269) **Characterizing fractured rock for fluid-flow, geomechanical, and paleostress modeling: Methods and preliminary results from Yucca Mountain, Nevada.** Barton, C.C.; Larsen, E.; Page, W.R.; Howard, T.M. Geological Survey, Denver, CO (United States). 1993. 74p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-78ET44802. Order Number DE94013203. Source: OSTI; NTIS; INIS; GPO Dep.

Fractures have been characterized for fluid-flow, geomechanical, and paleostress modeling at three localities in the vicinity of drill hole USW G-4 at Yucca Mountain in southwestern Nevada. A method for fracture characterization is introduced that integrates mapping fracture-trace networks and quantifying eight fracture parameters: trace length, orientation, connectivity, aperture, roughness, shear offset, trace-length density, and mineralization. A complex network of fractures was exposed on three 214- to 260-m 2 pavements cleared of debris in the upper lithophysal unit of the Tiva Canyon Member of the Miocene Paint-brush Tuff. The pavements are two-dimensional sections through the three-dimensional network of strata-bound fractures. All fractures with trace lengths greater than 0.2 m were mapped and studied.

731 (USGS-OFR–93-369) **Preliminary seismicity and focal mechanisms for the southern Great Basin of Nevada and California: January 1992 through September 1992.** Harmsen, S.C. Geological Survey, Denver, CO (United States). 1994. 213p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94013589. Source: OSTI; NTIS; INIS; GPO Dep.

The telemetered southern Great Basin seismic network (SGBSN) is operated for the Department of Energy's Yucca Mountain Project (YMP). The US Geological Survey, Branch of Earthquake and Landslide Hazards, maintained this network until September 30, 1992, at which time all operational and analysis responsibilities were transferred to the University of Nevada at Reno Seismological Laboratory (UNRSL). This report contains preliminary earthquake and chemical explosion hypocenter listings and preliminary earthquake focal mechanism solutions for USGS/SGBSN data for the period January 1, 1992 through September 30, 1992, 15:00 UTC.

732 (USGS-OFR–93-477) **Lithology, fault displacement, and origin of secondary calcium carbonate and opaline silica at Trenches 14 and 14D on the Bow Ridge Fault at Exile Hill, Nye County, Nevada.** Taylor, E.M.; Huckins, H.E. Colorado Geological Survey, Denver, CO (United States). 1995. 64p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-78ET44802. Order Number DE95006158. Source: OSTI; NTIS; INIS; GPO Dep.

Yucca Mountain, a proposed site for a high-level nuclear-waste repository, is located in southern Nevada, 20 km east of Beatty, and adjacent to the southwest corner of the Nevada Test Site (NTS) (fig. 1). Yucca Mountain is located within the Basin and Range province of the western United States. The climate is semiarid, and the flora is transitional between that of the Mojave Desert to the south and the Great Basin Desert to the north. As part of the evaluation, hydrologic conditions, especially water levels, of Yucca Mountain and vicinity during the Quaternary, and especially the past 20,000 years, are being characterized. In 1982, the US Geological Survey, in cooperation with the US Department of Energy (under interagency agreement DE-A104-78ET44802), excavated twenty-six bulldozer and backhoe trenches in the Yucca Mountain region to evaluate the nature and frequency of Quaternary faulting (Swadley and others, 1984). The trenches were oriented perpendicular to traces of suspected Quaternary faults and across projections of known bedrock faults into Quaternary deposits. Trench 14 exposes the Bow Ridge Fault on the west side of Exile Hill. Although the original purpose of the excavation of trench 14 was to evaluate the nature and frequency of Quaternary faulting on the Bow Ridge Fault, concern arose as to whether or not the nearly vertical calcium carbonate (the term "carbonate" in this study refers to calcium carbonate) and opaline silica veins in the fault zone were deposited by ascending waters (ground water). These veins resemble in gross morphology veins commonly formed by hydrothermal processes.

733 (USGS-OFR–93-540-A) **Gravity and magnetic data of Midway Valley, southwest Nevada.** Ponce, D.A. (Geological Survey, Menlo Park, CA (United States)); Langenheim, V.E.; Sikora, R.F. Geological Survey, Denver, CO (United States). 1993. 22p. Sponsored by USDOE, Washington, DC (United States);Department of the Interior, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95004229. Source: OSTI; NTIS; INIS; US Geological Survey, Open-File Reports - ESIC, Box 25425, Federal Center, Denver, CO 80225; GPO Dep.

Detailed gravity and ground magnetic data collected along five traverses across Midway Valley on the eastern flank of Yucca Mountain in southwest Nevada are described. These data were collected as part of an effort to evaluate faulting in the vicinity of proposed surface facilities for a potential nuclear waste repository at Yucca Mountain. Geophysical data show that Midway Valley is bounded by large gravity and magnetic anomalies associated with the Bow Ridge and Paintbrush Canyon faults, on the west side of Exile Hill and on the west flank of Fran Ridge, respectively. In addition, Midway Valley itself is characterized by a number of small-amplitude anomalies that probably reflect small-scale faulting beneath Midway Valley.

734 (USGS-OFR–93-586-A) **Gravity and magnetic study of Yucca Wash, southwest Nevada.** Langenheim, V.E. (Geological Survey, Menlo Park, CA (United States)); Ponce, D.A.; Oliver, H.W.; Sikora, R.F. Geological Survey, Denver, CO (United States). 1993. 41p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95004228. Source: OSTI; NTIS; INIS; US Geological Survey, Open-File Reports - ESIC, Box 25425, Federal Center, Denver, CO 80225; GPO Dep.

Gravity and ground magnetic data were collected along five traverses across and one traverse along Yucca Wash in the southwest quadrant of the Nevada Test Site. Two additional ground magnetic profiles were collected approximately 100 m to either side of the longitudinal profile. These data do not indicate major vertical offsets greater than 100 m using a density contrast of 0.2 to 0.3 g/cm^3 along the proposed Yucca Wash fault. A broad magnetic high coincides with the location of the hydrologic gradient. Density profiling, a technique used to determine the average density of small topographic features, suggests that the density of near-surface material in the vicinity of Yucca Wash is about 2.0 g/cm^3.

735 (USGS-OFR–93-651) **Meteorological, stream-discharge, and water-quality data for 1986 through 1991 from two small basins in central Nevada.** McKinley, P.W.; Oliver, T.A. Geological Survey, Denver, CO (United States). 1994. 167p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94009861. Source: OSTI; NTIS; U.S. Geological Survey, Open-File Reports Section, MS 517, Box 25286, Denver Federal Center, Denver, CO 80225; GPO Dep.

The U.S. Geological Survey (USGS), in cooperation with the U.S. Department of Energy, is investigating the volcanic tuffs of Yucca Mountain, Nevada, for their suitability as storage sites for nuclear waste. Two small basins, measuring less than 2 square miles, were studied to determine the volume of precipitation available for recharge to the ground water. The semiarid 3 Springs Basin is located to the east of Kawich Peak in the Kawich Range east of Tonopah, Nevada. Stewart Basin is a subalpine drainage basin north of Arc Dome in the Toiyabe Range north of Tonopah, Nevada. This publication presents the meteorological, stream-discharge, and water-quality data collected during the study. Meteorological data collected include air temperature, soil temperature, solar radiation, and relative humidity. Stream-discharge data were collected from the surface-water outlet of each basin. Water-quality data are chemical analyses of water samples collected from surface- and ground-water sources. Data were collected throughout the two basins. Each basin has a meteorological station located in the lower and upper reaches of the basin. Hydrologic records include stream-discharge and water-quality data from the lower meteorological site and water-quality data from springs within the basins. Meteorological data are available from the lower sites from the winter of 1986 through the fall of 1991. Periods of data collection were shorter for additional sites in the basin.

736 (USGS-OFR–93-690) **Preliminary study of lead isotopes in the carbonate-silica veins of Trench 14, Yucca Mountain, Nevada.** Zartman, R.E.; Kwak, L.M. Geological Survey, Denver, CO (United States). 15 Dec 1993. 18p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94013976. Source: OSTI; NTIS; INIS; GPO Dep.

The sub-vertical carbonate-silica veins filling the Bow Ridge Fault, where exposed in Trench 14 on the east side of Yucca Mountain, carry a lead isotopic signature that can be explained in terms of local sources. Two isotopically distinguishable–silicate and carbonate–fractions of lead are recognized within the vein system as well as in overlying surficial calcrete deposits. The acid-insoluble silicate fraction is contributed largely from the decomposing Miocene volcanic tuff, which forms the wall rock of the fault zone and is a ubiquitous component of the overlying soil. Lead contained in the silicate fraction approaches in isotopic composition that of the Miocene volcanic rocks of Yucca Mountain, but diverges from it in some samples by being more enriched in uranogenic isotopes. The carbonate fraction of lead in both vein and calcrete samples resides dominantly in the HCl- and CH_3COOH-soluble calcite. HCl evidently also attacks and removes lead from silicate phases, but the milder CH_3COOH dissolution procedure oftentimes identifies a significantly more radiogenic lead in the calcite. Wind-blown particulate matter brought to the area from Paleozoic and Late Proterozoic limestones in surrounding mountains may be the ultimate source of the calcite. Isotopically more uniform samples suggest that locally the basaltic ash and other volcanic rock have contributed most of the lead to both fractions of the vein system. An important finding of this study is that the data does not require the more exotic mechanisms or origins that have been proposed for the veins. Instead, the remarkably similar lead isotopic properties of the veins to those of the soil calcretes support their interpretation as a surficial, pedogenic phenomenon.

737 (USGS-OFR–94-49) **The Sundance fault: A newly recognized shear zone at Yucca Mountain, Nevada.** Spengler, R.W. (Geological Survey, Denver, CO (United States)); Braun, C.A.; Martin, L.G.; Weisenberg, C.W. Geological Survey, Denver, CO (United States). 1994. 12p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94009403. Source: OSTI; NTIS; INIS; GPO Dep.

Ongoing detailed mapping at a scale of 1:240 of structural features within the potential repository area indicates the presence of several previously unrecognized structural features. Minor north-trending west-side-down faults occur east and west of the Ghost Dance fault and suggest a total width of the Ghost Dance fault system of nearly 366 m (1200 ft). A zone of near-vertical N30° – 40°W – trending faults, at least 274 m (900 ft) wide, has been identified in the northern part of our study area and may traverse across the proposed repository area. On the basis of a preliminary analysis of available data, we propose to name this zone the "Sundance fault system" and the dominant structure, occurring near the middle of the zone, the "Sundance fault." Some field relations suggest left-stepping deflections of north-trending faults along a preexisting northwest-trending structural fabric. Other field observations suggest that the "Sundance fault system" offsets the Ghost Dance fault system in an apparent right lateral sense by at least 52 m (170 ft). Additional detailed field studies, however, are needed to better understand structural complexities at Yucca Mountain.

738 (USGS-OFR–94-54) **Selected ground-water data for Yucca Mountain Region, southern Nevada and eastern California, through December 22.** La Camera, R.J.; Westenburg, C.L. USDOE Nevada Operations Office, Las Vegas, NV (United States). 1994. 169p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94017061. Source: OSTI; NTIS; INIS; GPO Dep.

The U.S. Geological Survey, in support of the U.S. Department of Energy, Yucca Mountain Site-Characterization Project, collects, compiles, and summarizes hydrologic data in the Yucca Mountain region. The data are collected to allow assessments of ground-water resources during studies to determine the potential suitability of Yucca Mountain for storing high-level nuclear waste. Data on ground-water levels at 36 sites, ground-water discharge at 6 sites, ground-water quality at 19 sites, and ground-water withdrawals within Crater Flat, Jackass Flats, Mercury Valley, and the

Amargosa Desert are presented. Data on ground-water levels, discharges, and withdrawals collected by other agencies (or as part of other programs) are included to further indicate variations through time at selected monitoring locations. Data are included in this report from 1910 through 1992.

739 (USGS/OFR–94-303) **Water levels in wells J-11 and J-12, 1989-91, Yucca Mountain Area, Nevada.** Boucher, M.S. Geological Survey, Denver, CO (United States). 1994. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95004831. Source: OSTI; NTIS; INIS; U.S. Geological Survey, Earth Science Information Center, Open-File Reports Section, Box 25286, MS 517, Denver Federal Center, Denver, CO 80225; GPO Dep.

Water levels have been measured in the Yucca Mountain area, Nevada, since 1981 in order to gain a better understanding of the ground-water flow system in the area. Water levels in wells J-11 and J-12 have been periodically measured using calibrated reeled steel tapes since 1989, however, calculation of water-level altitude was not possible prior to 1993 due to missing reference elevations. These elevations were determined in 1993 by the U.S. Geological Survey. During 1989-91, water-level altitudes for well J-11 ranged from 732.09 to 732.40 meters and the mean water-level altitude was 732.19 meters. During 1989-91, water-level altitudes for well J-12 ranged from 727.84 to 728.03 meters, and the mean water-level altitude was 727.95 meters.

740 (USGS-OFR–94-305) **Hydrochemical data base for the Death Valley Region, California and Nevada.** Perfect, D.L.; Faunt, C.C.; Steinkampf, W.C.; Turner, A.K. Geological Survey, Denver, CO (United States). 1995. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95006175. Source: OSTI; NTIS; INIS; U.S. Geological Survey, Earth Science Information Center, Open-File Reports Section, Box 25286, MS 517, Denver Federal Center, Denver, CO 80225 (United States); GPO Dep.

Report includes 2 diskettes designed to run on IBM PC or compatible equipment.

Ground-water chemistry data derived from samples collected within an approximately 100,000-square-kilometer area in the Southern Great Basin have been compiled into a digital data base. The data were compiled from published reports, the U.S. Geological Survey (USGS) National Water Information System (NWIS), and previously unpublished USGS files. The data are contained in two compressed files which self-expand into Lotus (.WK1) files. The first file contains 4,738 records (4.84 megabytes) and represents the basic compilation of all identified analyses. The second file is an edited version of the first and contains 3,733 records (3.84 megabytes). Editing included the removal of duplicate records and the combining of records, when appropriate. The analyses presented are of variable quality and comprehensiveness and include no isotopic data. Of the 3,733 analyses in the edited data base, 58 percent of the major ion concentrations balance to within ±10 percent. Most of the remaining records are not sufficiently complete for a balance to be calculated.

741 (USGS-OFR–94-311) **Water levels in the Yucca Mountain Area, Nevada, 1992.** O'Brien, G.M. (Geological Survey, Denver, CO (United States)); Tucci, P.; Burkhardt, D.J. USDOE Nevada Operations Office, Las Vegas, NV (United States); Geological Survey, Denver, CO (United States). 1995. 74p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95011249. Source: OSTI; NTIS; INIS; GPO Dep.

Water levels were monitored in 27 wells in the Yucca Mountain area, Nevada, during 1992. Fourteen wells were monitored periodically, generally on a monthly basis, and 13 wells representing 21 intervals were monitored hourly. All wells monitor levels in Tertiary volcanic rocks, except one which monitors levels in Paleozoic carbonate rocks. Water levels were measured using calibrated steel tapes and pressure transducers; steel-tape measurements were corrected for mechanical stretch, thermal expansion, and borehole deviation to obtain precise water-level altitudes. Water-level altitudes in the Tertiary volcanic rocks ranged from about 728 meters above sea level east of Yucca Mountain to about 1,035 meters above sea level north of Yucca Mountain. Water-level altitudes in the well monitoring the Paleozoic carbonate rocks varied between 751 and 753 meters above sea level during 1992. Water-level fluctuations were observed at 11 wells in response to the Landers, California earthquake on June 28, 1992. All data were acquired in accordance with a quality-assurance program to support the reliability of the data.

742 (USGS-OFR–94-312) **Streamflow and selected precipitation data for Yucca Mountain Region, southern Nevada and eastern California, water years 1986–90.** Kane, T.G. III; Bauer, D.J.; Martinez, C.M. USDOE Nevada Operations Office, Las Vegas, NV (United States). 1994. 122p. Sponsored by USDOE, Washington, DC (United States);Department of the Interior, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95001893. Source: OSTI; NTIS; INIS; GPO Dep.

Streamflow and precipitation data collected at and near Yucca Mountain, Nevada, during water years 1986–90 are presented in this report. The data were collected and compiled as part of the studies by the US Geological Survey, in cooperation with the US Department of Energy, to characterize surface-water hydrology in the Yucca Mountain area. Streamflow data include daily-mean discharges and peak discharges at 5 continuous-record gaging stations, and peak discharges at 10 crest-stage, partial-record stations and 2 miscellaneous sites. Precipitation data include cumulative totals at 20 stations maintained by the US Geological Survey and daily totals at 15 stations maintained by the Weather Service Nuclear Support Office, National Oceanic and Atmospheric Administration.

743 (USGS/OFR–94-317) **Selected hydrologic data from Fortymile Wash in the Yucca Mountain area, Nevada, water year 1992.** Savard, C.S. Geological Survey, Denver, CO (United States). 1995. 38p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95007192. Source: OSTI; NTIS; INIS; GPO Dep.

Precipitation totals of 245 and 210 mm were measured at UE-29 UZN #91 and UE-29 UZN #92 respectively, during the 1992 water year, October 1, 1991 to September 30, 1992. Approximately ninety percent of the precipitation fell during the period December 27 to April 2. Localized streamflow was generated in the Fortymile Wash drainage basin during the February 12-15, 1992 and March 31, 1992 precipitation, and infiltrated into the streambed materials. The streamflow went across the UE-29 UZN #91 neutron-access borehole location and within several meters of the UE-29 UZN #92 location. Neutron logging in these boreholes

showed increases in the volumetric water content of the unsaturated alluvium and indicated streamflow infiltrated to a depth of approximately 5 meters. The volumetric water content in the upper 5 meters then gradually decreased during the remaining part of the water year. Ground-water levels rose over one meter in wells UE-29 a#1 and UE-29 a#2, and one-half meter in neutron-access borehole LJE-29 UZN #91 following the streamflows. Water level declines of 0.5 meter in UE-29 a#1 and rises of 0.2 meter in UE-29 a#2 and 0.1 meter in UE-29 UZN #91 coincided with a June 29, 1992 earthquake at the Little Skull Mountain, located approximately 27 kilometers southeast of the wells.

744 (USGS-OFR–94-318) **Preliminary digital geologic maps of the Mariposa, Kingman, Trona, and Death Valley Sheets, California.** D'Agnese, F.A. (Geological Survey, Denver, CO (United States)); Faunt, C.C.; Turner, A.K. USDOE Nevada Operations Office, Las Vegas, NV (United States); Geological Survey, Denver, CO (United States). 1995. 19p. Sponsored by USDOE, Washington, DC (United States);Department of the Interior, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE96001064. Source: OSTI; NTIS; INIS; GPO Dep.

Parts of four 1:250,000-scale geologic maps by the California Department of Natural Resources, Division of Mines and Geology have been digitized for use in hydrogeologic characterization. These maps include the area of California between lat. 35°N; Long. 115°W and lat. 38°N, long. 118°W of the Kingman Sheet (Jennings, 1961), Trona Sheet (Jennings and others, 1962), Mariposa Sheet (Strand, 1967), and Death Valley Sheet (Streitz and Stinson, 1974). These digital maps are being released by the US Geological Survey in the ARC/INFO Version 6.1 Export format. The digitized data include geologic unit boundaries, fault traces, and identity of geologic units. The procedure outlined in US Geological Survey Circular 1054 (Soller and others, 1990) was sued during the map construction. The procedure involves transferring hard-copy data into digital format by scanning manuscript maps, manipulating the digital map data, and outputting the data. Most of the work was done using Environmental Systems Research Institute's ARC/INFO software. The digital maps are available in ARC/INFO Rev. 6.1 Export format, from the USGS, Yucca Mountain Project, in Denver, Colorado.

745 (USGS-OFR–94-342) **Summary of lithologic logging of new and existing boreholes at Yucca Mountain, Nevada, August 1993 to February 1994.** Geslin, J.K.; Moyer, T.C.; Buesch, D.C. Geological Survey, Denver, CO (United States). 1995. 44p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95011866. Source: OSTI; NTIS; INIS; GPO Dep.

Yucca Mountain, Nevada, is being investigated as a potential site for a high-level radioactive waste repository. This report summarizes the lithologic logging of new and existing boreholes at Yucca Mountain that was done from August 1993 to February 1994 by the Rock Characteristics Section, Yucca Mountain Project Branch, US Geological Survey (USGS). Units encountered during logging include Quaternary-Tertiary alluvium/colluvium, Tertiary Rainier Mesa Tuff, all units in the Tertiary Paintbrush Group, Tertiary Calico Hills Formation and Tertiary Prow Pass Tuff. We present criteria used for recognition of stratigraphic contacts, logging results as tables of contact depths for core from neutron (UZN) boreholes and graphical lithologic logs for core from non-UZN boreholes, and descriptions of several distinctive nonwelded tuffs recognized in the PTn hydrogeologic unit of the Paintbrush Group.

746 (USGS-OFR–94-451) **Summary of lithologic logging of new and existing boreholes at Yucca Mountain, Nevada, March 1994 to June 1994.** Geslin, J.K.; Moyer, T.C. Geological Survey, Denver, CO (United States). 1995. 16p. Sponsored by Geological Survey, Reston, VA (United States);USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95009443. Source: OSTI; NTIS; INIS; GPO Dep.

This report summarizes lithologic logging of core from boreholes at Yucca Mountain, Nevada, conducted from March 1994 to June 1994. Units encountered during logging include Quaternary-Tertiary alluvium and colluvium, Tertiary Rainier Mesa Tuff, all units in the Tertiary Paintbrush Group, and Tertiary Calico Hills Formation. Logging results are presented in a table of contact depths for core from unsaturated zone neutron (UZN) boreholes and graphic lithologic logs for core from north ramp geology (NRG) boreholes.

747 (USGS-OFR–94-456) **Meteorological, stream-discharge, and water-quality data for water year 1992 from two basins in Central Nevada.** McKinley, P.W. (Geological Survey, Denver, CO (United States)); Oliver, T.A. USDOE Nevada Operations Office, Las Vegas, NV (United States); Geological Survey, Denver, CO (United States). 1995. 56p. Sponsored by Geological Survey, Reston, VA (United States);USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95011552. Source: OSTI; NTIS; INIS; GPO Dep.

The US Geological Survey, in cooperation with the US Department of Energy, is studying Yucca Mountain, Nevada, as a potential repository for high level nuclear waste. As part of the Yucca Mountain Site Project, the analog recharge study is providing data for the evaluation of recharge to the Yucca Mountain ground-water system given a cooler and wetter climate than currently exists. The current and climatic conditions are favorable to the isolation of radioactive waste. Because waste isolation from the accessible environment for 10,000 years is necessary, climatic change and the potential for increased ground-water recharge need to be considered as part of the characterization of the potential repository. Therefore, two small basins, measuring less than 2 square miles, were studied to determine the volume of precipitation available for recharge to ground water. The semiarid 3-Springs Basin is located to the east of Kawich Peak in the Kawich Range east of Tonopah, Nevada. Stewart Basin is a subalpine drainage basin north of Arc Dome in the Toiyabe Range north of Tonopah, Nevada. The purpose of this publication is to make available the meteorological, stream-discharge, and water-quality data collected during the study. Meteorological data collected include air temperature, soil temperature, solar radiation, and relative humidity. Stream-discharge data were collected from the surface-water outlet of each basin. Water-quality data are chemical analyses of water samples collected from surface- and ground-water sources. Each basin has a meteorological station located in the lower and upper reaches of the basin. Hydrologic records include stream-discharge and water-quality data from the lower meteorological site and water-quality data from springs within the basins.

748 (USGS-OFR–94-460) **Lithostratigraphy of the Calico Hills Formation and Prow Pass Tuff (Crater Flat Group) at Yucca Mountain, Nevada.** Moyer, T.C. (Science Applications International Corp., Las Vegas, NV (United

States)); Geslin, J.K. Geological Survey, Denver, CO (United States). 1995. 59p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95014711. Source: OSTI; NTIS; INIS; GPO Dep.

Lithostratigraphic relations within the Calico Hills Formation and Prow Pass Tuff (Crater Flat Group) were reconstructed from analysis of core samples and observation of outcrop exposures. The Calico Hills Formation is composed of five nonwelded pyroclastic units (each formed of one or more pyroclastic-flow deposits) that overlie an interval of bedded tuff and a basal volcaniclastic sandstone unit. The Prow Pass Tuff is divided into four pyroclastic units and an underlying interval of bedded tuff. The pyroclastic units of the Prow Pass Tuff are distinguished by the sizes and amounts of their pumice and lithic clasts and their degree of welding. Pyroclastic units of the Prow Pass Tuff are distinguished from those of the Calico Hills Formation by their phenocryst assemblage, chemical composition, and ubiquitous siltstone lithic clasts. Downhole resistivity tends to mirror the content of authigenic minerals, primarily zeolites, in both for-mations and may be useful for recognizing the vitric-zeolite boundary in the study area. Maps of zeolite distribution illustrate that the bedded tuff and basal sandstone units of the Calico Hills Formation are altered over a wider area than the pyroclastic units of both the Calico Hills Formation and the upper Prow Pass Tuff.

749 (USGS-OFR–95-146) **Precipitation data for water years 1992 and 1993 from a network of nonrecording gages at Yucca Mountain, Nevada.** Ambos, D.S. (Science Applications International Corp., Golden, CO (United States)); Flint, A.L.; Hevesi, J.A. USDOE Nevada Operations Office, Las Vegas, NV (United States); Geological Survey, Denver, CO (United States). 1995. 100p. Sponsored by USDOE, Washington, DC (United States);Department of the Interior, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE96001063. Source: OSTI; NTIS; INIS; GPO Dep.

This report presents precipitation data collected in a storage gage network at Yucca Mountain, Nevada, from October 1, 1991, to September 30, 1993. The measured values indicate total accumulated precipitation for specified time intervals approximately corresponding to separate storm events. Installation of a precipitation monitoring network was initiated in January 1990, and was continually expanded and upgraded throughout the period ending in September 1993. The final network included 3 different gage types for a total of 133 gages at 108 locations within the three drainages overlying the potential repository site. Measured precipitation indicated above average accumulations for water years 1992 and 1993 relative to the most recent estimate of 6.7 inches for long-term average annual precipitation over the area of the network. The total precipitation averaged over the network in 1992 was about 8.2 inches with a maximum of about 11.2 inches measured at borehole USW GA-1. The total precipitation averaged over the network in 1993 was about 10.3 inches with a maximum of about 12.1 inches at neutron-access borehole UE-25 UZN #4.

750 (USGS-OFR–95-155) **Lithologic and geophysical logs of drill holes Felderhoff Federal 5-1 and 25-1, Amargosa Desert, Nye County, Nevada.** Carr, W.J. (Geological Survey, Denver, CO (United States)); Grow, J.A.; Keller, S.M. USDOE Nevada Operations Office, Las Vegas, NV (United States); Geological Survey, Denver, CO (United States). 1995. 14p. Sponsored by USDOE, Washington, DC (United States);Department of the Interior, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE96001062. Source: OSTI; NTIS; INIS; GPO Dep.

Two wildcat oil and gas exploration holes drilled in 1991 on the northern edge of the Amargosa Desert penetrated Tertiary and Quaternary sedimentary rocks, alluvium, and basalt, possible Tertiary volcanic or volcaniclastic rocks, and Tertiary (?) and Paleozoic carbonate rocks. The eastern-most of the two holes, Felderhoff-Federal 5-1, encountered about 200 feet of alluvium, underlain by 305 feet of basalt breccia and basalt, about 345 feet of probable Tertiary tuffaceous sedimentary rocks, and 616 feet of dense limestone and dolomite of uncertain age. Drill hole 25-1 penetrated 240 feet of alluvium and marl (?), and 250 feet of basalt breccia (?) and basalt, 270 feet of tuff (?) and/or tuffaceous sedimentary rocks, 360 feet of slide blocks (?) and large boulders of Paleozoic carbonate rocks, and 2,800 feet of Paleozoic limestone and dolomite. The two drill holes are located within a northerly trending fault zone defined largely by geophysical data; this fault zone lies along the east side of a major rift containing many small basalt eruptive centers and, farther north, several caldera complexes. Drill hole 25-1 penetrated an inverted paleozoic rock sequence; drill hole 5-1 encountered two large cavities 24-inches wide or more in dense carbonate rock of uncertain, but probable Paleozoic age. These openings may be tectonic and controlled by a regional system of northeast-striking faults.

751 (USGS-OFR–95-158) **Selected ground-water data for Yucca Mountain Region, Southern Nevada and Eastern California, Calendar year 1993.** Hale, G.S.; Westenburg, C.L. Geological Survey, Carson City, NV (United States). 1995. 69p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95014712. Source: OSTI; NTIS; INIS; GPO Dep.

Data are collected to allow assessments of ground-water resources during studies to determine the potential suitability of Yucca Mountain for storing high-level nuclear waste. Data on ground-water levels at 34 sites, ground-water discharge at 6 sites, and groundwater withdrawals within Jackass Flats, Mercury Valley, and Amargosa Desert are presented for calendar year 1993. Data on ground-water levels, discharges, and withdrawals collected by other agencies (or as part of other programs) are included to further indicate variations through time at selected monitoring locations. A statistical summary of ground-water levels at seven wells in Jackass Flats is presented. The statistical summary includes the number of measurements, the maximum, minimum, and median or mean water-level altitudes, and the average or standard deviation of the water-level altitudes for selected baseline periods and for calendar years 1992 and 1993.

752 (USGS/WRI–92-4016) **Preliminary hydrogeologic assessment of boreholes UE-25c No. 1, UE-25c No. 2, and UE-25c No. 3, Yucca Mountain, Nye County, Nevada.** Geldon, A.L. Geological Survey, Denver, CO (United States). 1993. 92p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95003785. Source: OSTI; NTIS; INIS; U.S. Geological Survey, Earth Science Information Center, Open File Reports Section, Box 25286, MS 517, Federal Center, Denver, CO 80225; GPO Dep.

The purpose of this report is to characterize the hydrogeology of saturated tuffaceous rocks penetrated by boreholes UE-25c #1, UE-25c #2, and UE-25c #3. These boreholes are referred to collectively in this report as the C-holes. The C-holes were drilled to perform multiwell aquifer tests and tracer tests; they comprise the only complex of closely

spaced boreholes completed in the saturated zone at Yucca Mountain. Results of lithologic and geophysical logging, fracture analyses, water-level monitoring, temperature and tracejector surveys aquifer tests, and hydrochemical sampling completed at the C-hole complex as of 1986 are assessed with respect to the regional geologic and hydrologic setting. A conceptual hydrogeological model of the Yucca Mountain area is presented to provide a context for quantitatively evaluating hydrologic tests performed at the C-hole complex as of 1985, for planning and interpreting additional hydrologic tests at the C-hole complex, and for possibly re-evaluating hydrologic tests in boreholes other than the C-holes.

753 (USGS-WRI-92-4065) **An estimate of the roughness length and displacement height of Sonoran Desert vegetation, south-central Arizona.** Claassen, H.C. (Geological Survey, Denver, CO (United States)); Riggs, A.C. Geological Survey, Denver, CO (United States); Geological Survey, Reston, VA (United States). 1993. 20p. Sponsored by USDOE, Washington, DC (United States);Geological Survey, Reston, VA (United States). DOE Contract AI08-92NV10874 ; AI08-78ET44802. Order Number DE94003606. Source: OSTI; NTIS; GPO; U.S. Geological Survey, Books and Open-File Reports Section, Box 25425, Mail Stop 517, Federal Center, Denver, CO 80225-0425; GPO Dep.

A somewhat unconventional technique using a tethered balloon was used to estimate the roughness length for momentum (z_m) and displacement height (d) for typical Sonoran Desert vegetation. It has been suggested that measurements of the meteorological fluxes of momentum, sensible heat, and latent heat are best done at heights above ground level determined by either the roughness length (z_m) or the size and shape of vegetation. Therefore, estimates of z_m and vegetation characteristics are a desirable prerequisite to developing a flux-measurement protocol. Because the literature contains little information on z_m for Sonoran Desert vegetation, it is desirable to measure z_m and the displacement height (d) associated with Sorioran Desert vegetation.

754 (USGS/WRI-93-4000) **Revised potentiometric-surface map, Yucca Mountain and vicinity, Nevada.** Ervin, E.M.; Luckey, R.R.; Burkhardt, D.J. Geological Survey, Denver, CO (United States). 1994. 30p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95003786. Source: OSTI; NTIS; INIS; U.S. Geological Survey, Earth Science Information Center, Open-File Reports Section, Box 25286, MS 517, Denver Federal Center, Denver, CO 80225; GPO Dep.

The revised potentiometric-surface map presented in this report updates earlier maps of the Yucca Mountain area using mainly 1988 average water levels. Because of refinements in the corrections to the water-level measurements, these water levels have increased accuracy and precision over older values. The small-gradient area to the southeast of Yucca Mountain is contoured with a 0.25-meter interval and ranges in water-level altitude from 728.5 to 73 1.0 meters. Other areas with different water levels, to the north and west of Yucca Mountain, are illustrated with shaded patterns. The potentiometric surface can be divided into three regions: (1) A small-gradient area to the southeast of Yucca Mountain, which may be explained by flow through high-transmissivity rocks or low ground-water flux through the area; (2) A moderate-gradient area, on the western side of Yucca Mountain, where the water-level altitude ranges from 775 to 780 meters, and appears to be impeded by the Solitario Canyon Fault and a splay of that fault; and (3) A large-gradient area, to the north-northeast of Yucca Mountain, where water level altitude ranges from 738 to 1,035 meters, possibly as a result of a semi-perched groundwater system. Water levels from wells at Yucca Mountain were examined for yearly trends using linear least-squares regression. Data from five wells exhibited trends which were statistically significant, but some of those may be a result of slow equilibration of the water level from drilling in less permeable rocks. Adjustments for temperature and density changes in the deep wells with long fluid columns were attempted, but some of the adjusted data did not fit the surrounding data and, thus, were not used.

755 (USGS/WRI-93-4025) **Precision and accuracy of manual water-level measurements taken in the Yucca Mountain Area, Nye County, Nevada, 1988-90.** Boucher, M.S. Geological Survey, Denver, CO (United States). 1994. 18p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95003787. Source: OSTI; NTIS; U.S. Geological Survey, Earth Science Information Center, Open-File Reports Section, Box 25286, MS 517, Denver Federal Center, Denver, CO 80225 (United States); GPO Dep.

Water-level measurements have been made in deep boreholes in the Yucca Mountain area, Nye County, Nevada, since 1983 in support of the US Department of Energy's Yucca Mountain Project, which is an evaluation of the area to determine its suitability as a potential storage area for high-level nuclear waste. Water-level measurements were taken either manually, using various water-level measuring equipment such as steel tapes, or they were taken continuously, using automated data recorders and pressure transducers. This report presents precision range and accuracy data established for manual water-level measurements taken in the Yucca Mountain area, 1988-1990. Precision and accuracy ranges were determined for all phases of the water-level measuring process, and overall accuracy ranges are presented.

756 (USGS-WRI-93-4144) **Pore-water extraction from unsaturated tuff by triaxial and one-dimensional compression methods, Nevada Test Site, Nevada.** Mower, T.E. (PRC Environmental Management, Inc., Denver, CO (United States)); Higgins, J.D.; Yang, In C.; Peters, C.A. Geological Survey, Denver, CO (United States). 1994. 78p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94015008. Source: OSTI; NTIS; INIS; GPO Dep.

The hydrologic system in the unsaturated tuff at Yucca Mountain, Nevada, is being evaluated for the US Department of Energy by the Yucca Mountain Project Branch of the US Geological Survey as a potential site for a high-level radioactive-waste repository. Part of this investigation includes a hydrochemical study that is being made to assess characteristics of the hydrologic system such as: traveltime, direction of flow, recharge and source relations, and types and magnitudes of chemical reactions in the unsaturated tuff. In addition, this hydrochemical information will be used in the study of the dispersive and corrosive effects of unsaturated-zone water on the radioactive-waste storage canisters. This report describes the design and validation of laboratory experimental procedures for extracting representative samples of uncontaminated pore water from welded and nonwelded, unsaturated tuffs from the Nevada Test Site.

757 (USGS-WRI–94-4104) **Estimates of ground-water recharge rates for two small basins in central Nevada.** Lichty, R.W.; McKinley, P.W. Department of the Interior, Washington, DC (United States). 1995. 31p. Sponsored by USDOE, Washington, DC (United States);Department of the Interior, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE96001883. Source: OSTI; NTIS; INIS; GPO Dep.

U.S. Geological Survey, Earth Science Information Center, Open-File Reports Section, Box 25286, MS 517, Denver Federal Center, Denver, CO 80225.

Estimates of ground-water recharge rates developed from hydrologic modeling studies are presented for 3-Springs and East Stewart basins, two small basins (analog sites) located in central Nevada. The analog-site studies were conducted to aid in the estimation of recharge to the paleohydrologic regime associated with ground water in the vicinity of Yucca Mountain under wetter climatic conditions. The two analog sites are located to the north and at higher elevations than Yucca Mountain, and the prevailing (current) climatic conditions at these sites is thought to be representative of the possible range of paleoclimatic conditions in the general area of Yucca Mountain during the Quaternary. Two independent modeling approaches were conducted at each of the analog sites using observed hydrologic data on precipitation, temperature, solar radiation, stream discharge, and chloride-ion water chemistry for a 6-year study period (October 1986 through September 1992). Both models quantify the hydrologic water-balance equation and yield estimates of ground-water recharge, given appropriate input data. Results of the modeling approaches support the conclusion that reasonable estimates of average-annual recharge to ground water range from about 1 to 3 centimeters per year for 3-Springs basin (the drier site), and from about 30 to 32 centimeters per year for East Stewart basin (the wetter site). The most reliable results are those derived from a reduced form of the chloride-ion model because they reflect integrated, basinwide processes in terms of only three measured variables: precipitation amount, precipitation chemistry, and streamflow chemistry.

758 (USGS-WRI–95-4035) **Shallow infiltration processes at Yucca Mountain, Nevada - neutron logging data 1984-93.** Flint, L.E.; Flint, A.L. Department of the Interior, Washington, DC (United States). 1995. 46p. Sponsored by USDOE, Washington, DC (United States);Department of the Interior, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE96001882. Source: OSTI; NTIS; INIS; U.S. Geological Survey, Earth Sciences Information Center, Open-File Reports Section, Box 25286, MS 517, Denver Federal Center, Denver, CO 80225; GPO Dep.

To determine site suitability of Yucca Mountain, Nevada, as a potential high-level radioactive waste repository, a study was devised to characterize net infiltration. This study involves a detailed data set produced from 99 neutron boreholes that consisted of volumetric water-content readings with depth from 1984 through 1993 at Yucca Mountain. Boreholes were drilled with minimal disturbance to the surrounding soil or rock in order to best represent field conditions. Boreholes were located in topographic positions representing infiltration zones identified as ridge-tops, sideslopes, terraces, and active channels. Through careful field calibration, neutron moisture logs, collected on a monthly basis and representing most of the areal locations at Yucca Mountain, illustrated that the depth of penetration of seasonal moisture, important for escaping loss to evapotranspiration, was influenced by several factors. It was increased (1) by thin soil cover, especially in locations where thin soil is underlain by fractured bedrock; (2) on ridgetops; and (3) during the winter when evapotranspiration is low and runoff is less frequent. This data set helps to provide a seasonal and areal distribution of changes in volumetric water content with which to assess hydrologic processes contributing to net infiltration.

759 (USGS-WRI–95-4061) **Physical and hydrologic properties of outcrop samples from a nonwelded to welded tuff transition, Yucca Mountain, Nevada.** Rautman, C.A.; Flint, L.E.; Flint, A.L.; Istok, J.D. Department of the Interior, Washington, DC (United States); Sandia National Labs., Albuquerque, NM (United States). 1995. 28p. Sponsored by USDOE, Washington, DC (United States);Department of the Interior, Washington, DC (United States). DOE Contract AI08-92NV10874 ; AC04-94AL85000. Order Number DE96001885. Source: OSTI; NTIS; INIS; U.S. Geological Survey, Earth Science Information Center, Open-File Reports Section, Box 25286, MS 517, Denver Federal Center, Denver, CO 80225; GPO Dep.

Quantitative material-property data are needed to describe lateral and vertical spatial variability of physical and hydrologic properties and to model ground-water flow and radionuclide transport at the potential Yucca Mountain nuclear-waste repository site in Nevada. As part of on-going site characterization studies of Yucca Mountain directed toward this understanding of spatial variability, laboratory measurements of porosity, bulk and particle density, saturated hydraulic conductivity, and sorptivity have been obtained for a set of outcrop samples that form a systematic, two-dimensional grid that covers a large exposure of the basal Tiva Canyon Tuff of the Paintbrush Group of Miocene age at Yucca Mountain. The samples form a detailed vertical grid roughly parallel to the transport direction of the parent ash flows, and they exhibit material-property variations in an interval of major lithologic change overlying a potential nuclear-waste repository at Yucca Mountain. The observed changes in hydrologic properties were systematic and consistent with the changes expected for the nonwelded to welded transition at the base of a major ash-flow sequence. Porosity, saturated hydraulic conductivity, and sorptivity decreased upward from the base of the Tiva Canyon Tuff, indicating the progressive compaction of ash-rich volcanic debris and the onset of welding with increased overburden pressure from the accumulating ash-flow sheet. The rate of decrease in the values of these material properties varied with vertical position within the transition interval. In contrast, bulk-density values increased upward, a change that also is consistent with progressive compaction and the onset of welding. Particle-density values remained almost constant throughout the transition interval, probably indicating compositional (chemical) homogeneity.

760 (USGS-WRI–95-4073) **Pneumatic testing in 45-degree-inclined boreholes in ash-flow tuff near Superior, Arizona.** LeCain, G.D. Department of the Interior, Washington, DC (United States). 1995. 27p. Sponsored by USDOE, Washington, DC (United States);Department of the Interior, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE96001886. Source: OSTI; NTIS; U.S. Geological Survey, Earth Science Information Center, Open-File Reports Section, Box 25286, MS 517, Denver Federal Center, Denver, CO 80225; GPO Dep.

Matrix permeability values determined by single-hole pneumatic testing in nonfractured ash-flow tuff ranged from 5.1 to $20.3*10^{-16}$ m^2 (meters squared), depending on the gas-injection rate and analysis method used. Results from the single-hole tests showed several significant correlations between permeability and injection rate and between permeability and test order. Fracture permeability values determined by cross-hole pneumatic testing in fractured ash-flow tuff ranged from 0.81 to 3.49×10^{-14} m^2, depending on injection rate and analysis method used. Results from the cross-hole tests monitor intervals showed no significant correlation between permeability and injection rate; however, results from the injection interval showed a significant correlation between injection rate and permeability. Porosity estimates from the cross-hole testing range from 0.8 to 2.0 percent. The maximum temperature change associated with the pneumatic testing was 1.2°C measured in the injection interval during cross-hole testing. The maximum temperature change in the guard and monitor intervals was 0.1°C. The maximum error introduced into the permeability values due to temperature fluctuations is approximately 4 percent. Data from temperature monitoring in the borehole indicated a positive correlation between the temperature decrease in the injection interval during recovery testing and the gas-injection rate. The thermocouple psychrometers indicated that water vapor was condensing in the boreholes during testing. The psychrometers in the guard and monitor intervals detected the drier injected gas as an increase in the dry bulb reading. The relative humidity in the test intervals was always higher than the upper measurement limit of the psychrometers. Although the installation of the packer system may have altered the water balance of the borehole, the gas-injection testing resulted in minimal or no changes in the borehole relative humidity.

761 (USGS/WRIR–92-4016) **Preliminary hydrogeologic assessment of boreholes UE-25c No. 1, UE-25c No. 2, and UE-25c No. 3, Yucca Mountain, Nye County, Nevada: Water-resources investigations report 92-4016.** Geldon, A.L. Geological Survey, Denver, CO (United States). 1993. 85p. Sponsored by Department of the Interior, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94009943. Source: OSTI; NTIS; INIS; GPO Dep.

The purpose of this report is to characterize the hydrogeology of saturated tuffaceous rocks penetrated by boreholes UE-25c No. 1, UE-25c No.2, and UE-25c No. 3. These boreholes are referred to collectively in this report as the C-holes. The C-holes were drilled to perform multiwell aquifer tests and tracer tests; they comprise the only complex of closely spaced boreholes completed in the saturated zone at Yucca Mountain. Results of lithologic and geophysical logging, fracture analyses, water-level monitoring, temperature and tracejector surveys, aquifer tests, and hydrochemical sampling completed at the C-hole complex as of 1986 are assessed with respect to the regional geologic and hydrologic setting. A conceptual hydrogeological model of the Yucca Mountain area is presented to provide a context for quantitatively evaluating hydrologic tests performed at the C-hole complex as of 1985, for planning and interpreting additional hydrologic tests at the C-hole complex, and for possibly re-evaluating hydrologic tests in boreholes other than the C-holes.

762 (USGS/WRIR–93-4000) **Revised potentiometric-surface map, Yucca Mountain and vicinity, Nevada: Water-resources investigations report 93-4000.** Ervin, E.M.; Luckey, R.R.; Burkhardt, D.J. Geological Survey, Denver, CO (United States). 1994. 33p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94012059. Source: OSTI; NTIS; INIS; GPO Dep.

This report presents a revised potentiometric-surface map based mainly on the 1988 average water levels at Yucca Mountain and the nearby vicinity extending from Crater Flat to Jackass Flats. Discussion includes an explanation of the revised potentiometric-surface map, an examination of yearly trends in the water levels, and adjustments for temperature and density effects in the deeper wells. Report scope focuses on the potentiometric surface of the uppermost saturated zone in the Tertiary volcanic rocks at Yucca Mountain. Some information, related to the underlying Paleozoic carbonate aquifer, pertinent to the volcanic flow system, is presented.

763 (USGS/WRIR–93-4025) **Precision and accuracy of manual water-level measurements taken in the Yucca Mountain area, Nye County, Nevada, 1988–1990: Water-resources investigations report 93-4025.** Boucher, M.S. Geological Survey, Denver, CO (United States). 1994. 18p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94011023. Source: OSTI; NTIS; INIS; GPO Dep.

Water-level measurements have been made in deep boreholes in the Yucca Mountain area, Nye County, Nevada, since 1983 in support of the US Department of Energy's Yucca Mountain Project, which is an evaluation of the area to determine its suit-ability as a potential storage area for high-level nuclear waste. Water-level measurements were taken either manually, using various water-level measuring equipment such as steel tapes, or they were taken continuously, using automated data recorders and pressure transducers. This report presents precision range and accuracy data established for manual water-level measurements taken in the Yucca Mountain area, 1988–90.

764 **Multimode reverse time VSP imaging over complex structures at Yucca Mountain, Nye County, Nevada.** Jaramillo, H.H. (Colorado School of Mines, Golden, CO (United States)); Balch, A.H.; Erdemir, C.; Rousseau, J.P. pp. 129-132 of 1993 Technical program: Expanded abstracts with biographies. Society of Exploration Geophysicists, Tulsa, OK (United States) (1993). pp. 1448 (CONF-930901–: 63. annual meeting and international exhibition of the Society of Exploration Geophysicists (SEG), Washington, DC (United States), 26-30 Sep 1993).

With VSP (Vertical Seismic Profiling) data, variable density plots of its observed, recorded wavefield reveal little about the nearby geologic structure. Considerable structural information is contained in the reflected events, but migration or some similar procedure is needed to image the reflectors and create an interpretable display of the structure. The authors have succeeded in imaging reflectors by reverse time wave equation migration in a physical elastic model of a simple fault, and in a complex physical 2-D scale model of Yucca Mountain, Nye County, Nevada. All four modes: P-P, P-S, S-P, and S-S can be imaged. Images are generated by forward scattered as well as back scattered events. The images compare favorably with the models can demonstrate the efficacy of the technique in VSP processing and interpretation.

765 **Spatial variability in hydrologic properties of a volcanic tuff.** Istok, J.D. (Oregon State Univ., Corvallis, OR

(United States). Dept. of Civil Engineering); Rautman, C.A.; Flint, L.E.; Flint, A.L. *Ground Water;* 32(5): 751-760 (Sep-Oct 1994). DOE Contract AC04-76DP00789 ; AI08-78ET44802.

Spatial variability of hydrologic properties was quantified for a nonwelded-to-welded ash flow tuff at Yucca Mountain, Nevada, the potential site of a high-level, nuclear waste repository. Bulk density, porosity, saturated hydraulic conductivity, and sorptivity were measured on core specimens collected from outcrops on a grid that extended vertically through the entire unit thickness and horizontally 1.3 km in the direction of ash transport from the volcanic vent. A strong, geologically determined vertical trend in properties was apparent that correlated with visual trends in degree of welding observed in the outcrop. The trend was accurately described by simple regression models based on stratigraphic elevation. No significant horizontal trends in properties were detected along the length of the transect. The validity of the developed model was tested by comparing model predictions with measured porosity values from additional outcrop sections and boreholes that extended 3,000 m north, 1,500 m northeast, and 6,000 m south of the study area. The model accurately described vertical porosity variations except for locations very close to the source caldera, where the model underpredicted porosity in the upper half of the section. The presence of deterministic geologic trends, such as those demonstrated for an ash flow unit in this study, can simplify the collection of site characterization data and the development of site-scale models.

766 Strain accumulation near Yucca Mountain, Nevada, 1983-1993. Savage, J.C. (Geological Survey, Menlo Park, CA (United States)); Lisowski, M.; Gross, W.K.; King, N.E.; Svarc, J.L. *Journal of Geophysical Research;* 99(B9): 18103-18107 (10 Sep 1994).

Over the decade 1983-1993 the U.S. Geological Survey has measured the deformation of a 50-km-aperture trilateration network centered on Yucca Mountain, the proposed disposal site for high-level nuclear waste in the United States. The network was surveyed in 1983, 1984, and 1993. The average annual principal strain rates are $0.010 \pm 0.020 \mu$strain/yr N90°W ± 24° and $-0.009 \pm 0.021 \mu$strain/yr N00°E ± 24°, indicating no significant strain accumulation. The southeast corner of the network was disturbed on June 29, 1992, by the Little Skull Mountain earthquake ($M_s = 5.4$), the epicenter of which is about 20 km southeast of the Yucca Mountain site. Using the seismically determined fault plane (dip 54°S55°E), the authors find that 0.580 ± 0.075 m of normal slip on a 5-km square rupture surface at a depth of about 8 km provides a good fit to the observed deformation in the southeast corner of the network. The inferred seismic moment is $(4.4 \pm 0.6) \times 10^{17}$ N m, which compares well with the observed seismic moment of 4.1×10^{17} N m. 10 refs., 2 figs., 2 tabs.

767 Evaluation of measurement scale using imbibition experiments in volcanic tuffs. Flint, A.L. (Geological Survey, Mercury, NV (United States)); Flint, L.E.; Richards, K.A. *Soil Science Society of America Journal;* 58(1): 94-102 (Jan-Feb 1994).

A major issue in the site characterization at Yucca Mountain, Nevada, a potential site for a high-level nuclear waste repository, is the relevance of laboratory-scale measurements on cores to field-scale processes, particularly water flow. Calculation of Philip's sorptivity parameter using imbibition of water into rock was selected as a simple test to describe hydrologic parameters at both laboratory and field scales and to study effects of sample size and spatial variability. Laboratory-scale imbibition experiments were conducted on two sizes of core from two boreholes drilled in layered nonwelded tuff and fractured welded tuff. Laboratory experiments were compared with field experiments in the boreholes using neutron logs and a field-scale Mariotte system. Measured sorptivity for both sizes of core were virtually identical and both could predict field-scale sorptivity if enough samples were used to account for spatial heterogeneity. Core data was less useful in predicting the neutron log data due to the nature of the neutron probe measurement and difficulties in accounting for effects of the unique system geometry. Mean neutron log values could not predict the field results from the welded borehole due to fractures transmitting but not retaining water, and could not predict laboratory results because of scale and sampling volume differences. The mean neutron log data could, however, approximate the large-scale field results in the nonwelded borehole. 19 refs., 6 figs., 3 tabs.

768 Relict colluvial boulder deposits as paleoclimatic indicators in the Yucca Mountain region, southern Nevada. Whitney, J.W. (Geologic Survey, Denver, CO (United States)); Harrington, C.D. *Geological Society of America, Bulletin;* 105(8): 1008-1018 (Aug 1993).

Six colluvial boulder deposits from Yucca Mountain, Nye County, Nevada, were dated by cation-ratio dating of rock varnish accreted on boulder surfaces. Estimated minimum ages of these boulder deposits range from 760 to 170 ka. Five additional older deposits on nearby Skull and Little Skull Mountains and Buckboard Mesa yielded cation-ratio minimum-age estimates of 1.38 Ma to 800 ka. An independent cosmogenic chlorine-36 surface exposure date was obtained on one deposit, which confirms an estimated early to middle Quaternary age. These deposits have provided the oldest age estimates for unconsolidated hillslope deposits in the southwestern United States. We suggest that the colluvial boulder deposits were produced during early and middle Pleistocene glacial/pluvial episodes and were stabilized during the transition to drier interglacial climates. By comparison to modern periglacial environments, winter minimum monthly temperatures of -3 to -5 °C were necessary to initiate freeze-thaw conditions of such vigor to physically weather relatively large volumes of large boulders from the upper hillslopes of the Yucca Mountain area. These conditions imply that early and middle Pleistocene glacial winter temperature were at least 1 to 3°C colder than existed during the last Pleistocene glacial episode and 7 to 9°C colder than present. 53 refs., 9 figs., 3 tabs.

769 Morphology and genesis of carbonate soils on the Kyle Canyon fan, Nevada, U.S.A. Reheis, M.C. (Geological Survey, Lakewood, CO (United States). Federal Center); Taylor, E.M.; Sowers, J.M.; McFadden, L.D.; Harden, J.W. *Geoderma;* 52: 303-342 (1992). DOE Contract AI08-78ET44802.

The physical and chemical properties of soils formed in an arid climate on calcareous alluvium of the Kyle Canyon alluvial fan, southern Nevada, were studied in order to infer the rates and relative importance of various soil-forming processes. These studies included field and microscopic observations and analyses of thin sections, major oxides, extractable iron, and clay minerals. The results are interpreted to reflect five major pedogenic processes: (1) the calcic horizons and calcretes of Kyle Canyon soils form by precipitation of $CaCO_3$, derived from eolian dust and alluvium, as clast coats, matrix cement, and massive layers; (2)

the A and uppermost B horizons are essentially dust-derived, for they contain large amounts of detrital material not present in the alluvial parent material, and their major-oxide content is similar to that of modern dust; (3) clay particles are translocated from A into B horizons; (4) iron-bearing minerals in the near-surface B horizons are slowly oxidized; (5) carbonate and aluminosilicate grains are both displaced and replaced by pedogenic $CaCO_3$; the silica released by replacement of aluminosilicates may be locally precipitated as amorphous or opaline silica and (or) incorporated into newly formed palygorskite and sepiolite. Rates of soil development at Kyle Canyon are approximate due to uncertainties in age estimates. Some soil field properties change at rates that are similar to rates for soils formed in rhyolitic parent material near Mercury, Nevada. The rate of accumulation of $CaCO_3$ (3–5 g m^{-2} yr^{-1}) at Kyle Canyon is an order of magnitude faster than that near Mercury, but is comparable to rates calculated for soils in southern New Mexico and Utah. This study is part of the Yucca Mountain Site Characterization Project. 63 refs.

WESTINGHOUSE ELECTRIC CORPORATION

770 Development of preliminary Nevada transportation accident characteristics. Tappen, J.J. (Westinghouse Electric Corp., Las Vegas, NV (United States)); Heitzman, A.; Hill, C.V. pp. 613-617 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The US DOE, Yucca Mountain Site Characterization Project Office (YMSCPO) has been given the responsibility for characterization of the potential repository site at Yucca Mountain, Nevada, and the analysis of repository-related impacts in the State of Nevada. In support of these responsibilities, the YMSCPO initiated a preliminary study to develop background information on the character of the transportation accidents occurring on the highways and raillines in the State of Nevada. The results of this preliminary study shows that while the transportation accidents in Nevada follow national trends, there are some distinct differences between Nevada and the rest of the Nation. This paper summarizes those results.

771 Application of the global positioning system to locating remote sites. Tappen, J.J. (Westinghouse Electric Corporation, Las Vegas, NV (United States)); Bell, S.; Follette, J. pp. 1967-1971 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The location of Near Field (NF) sampling stations, used for the radiological monitoring program portion of the site characterization phase of the Yucca Mountain Project, were determined using the Global Positioning System (GPS). Latitudinal and longitudinal position accuracies on the order of one second were achieved using the differential GPS technique. Acceptance test criteria and results are presented. Operational criteria for data acceptance and corrected data variability and reproducibility are discussed.

RELATED INFORMATION

772 (ANL–93/45) **Effects of radionuclide decay on waste glass behavior: A critical review.** Wronkiewicz, D.J. Argonne National Lab., IL (United States). Dec 1993. 64p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94010073. Source: OSTI; NTIS; INIS; GPO Dep.

This paper is an extension of a chapter in an earlier report [1] that provides an updated review on the status of radiation damage problems in nuclear waste glasses. This report will focus on radiation effects on vitrified borosilicate nuclear waste glasses under conditions expected in the proposed Yucca mountain repository. Radiation effects on high-level waste glasses and their surrounding repository environment are important considerations for radionuclide immobilization because of the potential to alter the glass stability and thereby influence the radionuclide retentive properties of this waste form. The influence of radionuclide decay on vitrified nuclear waste may be manifested by several changes, including volume, stored energy, structure, microstructure, mechanical properties, and phase separation. Radiation may also affect the composition of aqueous fluids and atmospheric gases in relatively close proximity to the waste form. What is important to the radionuclide retentive properties of the repository is how these radiation effects collectively or individually influence the durability and radionuclide release from the glass in the event of liquid water contact.

773 (ANL–94/14) **Nuclear Waste Programs semiannual progress report, April–September 1992.** Bates, J.K. (and others); Bradley, C.R.; Buck, E.C. Argonne National Lab., IL (United States). May 1994. 39p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94016807. Source: OSTI; NTIS; INIS; GPO Dep.

This document reports on the work done by the Nuclear Waste Programs of the Chemical Technology Division (CMT), Argonne National Laboratory, in the period April–September 1992. In these programs, studies are underway on the performance of waste glass and spent fuel in projected nuclear repository conditions to provide input to the licensing of the nation's high-level waste repositories.

774 (ANL–94/19) **ANL Technical Support Program for DOE Environmental Restoration and Waste Management: Annual report, October 1992–September 1993.** Bates, J.K. (and others); Bourcier, W.L.; Bradley, C.R. Argonne National Lab., IL (United States). Jun 1994. 140p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94017954. Source: OSTI; NTIS; INIS; GPO Dep.

This report is an overview of the progress during FY 1993 for the Technical Support Program that is part of the ANL Technology Support Activity for DOE Environmental Restoration and Waste Management (EM). The purpose is to evaluate, before hot start-up of the Defense Waste Processing Facility (DWPF) and the West Valley Demonstration Project (WVDP), factors that are anticipated to affect glass reaction in an unsaturated environment typical of what may be expected for the candidate Yucca Mountain repository site. Specific goals for the testing program include the

following: reviewing and evaluating available data on parameters that will be important in establishing the long-term performance of glass in a repository environment; performing tests to further quantify the effects of important variables where there are deficiencies in the available data; and initiating long-term tests to determine glass performance under a range of conditions applicable to repository disposal.

775 (BNL–49737) **Enumeration and characterization of microorganisms associated with the uranium ore deposit at Cigar Lake, Canada: Informal report.** Francis, A.J.; Joshi-Tope, G.; Gillow, J.B.; Dodge, C.J. Brookhaven National Lab., Upton, NY (United States). Mar 1994. 42p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC02-76CH00016. Order Number DE94016231. Source: OSTI; NTIS; INIS; GPO Dep.

The high-grade uranium deposit at Cigar Lake, Canada, is being investigated as a natural analog for the disposal of nuclear fuel waste. Geochemical aspects of the site have been studied in detail, but the microbial ecology has not been fully investigated. Microbial populations in an ore sample and in groundwater samples from the vicinity of the ore zone were examined to determine their effect on uranium mobility. Counts of the total number of bacteria and of respiring bacteria were obtained by direct microscopy, and the viable aerobic and anaerobic bacteria were assessed as colony forming units (CFUs) by the dilution plating technique. In addition, the population distribution of denitrifiers, fermenters, iron- and sulfur-oxidizers, iron- and sulfate-reducers, and methanogens was determined by the most probable number (MPN) technique.

776 (CEA-CONF–11814) **Elementary migration around the Oklo nuclear reactors. Implications for high level radioactive wastes storage.** Menet-Dressayre, C.; Menager, M.T. CEA Centre d'Etudes de la Vallee du Rhone, 30 - Marcoule (France). Dept. d'Exploitation du Retraitement et de Demantelement. 1993. 10p. (In French). (CONF-9310378–: Oklo Working Group Meeting, Bruxelles (Belgium), 11-12 Oct 1993). Order Number DE95605958. Source: OSTI; NTIS (US Sales Only); INIS.

The study of Uranium and rare earths near the reactors has displayed the radioelements transfer in the reactors neighbourhood. The main implications for high level radioactive wastes disposal in geological formations are discussed. 12 refs.

777 (CEA-CONF–11823) **Analysis of colloids from Oklo/Okelobondo and Bangombe waters.** Moulin, V.; Vilarem, J.P. CEA Centre d'Etudes de Cadarache, 13 - Saint-Paul-lez-Durance (France). Dept. Stockage Dechets. 1993. 7p. (CONF-9310364–: Oklo meeting, Brussels (Belgium), 11-12 Oct 1993). Order Number DE95601656. Source: OSTI; NTIS (US Sales Only); INIS.

In the framework of the hydrogeological and hydrogeochemical studies carried out on the Oklo/Okelobondo and Bangombe sites, the nature and physico-chemical characteristics of the colloids present in the waters sampled in these sites have been investigated. Different techniques have been used for this purpose, namely scanning electron microscopy, X-ray microanalysis and photon correlation spectroscopy. Informations on their size, composition and content have thus been obtained. Discussion on the possible origin and formation mechanisms of these colloids is performed. (author). 7 refs., 2 figs., 2 tabs.

778 (CEA-CONF–11972) **Plutonium in nature.** Madic, C. CEA Centre d'Etudes de la Vallee du Rhone, 30 - Marcoule (France). Dept. des Procedes de Retraitement. 1994. 41p. (In French). (CONF-9406334–: Conference on plutonium in nature, Pierrelatte (France), 24 Jun 1994). Order Number DE95631031. Source: OSTI; NTIS (US Sales Only); INIS.

Plutonium in nature comes from natural sources and anthropogenic ones. Plutonium at the earth surface comes principally from anthropogenic sources. It is easily detectable in environment. The plutonium behaviour in environment is complex. It seems necessary for the future to reduce releases in environment, to improve predictive models of plutonium behaviour in geosphere, to precise biological impact of anthropogenic plutonium releases.

779 **High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1.** 891p. American Nuclear Society; American Society of Civil Engineers, New York, New York (United States) (1991). Sponsored by American Society of Civil Engineers, New York, NY (United States);American Nuclear Society, La Grange Park, IL (United States). From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The final disposal of high level radioactive waste (HLW) has been one of the most arduous problems facing the nuclear industry. This issue has many facets, which are addressed in these proceedings. The papers herein contain the most current information regarding the conditioning and disposal of HLW. Most of the needs are technical in nature, such as the best form of the waste, the integrity of storage containers, design and construction of a repository, and characterization of the geology of a repository to provide assurance that radioactive and other hazardous materials will not reach the surrounding environment. Many of the papers discuss non-US programs. Continued international cooperation and technology exchange is essential. There are other concerns that must be addressed before the final emplacement of HLW. Some of the other issues addressed in these proceedings are conformance to regulations, transportation, socioeconomics, and public education. Any impediments in these areas must be resolved along with the scientific issues before final waste disposal. This conference provides a forum for information exchange. The papers in these proceedings will provide the basis for future planning and decisions. Continued cooperation of the technical community will ultimately result in the safe disposal of HLW. Individual abstracts are indexed separately for the data base.

780 **Computer-assisted geometric and kinematic analysis of subsurface faulting in the vicinity of Yucca Mountain, Nevada, using balanced geologic cross sections.** Young, S.R. (Southwest Research Institute, San Antonio, TX (United States)); Stirewalt, G.L.; Ratliff, R.A. pp. 248-259 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Computer-assisted geological cross section balancing methods are used in the geometric and kinematic analysis of subsurface structures in the vicinity of Yucca Mountain, Nevada, including underlying listric normal fault and detachment fault geometries and their relationships in a linked fault

system. Dips of hanging wall fault blocks are directly related to the shapes of underlying curved normal and detachment faults. Arrays of small faults that are pervasively distributed through the hanging wall blocks are interpreted to be the bulk deformation mechanism of the block. As the hanging wall slides over the underlying fault surface, the fault block deforms to accommodate itself to the shape of the fault. Distributed slip on the small fault array is assumed to accomplish this shape change. The deformation is modeled as general simple shear, such that changes in shape of the model fault blocks take place by distributed slip on uniformly oriented slip surfaces that are evenly spaced through the area of the block, replicating the behavior of a deck of cards. Computed listric normal fault trajectories and surface geologic data constrain the range of compatible depths to potential detachment fault zones below Yucca Mountain to between about 3.5 and 6 kilometers. This is at least 1 to 2 kilometers deeper than the contact between the base of the Tertiary volcanics and the Paleozoic section. Preliminary balanced versions of sections A-A′ and B-B′ of Scott and Bonk show that assumption of a vertical simple shear deformation mechanism for fault block distortion will produce geologically reasonable subsurface models of faulting.

781 The development process for unique underground equipment for waste handling. Karhnak, J.M. (UTD Inc., Newington, VA (United States)); Tanious, N.S. pp. 326-333 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The DOE is currently planning to site, construct, and operate a geologic repository at Yucca Mountain, Nevada for the disposal of high-level nuclear waste (HLW). The repository resembles an underground mine, but with a more severe environment due to the radiation and heat given off by the waste. Construction and operation of the repository will require the development of unique equipment for transportation, emplacement, and retrieval of the waste. Reliability will be an important consideration throughout the conception, design, fabrication, and test of the equipment. Creating a plan, staying with it, but knowing when to change requires a blend of knowledge of all the factors that will influence the acceptance and suitability of the new equipment. This paper is based on the authors' experiences in developing unique equipment for mining applications. It reviews the salient points that need to be included in a development plan, with examples of application of these points, and some suggestions for the development plan for equipment for waste handling operations.

782 Correlation of hydraulic conductivity and sonic velocity in water-saturated tuff. Shimo, Michito (Taisei Corp., Yokohama (Japan)). pp. 572-577 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

A laboratory study was conducted to investigate the correlation of hydraulic and sonic properties of water-saturated tuff. The hydraulic test used a new rock block testing machine, which has the capability of applying biaxial stresses and pore pressure on a 30 cm cube of rock. The hydraulic conductivity tensor obtained by the cross-hole injection test was clearly anisotropic with principle directions close to those for shear wave velocity to hydraulic conductivity reflects the effect of water bearing voids in retarding the wave propagation. This result suggests that the seismic exploration method may be used for the evaluation of the hydraulic anisotropy of the large volume of rock at the repository site.

783 Unintentional stoppages of trucks hauling high-level nuclear waste in Nevada. Glickman, T.S. (Resources for the Future, Washington, DC (United States)). pp. 618-625 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Any unintentional stoppage of trucks hauling high-level nuclear waste in Nevada could intensify public concerns about the negative impacts of the Yucca Mountain Project. This paper provides estimates of the expected number and frequency of such stoppages under several alternative scenarios for the routing and volume of the anticipated truck shipments. At least twice as many truck stoppages are expected to occur on freeways as on non-freeways, and at least twice as many are expected to occur in rural areas as in other areas. The expected frequency of such stoppages in the state is estimated to range from about 3 per year to one every 3 1/2 years. About one in every 4 of the stoppages is expected to take place in Las Vegas and 3 out of every 4 are expected to be non-accidents such as mechanical disablements. The minimum duration of the stoppages is expected to be on the order of half an hour for disablements and an hour for accidents.

784 Development of rail access to the proposed repository site at Yucca Mountain. Standish, P.N. (Westinghouse, Las Vegas, NV (United States)); Seidler, P.E.; Andrews, W.B.; Shearin, G. pp. 633-640 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

In accordance with the Nuclear Waste Policy Amendment Act of 1987, Yucca Mountain was designated as the initial site to be investigated as a potential repository for the disposal of high-level radioactive waste. The Yucca Mountain site is an undeveloped area located on the southwestern edge of the Nevada Test Site (NTS), about 100 miles northwest of Las Vegas. The site currently lacks rail service or an existing right-of-way. If the Yucca Mountain site is found suitable for the repository, rail service is considered desirable by the Office of Civilian Radioactive Waste Management (OCRWM) program because of the potential of rail transportation to reduce (1) costs and (2) number of shipments, relative to highway transportation. Therefore, it is necessary to conduct a study to determine (1) that there are alignments for a potential rail line from existing mainline railroads to Yucca Mountain and (2) that these are consistent

with present rail design standards and are acceptable relative to environmental and land access considerations.

785 **An approach to evaluate the sufficiency of highway bridges for nuclear spent fuel transportation.** Saiidi, M. (Univ. of Nevada, Reno, NV (United States)); Jiang, Y.; Maragakis, E: pp. 641-646 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The transportation of radioactive spent fuel can have a significant impact on bridge structures located on designated routes. Due to the critical nature of the cargo and because of the severe consequences of the failure of a bridge in carrying the vehicles containing the cargo, a careful and systematic examination of bridges along the route needs to be made and the economic impact needs to be determined. This paper presents a relatively general method to undertake these tasks. An actual bridge located in southern Nevada is used as an example to illustrate some of the major steps involved in the process. The need for the development of new limit states for bridges carrying the spent fuel traffic is discussed.

786 **Transportation access to Yucca Mountain: Critical Issues.** Halstead, R.J. (Agency for Nuclear Project, Carson City, NV (United States)); Souleyrette, R.R.; Bartolo, R. di. pp. 647-656 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract FG08-85NV10461. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Transportation planning for a repository at Yucca Mountain is complicated because of uncertainty about the modes and numbers of nuclear waste shipments and because of uncertainty about the routes which will be used. There could be as many as 76,000 truck shipments, or as few as 1,060 dedicated train shipments, during repository operations. The site lacks rail access. Three rail access options currently under study range in length from 120 miles to more than 400 miles. The site is more than 100 miles from the Interstate highway system. The UNLV Transportation Research Center has evaluated three rail and four highway routes using a broad range of impact measures. This preliminary evaluation found that the routing options differ significantly regarding resident and non-resident populations, environmentally sensitive areas, accident rates, and other factors. Crosscutting issues include impacts on Nevada Indian tribes, potential conflicts with US Air Force operations, and future population growth in southern Nevada. Considerable additional analysis will be required prior to environmental impact statement scoping.

787 **Political trust's role in explaining Nevada urban resident's perceptions of the proposed Yucca Mountain repository.** Dantico, M.K. (Arizona State Univ., Tempe, AZ (United States)); Mushkatel, A.H.; Pijawka, K.D. pp. 748-757 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

This paper examines the key role that political trust plays in explaining repository risk perceptions of urban residents of the Las Vegas metropolitan area. Findings from two surveys of urban residents confirm that very low levels of political trust exist among residents for the federal government and particularly the DOE and the Nuclear Regulatory Commission. Yet, high levels of political trust are found to be strongly related to low risk perceptions of the repository.

788 **Development of a structural model to analyze public opinion on a high-level radioactive waste facility.** Flynn, J. (Decision Research, Eugene, OR (United States)); Slovic, P.; Mertz, C.K.; Burns, W. pp. 773-779 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Studies show that Nevada residents and state officials oppose the proposed high-level radioactive waste repository project at Yucca Mountain. Nevada residents view the Yucca Mountain repository as having extremely high risk; nuclear experts, in contrast, feel the risks are very low. These experts have suggested that public risk perceptions may be reduced by better program management, increased trust in the federal government, and/or by increased benefits and compensation for accepting a repository. The model described in this paper is designed to examine the relationship between risk perception and various strategies for risk management using a confirmatory multivariate method known as covariance structure analysis.

789 **Nondestructive testing using borehole and surface seismic techniques to evaluate rock mass damage zones.** Nelson, P.P. (Univ. of Texas, Austin, TX (United States)); Stokoe, K.H. II. pp. 802-809 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

A suite of seismic tests was performed at the U12g tunnel at the Nevada Test Site. The methods include borehole (crosshole and downhole) and surface (Rayleigh wave and refraction) tests. Results indicate that the different methods should be considered complimentary, and that seismic methods can sensitively evaluate magnitudes and variations of in situ rock mass stiffness. In particular, near-surface low velocity (damage) zones are delineated quite well with Rayleigh wave and downhole methods.

790 **Effect of a low-permeability layer on calculated gas flow at Yucca Mountain.** Lu, Ning (Disposal Safety Inc., Washington, DC (United States)); Amter, S.; Ross, B. pp. 853-860 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive

waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Seasonal flows of air with velocities as high as 3.5 m/s have been observed in deep boreholes at Yucca Mountain. These flows are attributed to convective circulation arising from topographic relief, seasonal temperature variation, and density differences resulting from variation in gas composition. If a repository were built there, heat from the emplaced waste would also contribute to gas flow. Large-scale air flows may be significant to repository performance because they control the movement of carbon dioxide within the mountain and also result in a net flux of water vapor to the surrounding atmosphere. An understanding of the velocity, trajectories, and mixing of the gas in Yucca Mountain, is necessary both as input for a model of the carbon-14 movement in the unsaturated zone and evaluation of the net vapor flux. Amter and Ross developed a model called TGIF (TopoGraphic Induced Flow) to simulate gas flow under Yucca Mountain. This paper describes a systematic sensitivity study that was designed to test several aspects of the TGIF model when used to simulate gas flow under Yucca Mountain. Values of three important inputs to the model were systematically varied to form a matrix of 80 runs. The matrix consisted of five values of permeability contrast between a bedded tuff layer and surrounding welded units (in all cases, bulk permeabilities were used to represent the combined effect of both fractures and matrix permeability), four temperature profiles representing different stages of repository cooldown, and four finite-difference grids.

791 High Level Radioactive Waste Management: Proceedings, Volume 2. 895p. American Society of Civil Engineers, New York, NY (United States) (1991). Sponsored by American Society of Civil Engineers, New York, NY (United States);American Nuclear Society, La Grange Park, IL (United States). From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The proceedings of the second annual international conference on High Level Radioactive Waste Management, held on April 28–May 3, 1991, Las Vegas, Nevada, provides information on the current technical issue related to international high level radioactive waste management activities and how they relate to society as a whole. Besides discussing such technical topics as the best form of the waste, the integrity of storage containers, design and construction of a repository, the broader social aspects of these issues are explored in papers on such subjects as conformance to regulations, transportation safety, and public education. By providing this wider perspective of high level radioactive waste management, it becomes apparent that the various disciplines involved in this field are interrelated and that they should work to integrate their waste management activities. Individual records are processed separately for the data bases.

792 Demonstration of a repository performance assessment capability at the US Nuclear Regulatory Commission. Codell, R. (Nuclear Regulatory Commission, Washington, DC (United States)); Eisenberg, N.; McCartin, T.; Park, J. pp. 908-916 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

In order to better review licensing submittals for a High-Level Waste Repository, the US Nuclear Regulatory Commission staff has expanded and improved its capability to conduct performance assessments. A demonstration of this capability used the limited data from Yucca Mountain, Nevada to investigate a small set of scenario classes. Models of release and transport of radionuclides from a repository via the groundwater and direct release pathways provided preliminary estimates of releases to the accessible environment for a 10,000 year simulation time. Latin hypercube sampling of input parameters was used to express results as distributions and to investigate model sensitivities. This methodology demonstration should not be interpreted as an estimate of performance of the proposed repository at Yucca Mountain, Nevada.

793 A model for effective intergovernmental planning. Moore, R.C. pp. 1022-1026 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Effective intergovernmental planning processes are essential to the resolution of potential affects created by federal projects. Intergovernmental planning for the proposed Yucca Mountain High-level Nuclear Waste Repository has not been effective to date. In this paper, two successful planning efforts are described. The common elements of these processes are analyzed to provide a model that can be used for the resolution of impacts from other projects. Management authorities of the entities involved should establish a working group to conduct the intergovernmental planning. The parties must identify issues that can be resolved through intergovernmental planning. Clear management authority and direction to the staff participating the planning process is essential. Issues which cannot be resolved should not be included in the goals of the working group. Funding to support the planning process is essential.

794 Potential $^{14}CO_2$ releases from spent fuel containers at Yucca Mountain. Pescatore, C. (Brookhaven National Lab., Upton, NY (United States)); Sullivan, T.M. pp. 1066-1073 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The potential release of gaseous $^{14}CO_2$ from small perforations in spent fuel containers has been evaluated as a function of temperature, hole size, effective porosity of corrosion products within the hole, and time, based on the waste package design parameters and environmental conditions described in the Yucca Mountain Site Characterization Report (SCP). The SCP does not specify initial fill gas (argon) pressure and temperature. It is shown that, if significant ^{14}C oxidation takes place during the initial, inert-gas phase, an incentive exists to initially underpressurize the containers. This will avoid large, spiked releases of gaseous $^{14}CO_2$ and will result in delayed, smaller, and more uniform release rates over time. Therefore larger size perforations could be tolerated while meeting the applicable regulations.

795 **Forecasting behavioral response to a repository from stated intent data.** Easterling, D. (Univ. of Pennsylvania, Philadelphia, PA (United States)); Kunreuther, H.; Morwitz, V. pp. 1540-1547 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

To forecast repository-induced behavior from surveys of behavioral intention, we develop a model of the relation between stated intent and actual propensity. This model relies heavily on the notion of a latent true intent score. We also consider a number of factors that cause true intent to be, on average, a biased indicator of propensity. The forecasting strategy is applied to a survey of convention planners to estimate the proportion of conventions that Las Vegas would lose following various repository scenarios at the Yucca Mountain site.

796 **Payments-Equal-To-Taxes (PETT): An interpretation of Sections 116(c) (3) and 118(b) (4) of the Nuclear Waste Policy Act of 1982, as amended.** Benson, A. (DOE, Washington, DC (United States)); Moore, W.E.; Lesko, R. pp. 1555-1560 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Payments-Equal-To-Taxes (PETT) program breaks new ground in government interaction by creating a tax-like transfer of funds from the federal government to states and local government. The PETT program is one of the financial assistance provisions of the Nuclear Waste Policy Act of 1982, as amended [42 U.S.C. 10101, et seq.] (NWPAA). The NWPAA charges the US DOE with, among other things, the responsibility for investigation of potential sites and for licensing, constructing, and operating a repository for high-level radioactive waste and spent fuel and an MRS facility. The NWPAA also called for financial assistance to the jurisdictions in which the repository and MRS facility are to be located. One of the financial impacts to the jurisdictions would be loss of tax revenue since the Supremacy clause of the Constitution prohibits jurisdictions from taxing the federal government. The objective of the PETT program is to provide payments that will offset this loss. Since the NWPAA authorizes continued site characterization activities only in the state of Nevada, the focus of this paper will be on the PETT program in Nevada. However, the information presented here generally applied to implementation of the program in other states where site characterization activities have been conducted.

797 **Mechanical tunnel excavation in welded tuff.** Sperry, P.E. (Tunnel Construction Consultant, Boulder City, NV (United States)). pp. 1642-1645 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Technical Review Board for the US high-level radioactive waste facility at Yucca Mountain has recommended maximum use of "the most modern mechanical excavation techniques...in order to reduce disturbance to the rock walls and to achieve greater economy of time and cost." Tunnels for the waste repository at Yucca Mountain can be economically constructed with mechanical excavation equipment. This paper presents the results of mechanical excavation of a tunnel in welded tuff, similar to the tuffs of Yucca Mountain. These results are projected to excavation of emplacement drifts in Yucca Mountain using a current state-of-the-art tunnel boring machine (TBM).

798 **A first look at roadheader construction and estimating techniques for site characterization at Yucca Mountain, Nevada.** Neil, D.M. (Neil and Associates Inc., Aurora, CO (United States)); Taylor, D.L. pp. 1646-1651 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Yucca Mountain site characterization program will be based on mechanical excavation techniques for the mined repository construction and development. Tunnel Boring Machines (TBM's), Mobile Miners (MM), Raiseborers (RB), Blind Hole Shaft Boring Machines (BHSB), and Roadheaders (RH) have been selected as the mechanical excavation machines most suited to mine the densely welded and non-welded tuffs of the Topopah Springs and Calico Hills members. Heavy duty RH in the 70 to 100 ton class with 300 Kw cutter motors have been evaluated and formulas developed to predict machine performance based on the rock physical properties and the results of Linear Cutting Machine (LCM) tests done at the Colorado School of Mines (CSM) for Sandia National Labs. (SNL).

799 **New approaches for regional ground-water modeling in southern Nevada.** Turner, A.K. (Colorado School of Mines, Golden, CO (United States)); Kolm, K.E. pp. 852-858 of High level radioactive waste management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1992). pp. 1244 From 3. international high level radioactive waste management (IHLRWM) conference; Las Vegas, NV (United States); 12-16 Apr 1992.

Three-dimensional Geoscientific Information Systems (GSIS) can assist 3-D ground-water modeling of regional aquifer systems in areas with complex geologic and climatic conditions. In such areas, the complexity of the regional ground-water system frequently required the use of a 3-dimensional ground-water modeling approach supported by a true 3-dimensional geologic conceptual model. The ground-water system analysis involves four fundamental modules that are interactive using GSIS: (1) surface and subsurface characterization; (2) hydrogeologic and hydrologic conceptual modeling; (3) ground-water flow and transport modeling; and (4) statistical evaluation and sensitivity analysis. Within the analysis process, GSIS offers: (1) necessary data management and data audit trails; (2) the integration of diverse data sources; (3) rapid development, visualization, and testing of alternative model conceptualizations; and (4) integration with the numerical modeling steps. In addition, different ground-water flow and transport models, in either finite-element or finite-difference format, may be used with GSIS. A multidisciplinary research team is currently applying this approach for regional modeling efforts in southern Nevada, the site of a proposed high-level nuclear

waste repository. Initial studies involve a large area defined as the Death Valley regional ground water basin.

800 Effect of solid-phase selectivity on sorption of cobalt and strontium by zeolitized tuff. Rao, M.P. (Howard Univ., Washington, DC (United States)); Das, P.C.; Honga, E.U.; Helou, A.E. pp. 1587-1592 of High level radioactive waste management: Proceedings. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1992). pp. 1238 From 3. international high level radioactive waste management (IHLRWM) conference; Las Vegas, NV (United States); 12-16 Apr 1992.

It is necessary to have an understanding of the effect of selectivity on the sorptive interaction between solutions containing multiple radionuclides and the host rock of high-level nuclear waste repository. Sorption isotherm for the Co-Sr binary system with Nonscents, a zeolitized volcanic tuff material as the sorbent, was measured using columnar experimental techniques. Results show that Strontium ion is highly favoured on the solid phase at the expense of Cobalt ion. Thermodynamic equilibrium constant for the binary exchange and the solid phase activity coefficients for the two solute ions were computed.

801 Integrated performance assessment model for waste package behavior and radionuclide release. Kossik, R. (Golder Associates Inc., Redmond, WA (United States)); Miller, I.; Cunnane, M. pp. 1786-1793 of High level radioactive waste management: Proceedings. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1992). pp. 1238 From 3. international high level radioactive waste management (IHLRWM) conference; Las Vegas, NV (United States); 12-16 Apr 1992.

Golder Associates Inc. (GAI) has developed a probabilistic total system performance assessment and strategy evaluation model (RIP) which can be applied in an iterative manner to evaluate repository site suitability and guide site characterization. This paper describes one component of the RIP software, the waste package behavior and radionuclide release model. The waste package component model considers waste package failure by various modes, matrix alteration/dissolution, and radionuclide mass transfer. Model parameters can be described as functions of local environmental conditions. The waste package component model is coupled to component models for far-field radionuclide transport and disruptive events. The model has recently been applied to the proposed repository at Yucca Mountain.

802 Characterization of the Topopah spring and Tiva Canyon tuffs at Yucca Mountain. Singh, A. (North Carolina A & T State Univ., Greensboro, NC (United States)); Ilias, S.; Tatterson, G. pp. 1953-1958 of High level radioactive waste management: Proceedings. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1992). pp. 1238 From 3. international high level radioactive waste management (IHLRWM) conference; Las Vegas, NV (United States); 12-16 Apr 1992.

The purpose of this study was to provide effective diffusivity data which permit the calculation of the amount of diffusion of carbon dioxide and iodine through actual samples of Yucca Mountain tuffs. The effective diffusivity data of carbon dioxide and iodine through the tuff samples were determined using a single pellet high temperature diffusion cell as a function of temperature and sample moisture content. The pore structures of the samples were characterized by using a mercury porosimeter, surface area analyzer, scanning electron microscopy, and helium pycnometer. Effective diffusivity data obtained Here of the right order of magnitude. Diffusion took place primarily in the combined Knudsen and bulk diffusion regimes. As expected from these regimes, effective diffusivities varied linearly with temperature in some cases and up to the 3/2 power of temperature in other cases. The effective diffusivities were found to be a function of porosity and mean pore radius. Moisture content had little effect on the effective diffusivity data. Overall, the effects of porosity, mean pore radius, moisture content and temperature were consistent with theory and other data.

803 Scientific basis for nuclear waste management XVI. Materials Research Society symposium proceedings, Volume 294. Interrante, C.G. (ed.) (Nuclear Regulatory Commission, Washington, DC (United States)); Pabalan, R.T. (ed.). 959p. Materials Research Society, Pittsburgh, PA (United States) (1993). Sponsored by USDOE, Washington, DC (United States);Nuclear Regulatory Commission, Washington, DC (United States). From 16. Materials Research Society (MRS) fall meeting; Boston, MA (United States); 30 Nov - 5 dec 1992.

One most significant aspect of this particular symposium is the focus on the scientific basis for management of nuclear waste. Engineering principles and practices are important, but this symposium focuses on the science. The extension and application of engineering "know how" to waste management problems sometimes requires a degree of understanding not normally needed to solve other engineering problems. In materials science, for example, scientific understandings important to long-term behavior may be obtained from (1) characterizations and analyses of the structure and properties of materials, (2) the recognition of advancements needed to ensure performance, and (3) improvements in methods of fabrication and processing. In addition to the materials science topics addressed here (on waste forms, engineered barrier systems, and the near-field environment), the symposium addressed various far-field topics. The proceedings are divided into the following sections: spent fuel; glass and crystalline waste forms; glass performance–mechanisms and models; cementitious materials; container alteration; microbiologically influenced corrosion; near-field interactions; natural analogues; long-term prediction for engineered barriers; performance assessment of engineered barrier systems; radionuclide chemistry and transport; and performance assessment of geological systems. Selected papers are indexed separately for inclusion in the Energy Science and Technology Database.

804 Analysis of evaporation in nuclear waste boreholes in unsaturated tuff. Zhou, W. (Univ. of California, Berkeley, CA (United States)); Chambre, P.L.; Pigford, T.H.; Lee, W.W.L. pp. 439-446 of Scientific basis for nuclear waste management XVI. Interrante, C.G. (ed.); Pabalan, R.T. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1993). pp. 959 From 16. Materials Research Society (MRS) fall meeting; Boston, MA (United States); 30 Nov - 5 dec 1992.

We present an analysis of evaporation in a nuclear waste borehole in unsaturated tuff. In unsaturated tuff, water in contact with a waste container will evaporate due to the difference in vapor pressure between water in a flat film and water held in rock pores with curved interfaces. Decay heat will also enhance evaporation. It is important to study evaporation in a potential geologic repository of nuclear waste in unsaturated rock because the corrosion of waste containers is increased with liquid water. For radionuclides other than

gaseous ones, their release from waste solids requires liquid water.

805 **Oxidative alteration of uraninite at the Nopal I deposit, Mexico: Possible contaminant transport and source term constraints for the proposed repository at Yucca Mountain.** Leslie, B.W. (Southwest Research Institute, San Antonio, TX (United States)); Pearcy, E.C.; Prikryl, J.D. pp. 505-512 of Scientific basis for nuclear waste management XVI. Interrante, C.G. (ed.); Pabalan, R.T. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1993). pp. 959 Contract NRC-02-88-005. From 16. Materials Research Society (MRS) fall meeting; Boston, MA (United States); 30 Nov - 5 dec 1992.

The Nopal I uranium deposit at Pena Blanca, Mexico is being studied as a natural analog of the proposed high-level nuclear waste repository at Yucca Mountain. Identification of secondary uranium phases at Nopal I, and the sequence of their formation after uraninite oxidation, provides insight into the source term for uranium, and suggests that uranophane may control uranium release and transport in a silici, tuffaceous, chemically oxidizing, and hydrologically unsaturated environment. Possible constraints on contaminant transport at Nopal I are derived from the spatial distribution of uranium and from measurements of ^{238}U decay-series isotopes. The analyses indicate that flow of U-bearing fluids was influenced strongly by fracture density, but that the flow of these fluids was not restricted to fractures. Gamma spectroscopic measurements of ^{238}U decay-series isotopes indicates secular equilibrium, which suggests undetectable U transport under present conditions.

806 **Corrosion model validation in high level nuclear package research.** McNeil, M.B. (Nuclear Regulatory Commission, Washington, DC (United States)); Moody, J.B. pp. 549-556 of Scientific basis for nuclear waste management XVI. Interrante, C.G. (ed.); Pabalan, R.T. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1993). pp. 959 From 16. Materials Research Society (MRS) fall meeting; Boston, MA (United States); 30 Nov - 5 dec 1992.

The strategies for waste package (WP) performance validation will be based on site specific geologic and hydrogeochemical information plus models which can be used to predict potential WP lifetimes. The development and application of such models will include the evaluation of natural analogues (NA). These analogues are needed to resolve issues related to the validation of models. Natural analogues have not had extensive use or widespread acceptance in the area of waste package failure prediction. This lack of acceptance is due to the anticipated choice of alloys for waste package containers. Few of these alloys are similar to naturally occurring metals, and the proposed HLW repositories are in general in geologic settings not very similar to those in which naturally occurring metals are generally found. Natural and archaeological analogues can be used, however, in analysis of possible waste package failures as a means of testing proposed models for failure. In fact, the analogues are the only available mechanisms for testing models of long-term waste package behavior. A strategy is outlined for incorporating natural and archaeological analogue studies into waste package research, and examples are discussed. The natural/archaeological analogous approach which appears most promising is to use archaeological and mineral samples to develop an understanding of the identities and rates of the mineral alteration reactions at or near the surface of the package, improving present capability for estimating the lifetimes of metallic waste package containers.

807 **The role of siderophores in the transport of radionuclides.** Hersman, L.E. (Los Alamos National Lab., NM (United States)); Palmer, P.D.; Hobart, D.E. pp. 765-770 of Scientific basis for nuclear waste management XVI. Interrante, C.G. (ed.); Pabalan, R.T. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1993). pp. 959 From 16. Materials Research Society (MRS) fall meeting; Boston, MA (United States); 30 Nov - 5 dec 1992.

Iron exists in aerobic soil and water environments most commonly as insoluble Fe(III). Siderophores are powerful, microbially produced chelating agents that are used to mobilize the insoluble Fe(III) cation. Over 80 siderophores have been isolated and characterized, with some reportedly having iron-binding constants as high as 10^{52}. Fe(III) and Pu(IV) are similar in their charge/ionic radius ratio (4.6 and 4.2, respectively); therefore, Pu(IV) may serve as analog to Fe(III). It is possible that some radioactive wastes could be chelated by naturally occurring siderophores, thereby altering the transport rates of those elements through the subsurface environment. This investigation was initiated to investigate that possibility. The binding of $^{239}(IV)$ by four chelating agents is reported in this paper: a siderophore isolated and purified from a Pseudomonas sp.; desferal, a ferrioxamine siderophore commonly used for deferration therapy; EDTA, ethylenediaminetetraacetic acid; and, citrate, trisodium salt.

808 **Experimental study of uranium(6+) sorption of the zeolite mineral clinoptilolite.** Pabalan, R.T. (Southwest Research Institute, San Antonio, TX (United States)); Prikryl, J.D.; Muller, P.M.; Dietrich, T.B. pp. 777-782 of Scientific basis for nuclear waste management XVI. Interrante, C.G. (ed.); Pabalan, R.T. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1993). pp. 959 From 16. Materials Research Society (MRS) fall meeting; Boston, MA (United States); 30 Nov - 5 dec 1992.

Experiments on the sorption of uranium(6+) on clinoptilolite from solutions in equilibrium with atmospheric $CO_2(g)$ were conducted to understand the fundamental controls on uranium sorption on zeolite minerals, including the effects of pH, aqueous uranium speciation, and uranium concentration in solution. The results indicate that uranium(6+) species are strongly sorbed on the zeolite mineral clinoptilolite at near-neutral pH. The amount of uranium sorbed is strongly dependent on pH and, to some extent, on the total concentration of uranium. Uranium sorption on clinoptilolite is important in the pH range where $UO_2(OH)_2°(aq)$ is the predominant uranium aqueous species, whereas sorption is inhibited at pH's where carbonate- and hydroxy-carbonate-complexes are the primary uranyl species. Surface adsorption appears to be the main sorption mechanism, although at pH<4 the results suggest ion exchange may occur between the UO_2^{2+} ions in solution and the cations in the intracrystalline cation exchange sites of clinoptilolite. The effectiveness of zeolite-rich horizons underneath Yucca Mountain, Nevada, as barriers to actinide transport through sorption processes will depend strongly on groundwater chemistry. Reliable predictions of radionuclide transport through these horizons will need to properly account for changes in solution chemistry.

809 **Iterative performance assessment for the greater confinement disposal facilities: Preliminary results of round two.** Olague, N.E. (Sandia National Labs., Albuquerque, NM (United States)); Conrad, S.H.; Baer, T.A. pp. 899-907 of Scientific basis for nuclear waste management XVI. Interrante, C.G. (ed.); Pabalan, R.T. (ed.). Materials Research Society, Pittsburgh, PA (United States)

(1993). pp. 959 From 16. Materials Research Society (MRS) fall meeting; Boston, MA (United States); 30 Nov - 5 dec 1992.

The Department of Energy's Nevada Operations Office has disposed of a small quantity of transuranic waste at the Greater Confinement Disposal (GCD) facility in Area 5 of the Nevada Test Site. The Environmental Protection Agency standards for disposal of transuranic waste (40 CFR 191) require that a performance assessment be conducted and an iterative approach has been adopted. This approach consists of using performance assessment results to guide the collection of site characterization data, and in turn, new site characterization data is incorporated into each successive iteration of the performance assessment. The results of the first iteration indicated that the GCD site should be able to comply with 40 CFR 191. This paper presents results of the second iteration based on results from site-specific environmental tracer studies. These studies indicate significantly lower recharge values then those used in the first performance assessment iteration. For performance assessment these results imply that the downward ground-water advection pathway may be negligible, and therefore, the upward liquid diffusion pathway becomes more significant. The models and the model parameters that were used to simulate this upward pathway have been refined. The preliminary results from these models still indicate that the GCD facility should be able to comply with the Containment Requirements in 40 CFR 191.

810 Effects of some common geological features on two-dimensional variably saturated flow. Bagtzoglou, A.C. (Southwest Research Institute, San Antonio, TX (United States)); Ababou, R.; Sagar, B.; Islam, M.R. pp. 929-936 of Scientific basis for nuclear waste management XVI. Interrante, C.G. (ed.); Pabalan, R.T. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1993). pp. 959 From 16. Materials Research Society (MRS) fall meeting; Boston, MA (United States); 30 Nov - 5 dec 1992.

This paper presents results of unsaturated flow simulations undertaken as an auxiliary analysis for the Iterative Performance Assessment (IPA) project, one of the approaches adopted by the U.S. NRC to develop repository license application review capabilities. The effects on flow of common geological features, such as nonhorizontal stratification and vertical or near-vertical fault zones intersecting the strata, in a two-dimensional (2D) domain are studied. Results indicate that the presence of layers and crosscutting fault zones tend to induce three-dimensional (3D) unstable flows in the unsaturated zone. The instability is manifested in our simulations by an oscillatory behavior of steady state. This numerical instability imposes extremely stringent criteria on the time step used in the simulation. Finally, once stable steady-state solutions are attained, the effect of the crossing point in the matrix-fault unsaturated hydraulic conductivity curve on groundwater flux vectors and moisture content distributions is studied.

811 High Level Radioactive Waste Management: Proceedings: Volume 1. 1115p. American Nuclear Society, Inc., La Grange Park, IL 60525 (United States) (1993). Sponsored by American Society of Civil Engineers, New York, NY (United States);American Nuclear Society, La Grange Park, IL (United States). From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Individual papers are processed separately for the databases. The theme of the 1993 International High Level Radioactive Waste Management (IHLRWM) Conference, "Sharing Technologies for a Common Need" characterizes the objective of the entire conference series. The common need for all who are involved in high-level radioactive waste management is to find a technically and institutionally acceptable solution for the disposition of spent fuel and high-level waste that protects the public and the environment. High-level radioactive waste management is a multinational concern where every country can benefit from sharing its technology. Each year, the international community becomes more involved in this conference. This year, the fourth IHLRWM conference has 42 participating organizations and 50 papers approved for presentation. Of these, 16 of the organizations and 70 of the papers are from outside of the United States. As more and more of the world's electricity is generated by nuclear power plants, there is a greater need for information exchange and cooperative among countries and various international agencies. Through such cooperation, nations can share information, technology, and experience and a consensus to improve confidence in the safety of each nation's approach to solving its high-level waste management problems. Commenting the signing of two new international agreements in 1992, the former director of the US Department of Energy (DOE) Office of Civilian Radioactive Management (OCRWM), said, "As nuclear waste issues continue to be addressed in numerous countries, international cooperative research and development becomes an increasingly important way to maximize limited resources, build consensus on issues in the radioactive waste management and broaden our technical and institutional knowledge base."

812 Demonstration of a risk-based approach to high-level repository evaluation "Phase II". Shaw, R.A.; McGuire, R.K. pp. 1-5 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

This paper describes modifications to an integrated performance assessment model which is applicable to Yucca Mountain. The areas of modification were selected based on discussions with technical experts to identify the particular technical areas where this model would benefit from strengthening. Our discussions with the experts resulted in four broad classifications in which further exploration looked particularly fruitful and promising. These four areas were waste containment, source term, thermal aspects and hydrological aspects. The basis for these modifications and the process of incorporating these modifications in the models are described.

813 Preliminary assessment of fault rupture hazard at the Yucca Mountain Site based on expert judgement. Coppersmith, K.J. (Geomatrix Consultants Inc., San Francisco, CA (United States)); Youngs, R.R.; Perman, R.C.; Shaw, R.A. pp. 6-13 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The judgements of seven earth science experts were elicited to quantify the uncertainties associated with the likelihood of fault displacement through the proposed repository

at Yucca Mountain during the 10,000 year post-closure period. Each expert identified one or more approaches to modeling fault rupture hazard, regional tectonic models, locations of sources of fault displacement, maximum earthquake magnitudes or maximum coseismic displacement for each source, the likelihood of fault rupture through the repository, and the amount of displacement. The experts generally identified two basic approaches to assessing the hazard: first estimating the location and probability of earthquake occurrence and then the associated fault displacements; and considering only the location and probability of fault displacement directly. A wide variety of tectonic models were some level of credibility, ranging from high-angle planar faults to detachments separating strike-slip faults at depth from normal faults in the shallow crust. Recently acquired geologic data were relied on heavily to estimate the size of past displacements and their recurrence rates. Uncertainties were estimated for each component of the experts' models and the aggregated results are expressed as a probability distribution on the annual frequency of canister failure.

814 **Rainfall and net infiltration probabilities for future climate conditions at Yucca Mountain.** Long, A. (Univ. of Arizona, Tucson, AZ (United States)); Childs, S.W. pp. 112-121 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Performance assessment of repository integrity is a task rendered difficult because it requires predicting the future. This challenge has occupied many scientists who realize that the best assessments are required to maximize the probability of successful repository sitting and design. As part of a performance assessment effort directed by the EPRI, the authors have used probabilistic methods to assess the magnitude and timing of net infiltration at Yucca Mountain. A mathematical model for net infiltration previously published incorporated a probabilistic treatment of climate, surface hydrologic processes and a mathematical model of the infiltration process. In this paper, we present the details of the climatological analysis. The precipitation model is event-based, simulating characteristics of modern rainfall near Yucca Mountain, then extending the model to most likely values for different degrees of pluvial climates. Next the precipitation event model is fed into a process-based infiltration model that considers spatial variability in parameters relevant to net infiltration of Yucca Mountain. The model predicts that average annual net infiltration at Yucca Mountain will range from a mean of about 1 mm under present climatic conditions to a mean of at least 2.4 mm under full glacial (pluvial) conditions. Considerable variations about these means are expected to occur from year-to-year.

815 **Assessment of volcanic and tectonic hazards to high level radioactive waste repositories.** Wallmann, P.C. (Golder Associates Inc., Redmond, WA (United States)); Miller, I.; Kossik, R. pp. 188-195 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Golder Associates Inc. (GAI) has developed a computer program (RIP) for performing probabilistic total system performance assessment and site characterization strategy evaluation which can be applied in an iterative manner to evaluate repository site suitability and to guide characterization activities. The performance assessment model incorporated in RIP has three basic component models: (1) waste package behavior, (2) radionuclide transport pathways, and (3) disruptive events. Classes of disruptive events are specified in RIP by (1) a disruption rate (events/yr.), (2) "event descriptors" which describe event characteristics and magnitude, and (3) the consequences associated with an event. One of the strengths of RIP is its flexibility, which allows it to evaluate different sites and conceptual models. Examples of seismic and volcanic disruptive event models constructed by GAI for Yucca Mountain are presented. Analysis of the results of these models indicates that for the simulated models, neither of these event classes significantly impacts the performance of the proposed repository over a 10,000 year time span.

816 **Groundwater impacts of foreseeable human activities on a HLW repository.** Coleman, N.M. (Nuclear Regulatory Commission, Washington, DC (United States)). pp. 261-264 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Nuclear Regulatory Commission (NRC) staff has begun a program of Systematic Regulatory Analysis (SRA) to help ensure that all important technical issues related to the disposal of civilian, high-level nuclear wastes will be identified prior to the receipt of a license application. Large-scale groundwater withdrawals near a repository could have significant impacts on the groundwater flow system. Future large-scale withdrawals of groundwater could occur to support irrigation to growing population centers, such as Las Vegas. Various scenarios of groundwater withdrawals, along with other scenarios of future human activity, will need to be tested before evaluation of the Yucca Mountain site is complete.

817 **Diffusion of carbon dioxide through layers of the unsaturated zone at Yucca Mountain.** Ali, M.S. (North Carolina A&T State Univ., Greensboro, NC (United States)); Bardakci, T.; Ilias, S.; King, F.G. pp. 412-417 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 Contract C-66611. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The estimation of diffusive transport of gases through tuffs is important in order to assess the Yucca Mountain as an environmentally safe and acceptable repository for spent fuel and high-level radioactive waste. The purpose of this study is to provide effective diffusivity data which may be used to calculate the amount of diffusion of carbon dioxide through Yucca Mountain tuff layers to the environment. The effective diffusivity of carbon dioxide was measured for five tuff samples from different layers of the USW-G4 drillhole, which is located in the central part of the proposed repository horizon. The total depth of the USW-G4 is about 905 m. The tuff samples studied are from the following layers and depths: Vapor Phase (83.6 m), Upper Lithophysal (130.1 m), Middle Nonlithophysal (210.1 m), Lower Lithophysal (297.3 m), and Lower Nonlithophysal (356.3 m). A steady state counter-diffusion method, using gas chromatographic analysis, was used to determine the effective diffusivity of carbon dioxide through tuff samples. The effective diffusivity

increases linearly with temperature between 25°C and 125°C. The effective diffusivity also increases with increasing porosity of the tuffs for all the samples studied except the Vapor Phase tuff. To provide an explanation for low diffusion coefficient of carbon dioxide of Vapor Phase tuff, further study on pore structures and pore inner-connectivity is required. From the limited data of USW-G4 drillhole, it appears that the diffusion takes place primarily in the combined Knudsen and bulk diffusion regimes.

818 **Containment barrier system performance assessment modeling.** Bullen, D.B. (Iowa State Univ., Ames, IA (United States)). pp. 470-477 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

A mathematical model to predict the cumulative failure distribution for the containment barrier system (CBS) employed in a deep geologic disposal facility is presented as a function of near-field environmental conditions. The effects of container design, areal power density, and dominant heat transfer mode on the cumulative container failure distribution are studied. This model has been employed to describe the performance of the CBS as one part of a risk-based performance assessment of the Yucca Mountain site. The model employs Weibull and exponential distributions to describe container failures. Parameter values employed in the model are based upon simple, time-dependent, mechanistic models and relevant corrosion data, which describe failure of individual components of the CBS as a function of environmental conditions. The relative importance of container design, areal power density, and dominant heat transfer mode on predicted container performance is demonstrated through comparison of the results for each container design exposed to each set of environmental conditions.

819 **Mission analysis of the Exploratory Studies Facility.** Duffy, M.A. (Battelle Memorial Institute, Columbus, OH (United States)); Mele, R.; Mozhi, T.A.; Lemeshewsky, W.A.; Truong, T. pp. 515-520 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The mission of the Exploratory Studies Facility (ESF), as interpreted from the Nuclear Waste Policy Act, can be stated succinctly as, ...to conduct subsurface exploration and testing, in support of site suitability determination and license application, in a manner that protects the environment and nuclear waste isolation capabilities of the site. The objective of the ESF mission analysis effort was to expand this general mission statement to the explicit program needs that must be fulfilled by an ESF during the site characterization program. The scope of the ESF mission analysis was limited to the specification of test requirements that must be satisfied by an ESF in support of site characterization and, if the site is determined to be suitable, license application for construction of a geologic repository. The time period covers from initiation of ESF testing through either Presidential recommendation a a geologic repository or Secretarial determination of unsuitability as a geologic repository, whichever comes first. The analysis stems from the requirements contained in the Physical System Requirements (PSR)-Dispose of Waste document and draws upon the extensive technical knowledge behind preparation of the Site Characterization Program Baseline (SCPB).

820 **Using QA classification to guide design and manage risk.** Lathrop, J. (Strategic Insights, Los Altos, CA (United States)); DeKlever, R.; Petrie, E.H. pp. 530-537 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Raytheon Services Nevada has developed a classification process based on probabilistic risk assessment, using accident/impact scenarios for each system classified. Initial classification analyses were performed for the 20 systems of Package 1A of the Exploratory Studies Facility (ESF). The analyses demonstrated a solid, defensible methodological basis for classification which minimizes the use of direct engineering judgment. They provide guidance for ESF design and risk management through the identification of: the critical characteristics of each system that need to be controlled; and the parts of the information base that most need to be further developed through performance assessment or other efforts.

821 **An assessment of coupled thermal-hydrologic-mechanical-chemical processes.** Manteufel, R.D. (Center for Nuclear Waste Regulatory Analyses, San Antonio, TX (United States)); Ahola, M.P.; Turner, D.R.; Chowdhury, A.H. pp. 576-583 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 Contract NRC-02-88-005. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

A literature review was conducted to determine the state of knowledge available in the modeling of coupled thermal (T), hydrologic (H), mechanical (M), and chemical (C) processes relevant to the design and/or performance of the proposed high-level waste (HLW) repository at Yucca Mountain, Nevada. The review focuses on identifying coupling mechanisms between individual processes, and assessing their relative importance (i.e., if the coupling is either important, potentially important or negligible). The significance of considering THMC coupled processes lies in whether or not the processes impact the design and/or performance of the repository. While some of the coupled processes are relatively well characterized, many warrant further investigation. The subjective assessment provided here is based on the current understanding of the processes and data uncertainties, and may have to be modified as new data and information emerge. A review of the state of knowledge, such as reported herein, is considered useful in identifying potential coupling mechanisms and assessing their importance.

822 **Modeling of the ventilation for emplacement drift re-entry and rock drying.** Danko, G. (Univ. of Nevada, Reno, NV (United States)); Mousset-Jones, P. pp. 590-599 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Different ventilation scenarios were analyzed for a hot repository with a 114 Kw/Acre heat load, to determine the

time required to cool a drift to the point where the temperature of the air leaving the drift is at or below 51.66°C (125°F). The results show that it is possible to cool a drift for re-entry within less than three months using a high air flow rate of 94.37 m^3/s (200,000 cfm) at an inlet dry bulb temperature of 26.11°C (79°F), assuming worst-case scenarios. The continuous precooling of the drift with an air flow of 1.415 m^3/s (3,000 cfm) at the same inlet temperature has negligible effect upon drift and air temperatures, assuming dry wall conditions. However, the same precooling results in a significant reduction in the cooling time, to around one week, if a partially wet surface condition is assumed. If the moisture from the partially saturated rock around the drift is removed at a high rate by the ventilating air, assuming 10 percent equivalent wetness and using a continuous precooling air flow rate of 7.08 m^3/s (15,000 cfm) at an inlet temperature of 26.11°C (79°F), the drift will remain accessible. It is also found that cooling the air prior to entering the drift to 18.33°C (65°F) only marginally improves the required cooling time period.

823 **Discontinuities, rock deformation and fluid flow around emplacement rooms.** Yang, G. (Univ. of California, Berkeley, CA (United States)); Cook, N.G.W.; Myer, L.R. pp. 682-688 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

One of the major concerns for the design of the potential nuclear waste repository at Yucca Mountain is how to identify the fast flow paths and how to minimize the flow of the fast paths. To analyze the problem, we take two steps. First, the displacements and deformations of discontinuous rock masses around an underground excavation (emplacement room) must be determined so that increments of fracture width caused by the relaxation process can be estimated. Second, we must identify the fast paths so that proper measures can be taken to minimize or prevent the flow. In this study, a numerical model for rock deformation, Discontinuous Deformation Analysis developed by Shi, is used to accomplish the first task. To meet the second goal, the authors utilized techniques of graph theory to search through all the possible flow paths after rock deformation and highlighted the fast ones. The identification of fast paths may also provide the information needed to minimize the flow, which could lead to potential methods to secure the repository. The simulation results of Travis et al. and some further assumptions have been based to accomplish the analysis. However, the major interest of this study is the methodology to find the fast path, not the fundamentals of vadose zone flow.

824 **Analyses of natural resources in 10 CFR Part 60 as related to inadvertent human intrusion.** Miklas, M.P. (Center for Nuclear Waste Regulatory Analyses, San Antonio, TX (United States)); Lefevre, H.E. pp. 717-723 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The purpose of this paper is to examine the intent of the regulatory language of the portions of 10 CFR Part 60 which deal with considerations of the natural resources of a proposed geologic repository for high-level radioactive wastes as they relate to inadvertent human intrusion. Four Potentially Adverse Conditions (PAC) the requirements of 10 CFR 60.21(c)(13) are shown to be related to natural resources. Groundwater is identified as a natural resource known to be present at Yucca Mountain, Nevada. For economic considerations of natural resources, the "foreseeable future" is thought to be no more than 50 years. Two of the topics addressed by the PACs, subsurface mining and drilling at a proposed repository site, are pre-site-characterization activities which must be evaluated in the context of repository performance criteria set by the US EPA standard, 40 CFR Part 191. An alternative US DOE compliance demonstration to another PAC, 10 CFR 60.122(c)(17), might be to use an "explorationist perspective" of natural resource assessment. The Commission intends for DOE to evaluate the likelihood and consequence of inadvertent human intrusion into a geologic repository as a result of exploration or exploitation of natural resources within or near a proposed high-level radioactive waste geologic repository.

825 **New directions for EPA's high-level waste standards.** Galpin, F.L. (EPA, Washington, DC (United States)); Weinstock, L.G.; Gruhlke, J.M. pp. 724-729 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Recently enacted legislation passed by the 102nd Congress directs a significant change in the EPA's development of standards for spent fuel, high-level and transuranic wastes. The Waste Isolation Pilot Plant (WIPP) Land Withdrawal Act (PL 102-579) reinstates the major part of EPA's 40 CFR 191 radiation standards as promulgated in 1985. It further requires that EPA promulgate a final complete standard in six months and gives the EPA a major role in overseeing the WIPP's testing, design, and operation. The Energy Policy Act (PL 102-486) prescribes a procedure for EPA to follow in setting radiation standards for the Yucca Mountain site. This process requires contracting with the National Academy of Sciences and developing standards consistent with their findings and recommendations.

826 **EEI/UWASTE oversight of the DOE Repository Program by the Repository Information Exchange Team.** Henkel, C.J. (Edison Electric Institute, Washington, DC (United States)); Supko, E.M.; Schwartz, M.H. pp. 741-746 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Utility Nuclear Waste and Transportation Program of the Edison Electric Institute (EEI/UWASTE) has conducted reviews of the US DOE's repository program through its Repository Information Exchange Team (RIET or Team). Eight such reviews have been conducted since 1985 covering topics that include repository program management and control; repository schedule; repository budget; quality assurance; site characterization; repository licensing; environmental issues; and institutional and public information activities. The utility industry has used these repository program reviews as a forum for providing DOE's Office of Civilian Radioactive Waste Management (OCRWM) with comments on the direction of the repository program, advice for future actions regarding quality assurance activities and repository licensing, and suggestions for management and

control of the Repository Program. The most significant recommendations made by the utility industry through the RIET are discussed along with any subsequent action by OCRWM in response to or subsequent to utility industry recommendations. The process used by the RIET to develop its recommendations to OCRWM regarding the repository program is also discussed.

827 **Evaluating soil moisture and hydraulic conductivity in semi-arid rangeland soils.** Whitaker, M.P.L. (Univ. of Arizona, Tucson, AZ (United States)). pp. 930-936 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 Grant I-1486-88. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The US DOE's Office of Civilian Radioactive Waste Management (DOE-OCRWM) Fellowship Program supports various disciplines of academic research related to the isolation of radionuclides from the biosphere. The purpose of this paper is to provide an example of a university research application in the specific discipline of hydrology and water resources (a multi-disciplinary field encompassing engineering and the earth sciences), and to discuss how this research pertains to the objectives of the DOE-OCRWM Fellowship Program. The university research application is twofold: One portion focuses on the spatial variability of soil moisture (θ) and the other section compares point measurements with small watershed estimates of hydraulic conductivity (K) in a semi-arid rangeland soil in Arizona. For soil moisture measurements collected over a range of horizontal sampling intervals, no spatial correlation was evident. This outcome is reassuring to computer modelers who have assumed no spatial correlation for soil moisture over smaller scales. In regard to hydraulic conductivity, point measurements differed significantly from small watershed estimates of hydraulic conductivity which were derived from a calibrated and verified rainfall-runoff computer model. The estimates of saturated hydraulic conductivity (Ks) were obtained from previous computer simulations in which measured data was collected in the same research location as the present study.

828 **A formal communication process: Pathway to improved policy making.** Benson, A. (DOE, Washington, DC (United States)); Robison, A.C.; Seidler, P.E. pp. 986-994 of High Level Radioactive Waste Management: Proceedings. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1115 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

This paper will examine the efforts made and the steps taken by the US DOE's Office of Civilian Radioactive Waste Management (DOE/OCRWM) to establish and keep open lines of communication with officials in Nye County, Nevada, the location of Yucca Mountain, the site of a proposed high-level nuclear waste repository. These efforts include creating policies and procedures for conducting oversight of the Yucca Mountain Site Characterization Project (YMP), as well as developing programs for engaging in technical studies, requests for impact assistance and financial assistance, and ensuring there's a continuous flow of information to the residents of Nevada.

829 **Nuclear Regulatory Commission staff development of the license application review plan for a high-level radioactive waste repository.** Johnson, R.L. (Nuclear Regulatory Commission, Washington, DC (United States)); Holonich, J.J.; Lee, M.P.; Delligatti, M.S. pp. 1243-1247 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Nuclear Regulatory Commission staff has recently started a new initiative to develop the License Application Review Plan (LARP) which the staff will use in its reviews of the U.S. Department of Energy's (DOE's) license application (LA) for a geologic repository for the disposal of high-level radioactive waste (HLW). This paper describes the staff's approach for developing the LARP, the development schedule and current status, the organization and content of the LARP, and the staff's LA review strategy. Therefore, it gives a preview of the draft LARP which will be made available in late 1993. It also describes how the LARP will be used as guidance to the staff in conducting reviews of regulatory and technical issues important to the licensing of a geologic repository. Finally, the benefits to the NRC staff, DOE, and other parties are discussed.

830 **Geologic repository licensing strategy.** Berkowitz, L. (Civilian Radioactive Waste Management System, Washington, DC (United States)); Stern, M.E.; Roberts, J.P.; Desell, L.J. pp. 1248-1251 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The U.S. Department of Energy Office of Civilian Radioactive Waste Management's objective is to characterize and determine the suitability of the Yucca Mountain site and, if this site is found suitable, obtain authorization from the U.S. Nuclear Regulatory Commission to construct, operate, and eventually close a geologic repository at that site. The Department's licensing strategy involves the application of a process, the licensing process, that addresses the achievement of each of the elements of this objective. The applicable laws and regulations with which the Department must comply, including the Nuclear Waste Policy Act, as amended, the Energy Policy Act of 1992, the Atomic Energy Act of 1954, the National Environmental Policy Act, and the administrative Procedure Act, provide insights into what DOE must do if it is to achieve its objective. The Department's licensing strategy, discussed in this paper, is based on these insights.

831 **Modelling adsorption of mixtures of radionuclides by zeolitized tuff.** Rao, M.G. (Howard Univ., Washington, DC (United States)). pp. 1496-1503 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Multi-solute sorption isotherms were measured using 'Nonscents', a zeolited volcanic tuff material from Southeast Arizona. Isotherms for the three constituent binaries, Sr-Co, Cs-Sr and Cs-Co in the ternary system Cs-Sr-Co were obtained using a columnar flow technique. Results clearly show that sorbent-phase selectivity has considerable effect on the sorption process. Presence of cesium in the mixture considerably reduced the expected retardation of solutes Sr and Co in the tuff material. Cobalt is the least favored ion of

the ternary system on the sorbent phase. The isotherms were correlated with ion-exchange phase equilibrium model. Equilibrium constants for the three binary pairs, and the sorbent phase ionic activity coefficients were calculated. Triangle rule of the ion exchange phase equilibria has been validated for the Cs-Co-Sr Nonscents system. Sorbent phase selectivities for the ternary system have been successfully predicted for an experimental run.

832 **Research at Howard University on retardation of radionuclides by sorption processes during host rock–ground water interactions.** Rao, M.G. (Howard Univ., Washington, DC (United States)). pp. 1520-1526 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

As stated in a federal law the Nuclear Waste Policy Act, the U.S. Department of Energy (DOE) is responsible for locating a geologic repository for high-level nuclear waste. Among the three sites approved for intensive site characterization studies, many scientists consider the Yucca Mountain, Nevada site more suitable for a nuclear waste repository. A large number of scientists drawn from national laboratories, U.S. Geological Survey, and many private companies are intensively involved in studies that will determine if Yucca Mountain can be recommended as a high-level nuclear waste repository. The DOE is required to prove that the proposed repository will be safe for a period of 10,000 years. Though a multiple barrier approach will be used in the design of the repository, the host rock of the repository itself must provide sufficient retardation to radionuclide migration via sorption processes. To prove the host rock is capable of such retardation, one needs to understand the sorption mechanism of various radionuclides in constituent minerals of the host rock. Mathematical models that describe these sorption processes need to be developed and validated with experimental observations, and these models will be coupled to transport models to demonstrate retardation of radionuclides under flow conditions.

833 **Modeling of saturated zone at Yucca Mountain, Nevada.** Ahola, M.P. (SwRI/CNWRA, San Antonio, TX (United States)); Sagar, B. pp. 1602-1608 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 Contract NRC-02-88-005. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

This paper presents preliminary results of groundwater modeling of the saturated zone in the vicinity of Yucca Mountain. The analysis used both a regional (approximately 250 x 250 km) and subregional (50 x 50 km) finite difference model. Numerical simulations were conducted to determine the impact of various disruptive conditions that might take place over the life span of a potential repository located beneath Yucca Mountain on the saturated groundwater flow field, as well as changes in the watertable elevations. These conditions included increases in precipitation and groundwater recharge within the regional model, changes in permeability of existing hydrogeologic barriers, and the vertical intrusion of volcanic dikes at various orientations through the saturated zone. Based on the regional analysis, the rise in the water-table in the vicinity of Yucca Mountain due to various postulated conditions ranged from only a few meters to over 200 m in certain cases. The increase in evapotranspiration and surface runoff as the water table rises was neglected in this analysis. Results of the subregional model analysis, which was used to simulate intrusive dikes approximately 4 km in length in the vicinity of Yucca Mountain, showed water-table rises ranging from a few meters to as much as 103 m. Dikes oriented approximately north-south beneath Yucca Mountain produced the highest water-table rises. Some of the results from both the regional and subregional analysis are presented in this paper. A more complete discussion of the results and details of the analysis is given in a recent report by Ahola and Sagar.

834 **Geometric analysis of alternative models of faulting at Yucca Mountain, Nevada.** Young, S.R. (Center for Nuclear Waste Regulatory Analysis, San Antonio, TX (United States)); Stirewalt, G.L.; Morris, A.P. pp. 1818-1825 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 Contract NRC-02-88-005. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Realistic cross section tectonic models must be retrodeformable to geologically reasonable pre-deformation states. Furthermore, it must be shown that geologic structures depicted on cross section tectonic models can have formed by kinematically viable deformation mechanisms. Simple shear (i.e., listric fault models) is consistent with extensional geologic structures and fault patterns described at Yucca Mountain, Nevada. Flexural slip models yield results similar to oblique simple shear mechanisms, although there is no strong geological evidence for flexural slip deformation. Slip-line deformation is shown to generate fault block geometrics that are a close approximation to observed fault block structures. However, slip-line deformation implies a degree of general ductility for which there is no direct geological evidence. Simple and hybrid 'domino' (i.e., planar fault) models do not adequately explain observed variations of fault block dip or the development of 'rollover' folds adjacent to major bounding faults. Overall tectonic extension may be underestimated because of syn-tectonic deposition (growth faulting) of the Tertiary pyroclastic rocks that comprise Yucca Mountain. A strong diagnostic test of the applicability of the domino model may be provided by improved knowledge of Tertiary volcanic stratigraphy.

835 **Micromechanics of deformation in Topopah Spring tuff, Yucca Mountain, Nevada.** Wang, R. (Univ. of Arizona, Tucson, AZ (United States)); Kemeny, J.M. pp. 1873-1879 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 Grant MSS9022381. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Samples of Topopah Spring tuff from Yucca Mountain, Nevada have been tested and analyzed. Laboratory tests conducted include standard uniaxial and triaxial compression tests and special 'damage' tests in which samples are loaded to some proportion of their strength and analyzed with SEM microscopy. Based on the SEM analysis of the damaged samples, the micromechanics of rock deformation and failure in Topopah Spring tuff is determined. The results indicate that pores are the major initial microstructures in Topopah Spring tuff. Also, several mechanisms have been

found for microcracking under compressive stresses, including pore cracking, the linking of pore cracks, and the formation of en echelon arrays of axial cracks. The macroscopic cracks tend to propagate in the locations with the highest pore density. The final failure of Topopah Spring tuff is due to shear localization near the peak stress. The microbuckling of crack-induced columns has been found to be the major mechanism for inducing shear localization. The heating of Topopah Spring specimens up to 200°C results in no significant microcracking.

836 **Core and reaming bit studies in Yucca Mountain tuffs.** Gertsch, R.E. (Earth Mechanics Institute, Golden, CO (United States)); McCormick, J.F.; Wright, E.L. pp. 1880-1884 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 Contract YM-92-600. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Site Characterization Project is a major part of the work in determining the suitability of Yucca Mountain as a potential high level waste repository. Over 100 exploratory drill holes for the Project will be drilled in order to limit contamination of the in-situ rock formations. Dry drilling is not a common practice and drill bits suitable for the application need to be developed. To increase penetration rate and bit life, the Department of Energy (DOE) instituted an extensive drilling program at the Colorado School of Mines (CSM) to test and evaluate full sized core and reaming bits. Current test results of the on-going program show that drill bits with aggressive profiles perform best. Stratapac core bits outperform small diamond bits. The gage areas need improvement. Core bits fail first at the outer gage, while the rest of the bit remains relatively intact. Alternating cone reamer designs perform better than designs with all cones facing inward, because they drill the inner gage core hole more effectively.

837 **Tourist visitation impacts of the accident at Three Mile Island.** Himmelberger, J.J. (Clark Univ., Worcester, MA (United States)); Ogneva-Himmelberger, Y.A.; Baughman, M.L. pp. 1904-1910 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

This paper analyzes tourist visitation impacts of the March 27, 1979 accident at Three Mile Island. A review of the literature, supplemented with recollections from Pennsylvanian public officials, are used to specify a conventional tourism impact model which holds that depressed 1979 summer tourism season was more influenced by gasoline shortages and possibly other confounding variables (such as rainy local weather conditions and a polio outbreak) than by the nuclear accident. Regression analysis using monthly visitation data for Hershey Chocolate World, Gettysburg National Park, The Pennsylvania Dutch Convention and Visitor Bureau, and several state parks as dependent variables provide support for this model. Potential tourism implications of an accident at Yucca Mountain are briefly discussed in light of our findings.

838 **Assessing fault rapture hazard for the proposed repository at Yucca Mountain, Nevada: Demonstration of a methodology using expert judgements.** Perman, R.C. (Geomatrix Consultants, Inc., San Francisco, CA (United States)); Coppersmith, K.J.; Youngs, R.R.; Shaw, R.A. pp. 2086-2091 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

As part of the Electric Power Research Institute's High Level Waste (EPRI HLW) performance assessment, we have developed and demonstrated a methodology to estimate the magnitude and likelihood of earthquake-related fault rupture that could affect the proposed high-level waste repository at Yucca Mountain. A panel of seven earth sciences experts was selected to develop estimates of the probability of fault displacement through the repository, as well as to quantify the uncertainties associated with the assessment. A series of technical workshops focusing on the issues and involving expert judgement elicitation were conducted. Each expert was individually interviewed to elicit his judgement regarding the technical issues and to provide the technical basis for his assessment. The study illustrates a methodology for quantifying uncertainties associated with a complex technical issue that has been the subject of diversity of opinion.

839 **Scientific basis for nuclear waste management XVII.** Materials Research Society symposium proceedings, Volume 333. Barkatt, A. (ed.) (Catholic Univ. of America, Washington, DC (United States)); Van Konynenburg, R.A. (ed.). 964p. Materials Research Society, Pittsburgh, PA (United States) (1994). Sponsored by USDOE, Washington, DC (United States);Nuclear Regulatory Commission, Washington, DC (United States). From Fall meeting of the Materials Research Society (MRS); Boston, MA (United States); 29 Nov - 3 dec 1993.

The 17th Materials Research Society Symposium on the Scientific Basis for Nuclear Waste Management included 17 sessions, during which 120 papers were presented by scientists from 16 countries. The nuclear waste glass overview surveyed achievements to date and identified issues requiring further research. The objectives and limitations session noted the progress that has been made in developing a scientific basis for nuclear waste management, but questioned whether regulations calling for detailed predictions over a period of 10,000 years are either necessary or capable of being satisfied. The other papers presented at the Symposium described the progress of studies in a broad array of areas of nuclear waste science and technology. These areas included radiation effects and gas generation, ceramic materials, cementitious materials, actinides spent fuel, glass processing and properties, glass leaching, dissolution and alteration, natural and ancient analogues, transuranic wastes and special topics, sorption mechanisms, repository studies, geochemistry and hydrology, containers, and backfill materials. Several novel experimental techniques were described, as well as advances in modeling. An encouraging feature of the progress in modeling is that the agreement between calculated results based on models developed, refined and tested in the US and in other countries on one hand, and experimental data on the other, shows considerable improvement. This reflects greater understanding of the mechanisms involved in the release of radionuclides from the various components of the waste repository system, including the wasteforms themselves. Selected papers are indexed separately for inclusion in the Energy Science and Technology Database.

840 XPS and XRD studies of samples from the natural fission reactors in the Oklo uranium deposits. Sunder, S. (Whiteshell Research Labs., Manitoba (Canada)); Miller, N.H.; Duclos, A.M. pp. 631-638 of Scientific basis for nuclear waste management XVII. Barkatt, A. (ed.); Van Konynenburg, R.A. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1994). pp. 964 From Fall meeting of the Materials Research Society (MRS); Boston, MA (United States); 29 Nov - 3 dec 1993.

Mineral samples from the natural fission reactors 10 and 13 in the Oklo uranium deposits were studied using X-ray photoelectron spectroscopy (XPS) and X-ray diffraction (XRD) to gain information about the long-term behaviour of UO_2 fuel in a geological disposal vault. Two samples from reactor zone 10 (samples No. D81N-190292 and D73-88) and one sample from reactor zone 13 (sample No. SD37-S2/CD) were analysed. Low-resolution XPS spectra were recorded to determine the major elements present in the ore. High-resolution spectra were recorded to gain information about the chemical state of the elements present in the mineral samples. The samples show low values for the U^{6+}/U^{4+} ratio. The oxidation state of uranium in these samples is even lower than that in U_4O_9.The binding energies of the Pb 4f bands indicate most of the Pb is in the +2 oxidation state in these samples. The C ls band indicates the presence of organic carbon. XRD analysis shows that the main uranium-bearing phase is uraninite and lead is present mainly as galena. The significance of the results for nuclear fuel waste management is discussed.

841 Preliminary analysis of potential chemical environments inside failed waste containers at the proposed Yucca Mountain repository. Colten-Bradley, V. (Nuclear Regulatory Commission, Rockville, MD (United States)); Walton, J.C. pp. 755-760 of Scientific basis for nuclear waste management XVII. Barkatt, A. (ed.); Van Konynenburg, R.A. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1994). pp. 964 From Fall meeting of the Materials Research Society (MRS); Boston, MA (United States); 29 Nov - 3 dec 1993.

Prediction of radionuclide release rates for high-level waste requires estimates of the rates of waste form alteration and formation of secondary minerals inside the failed canister. Unsaturated repository sites may promote development of a variety of chemical environments related to two phase (liquid/vapor) transport and temperature gradients caused by radiogenic decay. A mass balance (shell balance) approach is used to estimate the effects of dripping water, evaporation, and condensation on the waste canister and the presence of saline water inside the failed waste canister. The simplified calculations predict large variability of water chemistry over spatial scales of a few centimeters. The effects of the predicted aqueous chemistry on waste form alteration, secondary mineral formation, and radionuclide solubility are examined.

842 Diffusive transport of carbon dioxide through USW-G4 Topopah Spring Tuffs. Ali, M.S. (North Carolina AT&T State Univ., Greensboro, NC (United States)); King, F.G.; Ilias, S. pp. 827-834 of Scientific basis for nuclear waste management XVII. Barkatt, A. (ed.); Van Konynenburg, R.A. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1994). pp. 964 Contract C-66611. From Fall meeting of the Materials Research Society (MRS); Boston, MA (United States); 29 Nov - 3 dec 1993.

The estimation of diffusive transport of gases through tuffs is important in order to assess whether Yucca Mountain is an environmentally safe and acceptable repository for high-level radioactive waste. The purpose of this study is to provide effective diffusivity data which may be used to calculate the amount of diffusion of carbon dioxide through Yucca Mountain tuff layers to the environment. The effective diffusivity of carbon dioxide was measured for tuff samples from five different layers of the USW-G4 drillhole, which is located in the central part of the proposed repository horizon. The tuff samples studied are from the following layers and depths: Vapor Phase (83.6 m), Upper Lithophysal (130.1 m), Middle Nonlithophysal (224.5 m), Lower Lithophysal (243.9 m, 266.9 m, 297.3 m and 335.2 m), and Lower Nonlithophysal (356.3 m and 371.0 m). A steady-state, counter-diffusion method, using gas chromatographic analysis, was used to determine the effective diffusivity of carbon dioxide through tuff samples. Effective diffusivity increased with temperature between 25°C and 125°C for all layers. The effect of temperature on diffusivity correlated well using second-order polynomials. The porosity, specific surface area and mean pore radius were also determined. In general, diffusivity increased with porosity, specific surface area and mean pore radius, but did not correlate well. From the measured data, it appears that the diffusion takes place primarily in the combined Knudsen and bulk diffusion regimes.

843 Probabilistic calculations of groundwater travel time in heterogeneous three-dimensional porous media. Bagtzoglou, A.C. (Southwest Research Institute, San Antonio, TX (United States)); Baca, R.G. pp. 849-854 of Scientific basis for nuclear waste management XVII. Barkatt, A. (ed.); Van Konynenburg, R.A. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1994). pp. 964 Contract NRC-02-88-005. From Fall meeting of the Materials Research Society (MRS); Boston, MA (United States); 29 Nov - 3 dec 1993.

Groundwater travel time (GWTT) estimation at a potential high-level waste (HLW) repository is subject to various technical uncertainties. These uncertainties stem from model and data uncertainties and cannot be resolved with field tests because of the long time (>1,000 yr) and large space (>5,000 m) scales involved. Therefore, computational methods for demonstrating and determining compliance with the GWTT rule will be used. Stochastic theory based approaches constitute a natural framework for performing GWTT estimations under conditions of uncertain and/or limited data. This study employs the generation of spatially correlated hydraulic conductivity fields by the Nearest Neighbor Model (NNM). Repeated (Monte Carlo) realizations of the statistically equivalent random fields are obtained, and the saturated steady-state groundwater flow equation is solved. These results are then used to estimate GWTT along particular paths by releasing a large number of water particles at various starting points. By doing so, path variability is sampled through the realization ensemble space and also through the independent particle "flights" within a specific flow field realization. The uncertainty in predicted GWTT due to parameter variability is assessed for a data set characteristic of the saturated zone at Yucca Mountain at three levels of parameter heterogeneity. However, since several parameters and the boundary conditions of the problem have been arbitrarily assumed, direct conclusions regarding the proposed Yucca Mountain site cannot be drawn from this study.

844 Performance assessment modeling of a multipurpose container. Bullen, D.B. (Iowa State Univ., Ames,

IA (United States)). pp. 869-880 of Scientific basis for nuclear waste management XVII. Barkatt, A. (ed.); Van Konynenburg, R.A. (ed.). Materials Research Society, Pittsburgh, PA (United States) (1994). pp. 964 From Fall meeting of the Materials Research Society (MRS); Boston, MA (United States); 29 Nov - 3 dec 1993.

A mathematical model to predict the cumulative failure distribution for the engineered barrier system employed in a deep geologic disposal facility as a function of container design and near-field environmental conditions has been developed. The model employs Weibull and exponential distributions to describe cumulative container failures as a function of time. Parameter values employed in the model are based upon simple, time-dependent, mechanistic models and relevant corrosion data, which describe failure of individual components of the container as a function of environmental conditions. Recent developments in container design for the Yucca Mountain site center on the possible deployment of Multi-Purpose Containers (MPC). These containers will be designed and constructed to serve as transport casks, interim storage containers, and disposal containers. The current container performance assessment model is applied to evaluate the long-term performance of various MPC designs under the areal power density and heat transfer regimes expected in the Yucca Mountain environment. This model has previously been employed to describe the performance of the container as one part of a risk-based performance assessment of the Yucca Mountain site. The relative importance of container design, areal power density, and dominant heat transfer mode on predicted MPC performance is demonstrated through comparison of the cumulative container failure distributions for each MPC design when exposed to expected Yucca Mountain environmental conditions.

845 (CONF-940225–Vol.1) **Technology and programs for Radioactive Waste Management and Environmental Restoration. Volume 1.** Post, R.G. (ed.) (Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines). Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines; New Mexico State Univ., University Park, NM (United States); Waste-Management Education and Research Consortium (WERC), Las Cruces, NM (United States); USDOE, Washington, DC (United States). ©1994. 814p. Sponsored by USDOE, Washington, DC (United States). From Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994. Source: Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States).

This report discusses research and development programs dedicated to the management of the wastes and remediation of the environment. Topics discussed include: international programs; remedial action; clean up of uranium mines and mills; radioactive waste disposal; progress of the Yucca Mountain Project; and underground radioactive waste storage tank safety. This is the leading abstract, individual papers have been indexed individually for the databases.

846 (CONF-940225–Vol.1, pp. 781-785) **Environmental release of carbon-14 gas from a hypothetical nuclear waste repository.** Lehto, M.A. (Rogers & Associates Engineering Corporation, Salt Lake City, UT (United States)); Merrell, G.B. Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines; New Mexico State Univ., University Park, NM (United States); Waste-Management Education and Research Consortium (WERC), Las Cruces, NM (United States); USDOE, Washington, DC (United States). 1994. From Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994. In *Technology and programs for Radioactive Waste Management and Environmental Restoration. Volume 1.* 814p. Source: Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States).

Radioisotopes may form gases in a spent nuclear fuel waste package due to elevated temperatures or degradation of the fuel rods. Radioactive carbon-14, as gaseous carbon dioxide, is one of the gaseous radioisotopes of concern at an underground disposal facility for spent nuclear fuel and high-level radioactive waste. Carbon-14 dioxide may accumulate inside an intact waste container. Upon breach of the container, a potentially large pulse of carbon-14 dioxide gas may be released to the surrounding environment, followed by a lower, long-term continuous release. If the waste were disposed of in an unsaturated geologic environment, the carbon-14 gas would begin to move through the unsaturated zone to the accessible environment. This study investigates the transport of radioactive carbon-14 gas in geologic porous media using a one-dimensional analytical solution. Spent nuclear fuel emplaced in a deep geologic repository located at a generic unsaturated tuff site is analyzed. The source term for the carbon-14 gas and geologic parameters was obtained from previously published materials. The one-dimensional analytical solution includes diffusion, advection, radionuclide retardation, and radioactive decay terms. Two hypothetical sites are analyzed. One is dominated by advective transport, and the other is dominated by diffusive transport. The dominant transport mechanism at an actual site depends on the site characteristics. Results from the simulations include carbon-14 dioxide travel times to the accessible environment and the total release to the environment over a 10,000-year period. The results are compared to regulatory criteria.

847 (CONF-940225–Vol.2, pp. 1187-1191) **Whatever became of 40 CFR Part 191?.** Clark, R.L.; Gruhlke, J.M.; Cameron, T.C. Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines; New Mexico State Univ., University Park, NM (United States); Waste-Management Education and Research Consortium (WERC), Las Cruces, NM (United States); USDOE, Washington, DC (United States). 1994. From Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994. In *Technology and programs for Radioactive Waste Management and Environmental Restoration. Volume 2.* 750p. Source: Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States).

In 1985, the United States Environmental Protection Agency issued 40 CFR Part 191, Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes. These standards set the levels of exposure and release, for the United States, which are permitted in the general environment as a result of the management and disposal of the subject wastes. Those standards were challenged in Federal court and, in 1987, the disposal portion of the standards were remanded to the Agency. Since then, the Agency has worked toward reestablishing the standards. In October 1992, the Waste Isolation Pilot Plant Land Withdrawal Act reinstated most of the disposal standards in Part 191 and established a short time period for reestablishment of the entirety of the disposal standards. The Agency proposed new sections on February 10, 1993; the final sections were published in the December 20, 1993 Federal Register.

The Agency has limited annual individual doses to 150 microsieverts committed effective dose received through all pathways. Also, for underground sources of drinking water, there is an annual limit of four microsieverts committed effective dose received from beta- and gamma-emitting radionuclides transported through the ground-water pathway and separate concentration limits on alpha-emitting radionuclides. While not a standard, another important aspect of this rulemaking was the Agency responding to a Court direction to further consider the question of whether geologic repositories are a form of underground injection; the Agency has decided that they are not. Also, in October 1992, the Energy Policy Act was enacted. Section 801 directed the Agency to contract with the National Academy of Sciences (NAS) to conduct a study to provide findings and recommendations on standards for protection of the public health and safety from radioactive materials in the repository at Yucca Mountain.

848 (CONF-940225--Vol.2, pp. 1193-1197) **Issues and impacts of the repromulgation of 40 CFR Part 191.** Brocoum, S.; Bower, B.; Regnier, E. Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines; New Mexico State Univ., University Park, NM (United States); Waste-Management Education and Research Consortium (WERC), Las Cruces, NM (United States); USDOE, Washington, DC (United States). 1994. From Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994. In *Technology and programs for Radioactive Waste Management and Environmental Restoration. Volume 2.* 750p. Source: Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States).

Legislation in 1992 has resulted in the Environmental Protection Agency's (EPA) standards for disposal of high-level and transuranic radioactive waste, 40 CFR 191, being repromulagated with significant changes to some sections while revision of other sections was not considered. Concurrent legislation directed that separate standards with a different basis be developed for any repository at the Yucca Mountain site. There are many issues which are being addressed in the context of a compliance criteria rulemaking for 40 CFR 191, and, for the Yucca Mountain site, by a National Academy of Sciences Committee.

849 (CONF-940225--Vol.3, pp. 1715-1718) **A multiple-method approach to flood assessment at a low-level radioactive waste site in southern Nevada.** Miller, J.J. (Raytheon Services Nevada, Las Vegas, NV (United States)); Gustafson, D.L.; Schmeltzer, J.S. Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines; New Mexico State Univ., University Park, NM (United States); Waste-Management Education and Research Consortium (WERC), Las Cruces, NM (United States); USDOE, Washington, DC (United States). 1994. From Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994. In *Technology and programs for Radioactive Waste Management and Environmental Restoration. Volume 3.* 857p. Source: Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States).

Flood hazard analysis on alluvial fans using Federal Emergency Management Agency (FEMA) method are not limited to the FEMA Alluvial Fan Methodology (FEMA AFM). Flood hazard delineations using a combination of methods provide a more thorough assessment that using only the FEMA AFM. Other FEMA-accepted methods, such as the HEC-2 model for shallow concentrated flow and the Manning Equation for sheetflow, may be more appropriate. A flood assessment using a multiple-method approach was performed to determine the 100-year flood hazard in this arid region. Understanding the limitations and assumptions of these methods is important to determine which method is applicable and when a method can provide reasonable results.

850 (CONF-940225--Vol.3, pp. 1909-1917) **Illustrative probabilistic biosphere model for Yucca Mountain individual risk calculations.** Wilems, R.E. (Del Mar Consulting, Corpus Christi, TX (United States)). Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines; New Mexico State Univ., University Park, NM (United States); Waste-Management Education and Research Consortium (WERC), Las Cruces, NM (United States); USDOE, Washington, DC (United States). 1994. From Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994. In *Technology and programs for Radioactive Waste Management and Environmental Restoration. Volume 3.* 857p. Source: Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States).

The proposed EPA Standards for the disposal of spent fuel, high-level and transuranic radioactive waste prescribe future biosphere--one in which no sustained human activity occurs inside the controlled zone, yet sustained use of groundwater occurs just outside the controlled zone boundary. Performance assessments have generally assumed a person at this location extracts all his water needs directly from the projected contaminated plume for all of his life. Dose to this maximally-exposed individual is too conservative a measure of performance for a nuclear waste repository and does not reflect the isolation characteristics of a site. A better measure is individual risk in which uncertainties in biosphere characteristics for the longer periods of performance, for a site like Yucca Mountain only those characteristics associated with well water scenarios need be prescribed. Such a prescription of the biosphere is appropriate because the goal of the regulations is to provide indicators of future performance so the regulators can make a responsible decision regarding reasonable assurance of public health and safety.

851 (CONF-940225--Vol.3, pp. 1925-1931) **Bridging the gap between performance assessment and data collection for waste disposal systems: A proposed approach using genetic algorithms.** Bonano, E.J. (Beta Corporation International, Albuquerque, NM (United States)); Thies, J.A. Arizona Univ., Tucson, AZ (United States). Coll. of Engineering and Mines; New Mexico State Univ., University Park, NM (United States); Waste-Management Education and Research Consortium (WERC), Las Cruces, NM (United States); USDOE, Washington, DC (United States). 1994. From Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994. In *Technology and programs for Radioactive Waste Management and Environmental Restoration. Volume 3.* 857p. Source: Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States).

Iterative performance assessment (PA) has been generally accepted as the preferred method for identifying sources of uncertainty in performance measure(s) prescribed by regulations governing the disposal of radioactive wastes. Once the important sources of uncertainty have been identified and ranked in order of relative importance,

(e.g., those that have the highest impact on the uncertainty) this information can be used to select data-collection strategies that can be used to gather the additional data necessary to resolve those uncertainties. In principle, this is a well-founded concept; however, it has seen little successful application on repository programs. There are two reasons for this lack of success. First, current iterative PA's are tailored for dealing with parameter uncertainties only. Other, perhaps more important sources of uncertainty, such as model uncertainty are not effectively addressed. It can be argued that parameter uncertainties cannot be determined with certainty if the models' validity has not been established. Second, even if parameter uncertainties have been determined, there are other factors, such as technical feasibility and public acceptability of the experiments, that need to be taken into account before developing practical guidance for data collection and data quality objectives. The use of genetic algorithms (GA's) appears to be a promising tool that can be applied to iterative PA to overcome the aforementioned limitations. GA's are search and optimization techniques that emulate the evolution, over several generations, of natural systems in the solution of complex problems. Although GA's have not been applied to PA, past experiences in solving complex engineering problems using GA's have generated very encouraging results. GA's seem to have the necessary attributes for addressing difficult technical and regulatory issues, such as the resolution of conceptual model uncertainty.

852 **The long term radioactive storage alternative.** Draffin, C.W. Jr. (BDM Federal, Inc., Germantown, MD (United States)); Little, R.G.; Blauvelt, R. pp. 13-17 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 373 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

With uncertainty regarding the Yucca Mountain geologic repository being just one manifestation of the controversy over where, how, and whether radioactive waste can be safely treated and disposed in a publicly acceptable manner, the authors suggest that a new approach regarding the storage of spent nuclear fuel (SNF) and radioactive waste is needed and, fortunately, available. Safely storing wastes in an environmentally-acceptable, monitored manner while a national political and technical consensus is reached on how to properly treat it prior to its ultimate disposal may be the most cost-effective and rational method of addressing these issues in the interim. Because of the limitations imposed on treatment and disposal options by state governments, legislative and regulatory requirements, and legal challenges, spent fuel, other reactor irradiated nuclear material (RINM), and radioactive waste are remaining where they were produced, usually in facilities neither sited nor designed with long-term storage in mind. The inertia associated with difficult choices based on imperfect information has resulted in a decision-making gridlock where an unpopular status quo continues and promising solutions remain untried. However, well-planned and locally accepted centralization of wastes (especially medical) within states and/or acceptance of dry spent fuel storage at each nuclear generating station can break the current gridlock of disposal and storage actions and inactions and can result in a more desirable outcome both in the intermediate and long term.

853 **1993 recreational vehicle (RV) park census in Beatty and Pahrump, Nevada.** Levy, L.E. (Planning Information Corp., Denver, CO (United States)); Housel, M.D. pp. 48-55 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 373 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

This paper reports on the second annual study of seasonal nonpermanent residents in the towns of Beatty and Pahrump in southern Nye County, Nevada, situs county of the Yucca Mountain Site Characterization Project. The study used a census of recreational vehicle (RV) park managers to enumerate and characterize in demographic terms nonpermanent residents staying in RV parks. The questionnaire sought information from RV park managers which ordinarily would come from a household survey. The main objective was to study "snowbirds", the households of older couples who stay for a month or more each winter. The findings suggest that snowbirds are a majority of the seasonal influx of nonpermanent residents to RV parks in Pahrump. In contrast, a group called "seasonal travelers", similar demographically but who stay less than a month, dominate the seasonal nonpermanent population in Beatty's RV parks. The study also tentatively identified the seasonality of nonpermanent resident occupancy. Because only RV parks were contacted, the study left unanswered the question of how many snowbirds live in other types of accommodations in Beatty and Pahrump.

854 **Public opinion polling and the Yucca Mountain controversy: A seven year inventory December 1986–August 1993.** Himmelberger, J.J. (Clark Univ., Worcester, MA (United States)); Baughman, M.L. pp. 142-149 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 1. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 373 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

This paper presents an inventory of recent (12/87-6/93) public opinion polling activities related to the proposed Yucca Mountain repository. The inventory of polls is discussed in terms of sponsor intentions/objectives, populations polled, survey design/implementation characteristics, and media attention to key findings. We close with some observations on "like" questions as asked over time to Nevadans to shed light on the state of public opinion related to the proposed repository.

855 **A tunnel boring system for the Yucca Mountain Project.** Short, S.N. (Construction & Tunneling Services, Inc., Kent, WA (United States)). pp. 381-385 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Design of the Yucca Mountain Project (YMP) tunnel boring machine (TBM) and backup began in June of 1993, with fabrication, machining and light assembly proceeding through to the end of the year. The original specifications for the project were contained in the request for quote for the YMP TBM and in Construction & Tunneling Services proposal document. As with all complex custom assignments,

much of the finer details of the definition of the final scope of delivery was concurrent with the design effort itself. The summation of this effort is described in this paper. The major technical scope of the machine delivery is defined by the parameters listed in TABLE 1. Within the confines of the installed power and design excavation rates, the final product has been tailored to suit the particular needs of the project.

856 **Application of heavy duty roadheaders for underground development of the Yucca Mountain Exploratory Study Facility.** Rostami, J. (Colorado School of Mines, Golden, CO (United States)); Ozdemir, L.; Neil, D.M. pp. 395-402 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 Contract SC-YM-93-159. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Heavy duty roadheaders of 100 ton weight class are being considered for the excavation of the test rooms and alcoves along the main ramp and in the main repository level at the Yucca Mountain site. The current design of the candidate machines was studied and appropriate modifications are proposed. Computer programs for design optimization and performance prediction of roadheaders were developed. Results of computer modeling and operational parameters of the proposed machines are presented in this paper.

857 **Development of a mechanical alcove excavator for the Yucca Mountain Exploratory Study Facility.** Roennkvist, E. (Colorado School of Mines, Golden, CO (United States)); Ozdemir, L.; Friant, J.E. pp. 411-416 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A 25 ft (7.6 m) diameter tunnel, bored nearly 26,000 ft (8 km) long, is planned as the initial opening into a rather thick strata of welded tuff rock, known as Topopah Springs (TSw2). The near term purpose of the tunnel is to examine the geology to determine if the selected formation is suitable to be used as a nuclear waste repository. In addition to the tunnel, some 30 to 40 alcoves are envisioned along the tunnel which will serve as rooms in and from which the various scientists can conduct their analytical experiments. In addition, a series of rooms and hallways are planned in an area set aside as "the main test facility". The overall site is known as The Exploratory Studies Facilities (ESF). The mission of this study program was to determine if a mechanical means of constructing the alcoves, rooms and hallways was feasible. Of particular interest were the alcoves which exit directly off of the main tunnel. The work for this study included determining a somewhat standard size for the initial alcove, determining whether existing equipment and/or technology was available, and determining if such equipment could be transported and launched from the main tunnel with minimum to no interruption to the main TBM operation. The study determined that no off the shelf equipment was both capable of effectively cutting welded tuff, and sufficiently mobile to meet the minimum interruption requirements. The study did determine that suitable technology was available, and that a special purpose machine was feasible. This paper describes the trade off studies conducted on various excavation methods, the system selected for conceptual design and the potential performance of a mobile alcove excavator.

858 **Novel, low-vibration excavation techniques for underground radioactive waste storage.** Kogelmann, W.J. (Advanced Excavation & Cutting Technologies, State College, PA (United States)). pp. 417-429 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

In order to meet the construction specifications of the challenging Yucca Mountain nuclear waste repository, novel, low-vibration tunneling and shaft sinking techniques must be applied. Conventional roadheaders, even with reduced cutting speed, cannot be employed due to the high strength and widely varying physical properties of the rock formations. The Multi Tool Miner (MTM) concept utilizes both an impact hammer, for efficient hard rock mining, and a cutter head, tooled with drag-bits (picks), to profile tunnel walls down to the sound, undisturbed rock, in order to meet the 10,000-year stability requirement for underground structures. As the operational requirements and rock conditions at the Yucca Mountain site are not suitable for wide, transverse "ripper" cutting drums, a small diameter, in-line, "milling auger" cutter head was developed. The synergetic combination of high-production hammer excavation and precise milling will facilitate the construction of stable, long-life underground structures within the budget limitations mandated by Congress.

859 **Further development of a source term model for a repository in unsaturated tuff.** Codell, R. (Nuclear Regulatory Commission, Washington, DC (United States)); Weller, R. pp. 477-484 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Performance assessments for a potential HLW site at Yucca Mountain should consider the unique characteristics of burying nuclear waste in unsaturated rock. Source term models have been a key part of NRC's first two performance assessments, but have relied on simplified concepts with large uncertainties. NRC is improving its preliminary models for the source term in several important areas, including: (1) incorporation of the latest designs for waste packages; (2) heat transfer near the waste; (3) contact of waste by liquid water, especially thermally induced flows; (4) mechanisms for waste package corrosion; (5) incorporation of spatial and temporal variability at several scales; (6) release of gaseous ^{14}C from the waste; (7) modes of waste package failure other than corrosion; (8) dissolution of radionuclides from the waste form; (9) waste forms other than spent nuclear fuel; (10) abstraction of complex models for use in total system performance assessments; and (11) identification of anticipated and unanticipated events and processes for subsystem performance assessment of the engineered barriers.

860 **An auxiliary ventilation design approach for the ESF development at Yucca Mountain.** Mousset-Jones, P. (Mackay School of Mines, Reno, NV (United States)); Calizaya, F. pp. 508-514 of High Level Radioactive Waste

Management: Proceedings of the fifth annual international conference. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 862 DOE Contract FC08-90NV10891. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

This paper summarizes the current status of a research project directed at ventilation design for the construction of long and complex development headings and describes an approach developed to determine the ventilation design parameters. The approach is based on the principle of partitioning a long ductwork into segments of finite length and solving separately the resulting networks. It has been incorporated into a computer program, written in Turbo Pascal for IBM PC micro-computers and compatible machines. An application of the program is illustrated by the detailed solution of two auxiliary ventilation systems for the Exploratory Studies Facilities (ESF) at Yucca Mountain.

861 **Implications of theories of asteroid and comet impact for policy options for management of spent nuclear fuel and high-level radioactive wastes.** Trask, N.J. (Geological Survey, Reston, VA (United States)). pp. 1324-1328 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Concern with the threat posed by terrestrial asteroid and comet impacts has heightened as the catastrophic consequences of such events have become better appreciated. Although the probabilities of such impacts are very small, a reasonable question for debate is whether such phenomena should be taken into account in deciding policy for the management of spent fuel and high-level radioactive waste. The rate at which asteroid or comet impacts would affect areas of surface storage of radioactive waste is about the same as the estimated rate at which volcanic activity would affect the Yucca Mountain area. The Underground Retrievable Storage (URS) concept could satisfactorily reduce the risk from cosmic impact with its associated uncertainties in addition to providing other benefits described by previous authors.

862 **Systems approach for design control at Monitored Retrievable Storage Project.** Kumar, P.N. (Department of Energy, Washington, DC (United States)); Williams, J.R. pp. 1365-1371 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

This paper describes the systems approach in establishing design control for the Monitored Retrievable Storage Project design development. Key elements in design control are enumerated and systems engineering aspects are detailed. Application of lessons learned from the Yucca Mountain Project experience is addressed. An integrated approach combining quality assurance and systems engineering requirements is suggested to practice effective design control.

863 **Treatment of uncertainty in the NRC regulatory process.** McGarry, J.M. III (Winston & Strawn, Washington, DC (United States)); Echols, F.S. pp. 1404-1416 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The information gained during the one to two decades of initial site characterization of Yucca Mountain, Nevada by the Department of Energy (DOE) will be used to make preliminary predictions about the suitability of the site to be developed as a geologic repository. If Yucca Mountain is designated as suitable for application for a construction authorization pursuant to the terms and conditions of the Nuclear Waste Policy Act (NWPA), as amended, then DOE will submit to the Nuclear Regulatory Commission (NRC) an application for a construction authorization. Much of the information supporting site recommendation and a construction authorization will be subject to significant uncertainty. However, both the NWPA and applicable NRC regulations are structured to accommodate this uncertainty in the administrative decisionmaking process such that appropriate determinations can be made at each stage of repository development, operation and permanent closure.

864 **U.S. NRC staff views on the technical bases for Yucca Mountain standards.** Federline, M.V. (Nuclear Regulatory Commission, Washington, DC (United States)); Kotra, J.P.; Firth, J.R. pp. 1422-1428 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The National Academy of Sciences (NAS) has established a committee to examine the scientific and technical issues that underlie the health and safety standards for high-level waste (HLW) disposal. The NAS Committee is developing recommendations for the Environmental Protection Agency (EPA) concerning an appropriate standard for evaluating a potential HLW repository at Yucca Mountain. Because of its regulatory role for the protection of public health and safety, the US Nuclear Regulatory Commission (NRC) has a significant interest in the progress and outcome of the NAS study as well as in the form and content of any standards EPA ultimately promulgates. The NRC will be required to revise its regulations for consistency with EPA's environmental standards and, subsequently, to evaluate compliance of any proposed repository with NRC's regulations. This paper discusses those issues which, in the NRC staff's view, are critical to the formulation of disposal standards for high-level waste and spent fuel, and which the NAS and, eventually, EPA and NRC will need to address.

865 **A health risk based approach for HLW repository environmental protection criteria.** Williams, R.F. (Electric Power Research Institute, Palo Alto, CA (United States)); Yang, R.L.; McGuire, R.; Wilems, R.E. pp. 1435-1450 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

This paper illustrates a health risk based criteria for the potential HLW repository at Yucca Mountain. The criteria is expressed as an overall health risk goal. Compliance with the standard is proposed to be demonstrated by meeting specific design requirements and design objectives. It is

proposed that different degrees of proof apply to design objectives and design requirements. The approach also proposes a combination of more conventional code-like requirements and probabilistic requirements for protection of public health and safety and the environment. The strawman criteria are similar in many respects to ICRP 46, and European repository criteria. However, we propose that the probability distribution of dose to an average individual in a critical population group be used as the measure of health risk. Implementation is illustrated through a probabilistic analysis of a future site specific biosphere.

866 **Models for source term, flow, transport and dose assessment in NRC's Iterative Performance Assessment, Phase 2.** McCartin, T. (Nuclear Regulatory Commission, Washington, DC (United States)); Codell, R.; Neel, R.; Ford, W.; Wescott, R.; Bradbury, J.; Sagar, B.; Walton, J. pp. 1469-1479 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The core consequence modules for the recently completed Phase 2 Iterative Performance Assessment (IPA) of the Yucca Mountain repository for high-level nuclear waste depend on models for releases from the engineered barrier system (source term), flow of liquid and gas, transport of radionuclides in the geosphere and assessment of dose to target populations. The source term model includes temperature and moisture phenomena in the near-field environment, general, pitting and crevice corrosion, contact of the waste form by water, dissolution and oxidation of the waste form, and transport of dissolved and gaseous radionuclides from the waste package by advection and diffusion. The liquid flow and transport models describe water flow through fractures and matrix in both the unsaturated and saturated zones. Models for flow of gas and transport of $^{14}CO_2$ released from the engineered barrier system to the atmosphere take into account repository heat and the geothermal gradient. The dose assessment model calculates doses to a regional population and a farm family for an assumed reference biosphere in the vicinity of the repository. The Phase 2 IPA led to a number of suggestions for model improvement: (1) improve the ability of the models to include spatial and temporal variability in the parameters; (2) improve the coupling among processes, especially the effects of changing environments in the waste packages; (3) develop more mechanistic models, but abstracted for use in total system performance assessment; and (4) use more site specific parameters, especially for the dose assessments.

867 **IPA Phase 2 sensitivity and uncertainty analysis.** Colten-Bradley, V. (Nuclear Regulatory Commission, Washington, DC (United States)); Codell, R.; Byrne, M.R. pp. 1480-1491 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The NRC's Phase 2 Iterative Performance Assessment (IPA) used Monte Carlo techniques to propagate uncertainty for up to 297 independent variables and nine scenarios through computer models representing the performance of the Yucca Mountain repository. The NRC staff explored the use of a number of parametric and non-parametric tests and graphical methods to display the probabilistic results. Parametric tests included regression and differential analysis. Non-parametric tests included the Kolmogorov-Smirnov test and Sign test. Graphical methods included the Complementary Cumulative Distribution Function (CCDF), hair diagram, scatter plots, histograms and box plots. Multiple linear regression of raw, ranked, standardized and other transformed variables determined the gross sensitivity over the parameter space. CCDF's were also generated from subsets of the 400 vector sets formed by screening the vectors according to values of derived variables related to the behavior of the engineered and natural systems. While no single statistical or graphical technique proved to be useful in all cases, diverse methods of sensitivity and uncertainty analysis identified the same important input parameters.

868 **The use of expert judgment elicitation to predict future climate for the Yucca Mountain Nevada vicinity.** DeWispelare, A. (Center for Nuclear Waste Regulatory Analyses, San Antonio, TX (United States)); Miklas, M.P. Jr.; Clemen, R.T.; Herren, L.T.; Park, J.R. pp. 1614-1621 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 Contract NRC-02-88-005. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Expert judgment elicitations are expected to supplement other data used to assess the long-term safety of a high-level waste (HLW) geologic repository. The US Nuclear Regulatory Commission (NRC) is examining the applicability of expert judgment elicitation to the licensing process. This paper describes the basis and conduct of an expert judgment elicitation project focused on the future climate around Yucca Mountain, Nevada (YMNV). Results in terms of climate predictions over the next 10,000 years are presented.

869 **Using performance assessment for radioactive waste disposal decision making - implementation of the methodology into the third performance assessment iteration of the greater confinement disposal site.** Gallegos, D.P. (Sandia National Labs., Albuquerque, NM (United States)); Conrad, S.H.; Baer, T.A. pp. 1671-1681 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 DOE Contract AC04-76DP00789. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The US Department of Energy is responsible for the disposal of a variety of radioactive wastes. Some of these wastes are prohibited from shallow land burial and also do not meet the waste acceptance criteria for proposed waste repositories at the Waste Isolation Pilot Plant (WIPP) and Yucca Mountain. These wastes have been termed "special-case" waste and require an alternative disposal method. From 1984 to 1989, the Department of Energy disposed of a small quantity of special-case transuranic wastes at the Greater Confinement Disposal (GCD) site at the Nevada Test Site. In this paper, an iterative performance assessment is demonstrated as a useful decision making tool in the overall compliance assessment process for waste disposal. The GCD site has been used as the real-site implementation and test of the performance assessment approach. Through the first two performance assessment iterations for the GCD site, and the transition into the third,

we demonstrate how the performance assessment methodology uses probabilistic risk assessment concepts to guide effective decisions about site characterization activities and how it can be used as a powerful tool in bringing compliance assessment decisions to closure.

870 **Role of U.S. Nuclear Regulatory Commission's On-Site Representatives in pre-licensing activities for a high-level radioactive waste repository.** Justus, P.S. (Nuclear Regulatory Commission, Las Vegas, NV (United States)); Gilray, J. pp. 1712-1715 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Under the Nuclear Waste Policy Act, the US Department of Energy and the US Nuclear Regulatory Commission are required to consult with each other prior to DOE's submittal of a license application to construct a high-level radioactive waste repository. DOE entered into an agreement which, in part, enabled NRC On-Site Representatives to be stationed at a high-level waste candidate site "principally to serve as a point of prompt informational exchange and consultation and to preliminary identify concerns about such investigations relating to potential licensing issues." On-Site Representatives' direct observation of site characterization activities including construction of an underground studies facility (at Yucca Mountain, NV candidate site) provides NRC staff opportunities to help ensure that DOE will develop data which are appropriate to determine if the site will safely isolate waste and which will be defensible in a License Application. The On-Site Representatives, through supervision and input from the Division of High-Level Waste Management, may consult with the DOE site project office and its contractor staff on items pertaining to management and program controls necessary to satisfy NRC licensing needs, such as demonstrated application of procedural controls and technical data that will support a License Application. The On-Site Representatives interact with DOE through consultations with project staff, quality assurance workshops, observations of reviews of computer software and Q-List considerations, responses to audit and surveillance observations and day-to-day contact with DOE site management, QA staff, and technical investigators.

871 **The case for retrievable high-level nuclear waste disposal.** Roseboom, E.H. Jr. (Geological Survey MS-106, Reston, VA (United States)). pp. 1774-1781 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 3. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 699 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Plans for the nation's first high-level nuclear waste repository have called for permanently closing and sealing the repository soon after it is filled. However, the hydrologic environment of the proposed site at Yucca Mountain, Nevada, should allow the repository to be kept open and the waste retrievable indefinitely. This would allow direct monitoring of the repository and maintain the options for future generations to improve upon the disposal methods or use the uranium in the spent fuel as an energy resource.

872 **The role of fracture coatings on water imbibition into unsaturated tuff.** Chekuri, V.S. (Univ. and Community College System of Nevada, Reno, NV (United States)); Tyler, S.W.; Fordham, J.W. pp. 1891-1896 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A thin lining of low permeability material on fracture walls may significantly impede imbibition into the matrix of unsaturated fractured tuff. Capillary forces from the matrix acting on the mobile liquid water in the fractures start the process of imbibition. A convenient measure of the property of imbibition is the sorptivity. To investigate the role of fracture coatings on sorptivity in the laboratory we modified a simple sorptivity cell. This sorptivity cell was used to measure imbibition across the fracture surfaces and to investigate the role of fracture coatings. Results of Tiva Canyon tuff samples collected from surface outcrops near Yucca Mountain were contrary to the hypothesis that the fracture coating may impede imbibition.

873 **Statistical considerations on large-scale geomechanics test design for nuclear waste repository characterization.** Kim, Kunsoo (Columbia Univ., New York, NY (United States)); Gao, Hang. pp. 1922-1929 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 Grant 1124136FY93. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A statistical method based on a Monte Carlo simulation and the statistics of extremes is employed to characterize the natural variability of the rock mass properties for siting a high level nuclear waste repository. The method is applied to the well documented NNWSI and BWIP data to assess its validity. The results of the analysis suggest that the large-scale tests should be designed to provide information to describe the rock mass properties in analytical forms, not just to produce discrete data points. Ancillary tests including the constituent material properties for the analytical relationships should be planned as an integral part of the large-scale tests. Then, via Monte Carlo simulation one can estimate the distribution functions of rock mass properties which permit to assess the variability of the rock mass behavior in repository conditions.

874 **Yucca Mountain: A potential trade-off in radiological hazards.** Spiegler, P. (Nuclear Waste Project Office, Carson City, NV (United States)). pp. 1959-1963 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Simple and preliminary calculations show that the excess emanation of radon and radon daughter products resulting from the heating of the rock could produce effective dose equivalent rates comparable to or greater than those of background radiation over large areas surrounding the Yucca Mountain site. This important issue is not being properly addressed in the licensing and characterization strategy of the Yucca Mountain site. The excess emanation of radon and radon daughter product could be an important constraint on the aereal power density, which is a repository

design parameter that is under review at the writing of this paper. The review became necessary because the DOE is considering the disposal of spent fuel in multi-purpose canisters and because the DOE has indicated the intention of storing more than 70,000 MTU of spent fuel at Yucca Mountain. Also very important, excess radon emanation could stimulate a debate that the Yucca Mountain site is a trade-off of one radiological hazard for another.

875 **Testing conceptual unsaturated zone flow models for Yucca Mountain.** Brown, T.P. (L. Lehman & Associates, Inc., Burnsville, MN (United States)); Lehman, L.L.; Nieber, J.L. pp. 1999-2006 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

An important component of site characterization and suitability assessment of the proposed nuclear waste repository at Yucca Mountain, Nevada is determination of the most appropriate conceptual model of the hydrologic mechanisms governing saturated and unsaturated flow for the site. As observers in the ITNRAVAL Unsaturated Zone Working Group, L. Lehman & Associates conducted a modeling exercise which numerically examined alternative conceptual flow models. Information was provided to the Working Group by the U.S. Geological Survey. Additional published data were utilized to fill in data gaps and to provide additional confidence in results. Data were modeled utilizing one and two dimensional matrix and fracture numerical models. Good agreement was obtained using a 2-dimensional dual porosity fracture flow model. Additional measures are needed to constrain the field conditions enough to validate conceptual models using numerical models. Geochemical data on tritium, chlorine-36, or carbon-14 concentrations or temperature profiles which can give estimates of time since recharge for water in the unsaturated zone, are needed to eliminate the non-uniqueness of various model solutions.

876 **Above and below boiling thermal loading strategies for large waste packages.** Smith, M.L. (Virginia Power, Glen Allen, VA (United States)). pp. 2146-2151 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A simplified repository thermal model was developed with the Mathcad computer code which indicates that large waste packages may be compatible with both above and below boiling repository thermal loading strategies. Minimum spent fuel decay time of at least 20 to 30 years was shown to be important for both thermal loading strategies. Constant isothermal boundary conditions are assumed at the ground surface (296 K) and 305 meters below the water table (309.7 K) with a uniform temperature change of 1.55 10^{-2} K/meter. Homogeneous tuff properties are assumed: conductivity (2.1 watt/m-k); density (2.22 gm/cm^3); and thermal capacitance (2.17 joule/cm^3 K). Based on these properties, the tuff thermal diffusion coefficient is 9.68 $\times$ 10^{-7} m^2/sec.

877 **Liquid infiltration through the boiling-point isotherm in a desiccating fractured rock matrix.** Phillips, O.M. (John Hopkins Univ., Baltimore, MD (United States)). pp. 2189-2196 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 Contract NRC-02-88-005. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Over a long time interval, the integrity of the radioactive waste repository proposed at Yucca Mountain may be compromised by corrosion accelerated by intermittent wetting which could occur by episodic infiltration of meteoric water from above through the fracture network. A simple two-dimensional model is constructed for the infiltration of liquid water down a fracture in a permeable rock matrix, beyond the boiling-point isotherm. The water may derive from episodic infiltration or from the condensation of steam above a desiccating region. Boiling of the water in the fracture is maintained by heat transfer from a surrounding superheated matrix blocks. There are two intrinsic length scales in this situation, (1): $l_s = \rho_l q_o L/(k_m \beta)$ which is such that the total heat flow over this lateral distance balances that needed for evaporation of the liquid water infiltration, and (2): The thermal diffusion distance $l_\theta = (k_m t)^{\frac{1}{2}}$ which increases with time after the onset of infiltration. The primary results are: (a) for two-dimensional infiltration down an isolated fracture or fault, the depth of penetration below the (undisturbed) boiling point isotherm is given by $\frac{1}{2}\pi^{\frac{1}{2}}(l_s l_\theta)^{\frac{1}{2}}$, and so increases as $t^{\frac{1}{4}}$. Immediately following the onset of infiltration, penetration is rapid, but quickly slows. This behavior continues until l_θ (and D) become comparable with l_s. (b) With continuing infiltration down an isolated fracture or cluster of fractures, when $l_\theta >> l_s$ the temperature distribution becomes steady and the penetration distance stabilizes at a value proportional to l_s. (c) Effects such as three-dimensionality of the liquid flow paths and flow rates, matrix infiltration, etc., appear to reduce the penetration distance.

878 **Thermosyphon analysis of a repository: A simplified model for vapor flow and heat transfer.** Manteufel, R.D. (Center for Nuclear Waste Regulatory Analyses, San Antonio, TX (United States)); Powell, M.W. pp. 2207-2216 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 Contract NRC-02-88-005. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A simplified model is developed for thermally-driven buoyant gas flow in an unsaturated repository such as that anticipated at Yucca Mountain. Based on a simplified thermosyphon model, the strength of buoyant gas flow is related to key thermal-hydraulic parameters (e.g., bulk permeability and maximum repository temperature). The effects of buoyant gas flow on vapor flow and heat transport near the repository horizon are assessed, namely: (i) the strength of buoyant flow through the repository, (ii) the effect of buoyant flow on vapor transfer, and (iii) the effect of buoyant flow on heat transfer.

879 **Pressure-driven gas flow in heated, partially-saturated porous media.** Dodge, F.T. (Southwest Research Institute, San Antonio, TX (United States)); Green, R.T. pp. 2217-2227 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 Contract

NRC-02-93-005. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Calculations have been made at the Center for Nuclear Waste Regulatory Analyses (CNWRA) to assess the importance of the various driving mechanisms of heat and mass transport at a high-level nuclear waste (HLW) repository located in the unsaturated zone. Scoping measurements of the relative importance of vapor movement by buoyancy forces and by advective forces have been made for a proposed laboratory-scale experiment to be conducted at CNWRA and for a proposed field-scale heater experiment by U.S. Department of Energy (DOE) at Fran Ridge. These scoping measurements are made using a set of dimensionless terms assembled for this analysis. Numerical simulations of the same laboratory- and field-scale experiments are made using VTOUGH. These calculations will be used to predict (and design in the case of the laboratory-scale experiment) the redistribution of moisture in response to the imposition of heat on the two experiments.

880 **The Cigar Lake analog study: An international R&D project.** Cramer, J.J. (Whiteshell Lab., Pinawa, Manitoba (Canada)); Sargent, F.P. pp. 2237-2242 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

This paper provides background information and summarizes the results of AECL's analog study on the Cigar Lake uranium deposit. This R&D project includes national and international cooperation with many organizations directly or indirectly involved in nuclear waste management research. The emphasis is on the analog aspects of this deposit and the implications of modelling activities related to the environmental and safety assessment of the Canadian disposal concept for nuclear fuel waste.

881 **A-TOUGH: A multimedia fluid-flow/energy-transport model for fully-coupled atmospheric-subsurface interactions.** Montazer, P. (Multimedia Environmental Technology, Inc., Newport Beach, CA (United States)); Hammermeister, D.; Ginanni, J. pp. 2333-2340 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Modeling the extreme thermodynamic conditions encountered in the near-ground surface atmosphere-soil boundary in desert environments requires a robust code that is capable of simulating fully-coupled flow and transports of water liquid, water vapor, and heat in porous and fractured media - where flow is usually laminar, and the atmosphere - where flow is usually turbulent. A-TOUGh (Atmospheric TOUGH) is developed to simulate the transport of air, vapor, and heat through an atmospheric boundary layer coupled with the transport of moisture, an air-vapor mixture, and heat through porous or fractured media. The three-dimensional nature of the code allows simulation of rough terrain and heterogeneous subsurface conditions encountered at site such as Yucca Mountain. The allowable range of temperatures (-50°C to 200°C) and relative humidities (0 to 100 percent) for this new code permits the simulation of complex processes such as condensation in fractures during the winter season. A-TOUGH can also be used to predict the effect that ventilation shafts and tunnels in underground facilities have on moisture conditions in the host fractured rocks over extended periods of time. A-TOUGH has been tested with several simple and complicated problem sets, including a two-dimensional low-level radioactive waste trench with a layered cap. This paper: (1) summarizes the physical and mathematical approach used by previous investigators and the current study to simulate near-surface unsaturated flow processes, (2) briefly describes the numerical procedures incorporated in A-TOUGH, and (3) presents the results of a calibration simulation based on published field data.

882 **Published attenuation functions compared to 6/29/1992 Little Skull Mountain earthquake motion.** Hofmann, R.B. (Center for Nuclear Waste Regulatory Analysis, San Antonio, TX (United States)); Ibrahim, A.K. pp. 2402-2408 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Several western U.S. strong motion acceleration earthquake attenuation functions are compared to peak accelerations recorded during the 6/29/1992 Little Skull Mountain, Nevada earthquake. The comparison revealed that there are several definitions of site-to-source distance and at least two definitions of peak acceleration in use. Probabilistic seismic hazard analysis (PSHA) codes typically estimate accelerations assuming point sources. The computer code, SEISM 1, was developed for the eastern U.S. where ground acceleration is usually defined in terms of epicentral distance. Formulae whose distance definitions require knowledge of the earthquake fault slip zone dimensions may predict very different near-field accelerations when epicentral distance is used. Approximations to achieve more consistent PSHA results are derived.

883 **A characterization study of fractured rock.** Karasaki, K. (Lawrence Berkeley Lab., CA (United States)); Freifeld, B.; Davison, C. pp. 2423-2428 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A suite of experiments are being conducted at a dedicated field study site in the Sierra Nevada foothills, near the town of Raymond, California to develop and test a multidisciplinary approach to the characterization of ground-water flow and transport in fractured rocks. A cluster of nine approximately 90m deep boreholes have been drilled at the site in a reverse V pattern with an angle of 60 degrees and with increasing spacing of 7.5, 15, 30, and 60 meters from the central well. A newly developed data acquisition system uses a 486 PC and centrally controls many of the test parameters. Intra- and cross-borehole geophysical surveys indicated that the flow is mainly confined to a few subhorizontal fracture zones. Various kinds of hydraulic tests were conducted with and without packers. A radial convergent tracer test was then conducted by injecting a three tracer mixture of deuterium, fluorescein, and micro-spheres followed by a mixture of bromide and fluoride in a well 30 m

away from the pumping well. Preliminary results show some differences between the breakthrough curves, which may have been strongly influenced by the borehole hydrodynamics.

884 **In situ stress determination research study.** Austin, W.G. (Bureau of Reclamation, Denver, CO (United States)); Thompson, P.M. pp. 2429-2436 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The objectives of this study are to evaluate and implement rock stress determination instruments and techniques developed by Atomic Energy of Canada Limited (AECL) at its Underground Research Laboratory (URL) for use in jointed rock and to continue the development of analytical and interpretation methods for stress determination results including effects of scale, structure and anisotropy. Testing and evaluation of the instruments and methods developed at URL need to be done in a similar rock type prior to underground access at the Yucca Mountain Site Characterization Project.

885 **Spring deposits and late pleistocene groundwater levels in southern Nevada.** Quade, J. (Univ. of Arizona, Tucson, AZ (United States)). pp. 2530-2537 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Ground-water discharge deposits dating to the last glacial cycle and to several earlier cycles crop out in at least ten valleys in the southern Great Basin. The elevation and distribution of these deposits allow us to reconstruct the elevation of the water table during periods of wetter climate over much of the region, including the area around Yucca Mountain, site of the proposed high-level nuclear waste repository. Results from areas undisturbed by recent ground-water pumpage reveal that water levels have varied by < 115 m, and in most cases much less, in the latter half of the Quaternary. The extent of ground-water discharge during older wet cycles is similar in scale to discharge during the last full-glacial period. This places most of the proposed repository horizon at least 85 to 285 m above the maximum levels attained by the water table under full-glacial climates. During the late-glacial period (~11,500 to 8000 B.P.), a pulse of renewed discharge, perhaps corresponding to the Younger Dryas event well-documented elsewhere, produced organic-rich mats and flowing streams in many localities.

886 **Potential of vertebrate studies for assessing past climate variations.** Livingston, S.D. (Desert Research Institute, Reno, NV (United States)). pp. 2562-2568 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Vertebrate remains are commonly recovered in the course of archaeological and paleontological investigations. They are routinely used as a source of data from which to reconstruct subsistence practices and environmental factors perceived as important to past people. But this source of information has not been recognized as relevant to estimation of late Quaternary climate changes in the Great Basin until recently. In this paper I summarize three ways that environmental information is encoded in prehistoric vertebrate assemblages and provide examples of evidence that vertebrates do reflect changes of interest for climatic studies.

887 **Tree-rings and climate: Implications for Great Basin paleoenvironmental studies.** Graybill, D.A. (Univ. of Arizona, Tucson, AZ (United States)); Rose, M.R.; Nials, F.L. pp. 2569-2573 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

The Quaternary Sciences Center of the Desert Research Institute is currently conducting a multi-phased study of floral, faunal, and geomorphic response to long- and short-term climate change and extremes in assessing Yucca Mountain's suitability as a high-level nuclear waste repository. Preliminary results of these studies indicate synchronous responses in late Holocene tree-ring, palynology and geomorphic records. A tree-ring chronology for paleoclimatic reconstruction is developed by collection of multiple cores from 20-60 living trees and a similar number of dead trees in a climate-sensitive location. Samples are cross-dated and every growth layer in each specimen is measured to the nearest .001 mm. The measured ring width series potentially contain a variety of climatic, biological, and anthropogenic signals. Each ring width series is subjected to a numerical standarization procedure that removes an age-related biological growth trend, reduces endogeneous and exogenous stand disturbance factors, and maximizes any climatic signal that is present. Each of these empirically defined components can be graphically portrayed and subjected to further analyses. The geophysical signal analysis techniques involved in the standarized protocol are well-documented and established. The final result is a tree-ring chronology that represents regional paleoclimatic variability over the time represented by the sample population.

888 **Late holocene climate derived from vegetation history and plant cellulose stable isotope records from the Great Basin of western North America.** Wigand, P.E. (Desert Research Institute, Reno, NV (United States)); Hemphill, M.L.; Patra, S.M. pp. 2574-2583 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 DOE Contract FC08-93NV11417. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Integration of pollen records, and fossil woodrat midden data recovered from multiple strata of fossil woodrat (Neotoma spp.) dens (middens) in both northern and southern Nevada reveal a detailed paleoclimatic proxy record for the Great Basin during the last 45,000 years in growing detail. Clear, late Holocene climate-linked elevational depressions of plant species' distributions have occurred throughout the Great Basin of up to 200 m below today's and by as much as 1000 m below what they were during the middle Holocene. Horizontal plant range extentions during the Holocene reflecting the final northern most adjustments to Holocene climates range up to several hundred kilometers in the Great Basin. Well documented lags evidenced in

the late Holocene response of vegetation communities to increased precipitation indicate reduced effectiveness in the ability of plant communities to assimilate excess precipitation. This resulted in significant runoff that was available for recharge. These responses, although indicating both rapid and dramatic fluctuations of climate for the Holocene, fall far short of the scale of such changes during the late Pleistocene. Extension of these results to Pleistocene woodrat den and pollen data evidence spans lasting several hundred to a thousand or more years during which significantly greater amounts of precipitation would have been available for runnoff or recharge.

889 **Effective unsaturated hydraulic property determination with the renormalization group approach: Methodology.** Mohanty, S. (Southwest Research Institute, San Antonio, TX (United States)); Bagtzoglou, C. pp. 2660-2668 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 Contract NRC-02-88-005. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

Assessing the performance of the potential high-level waste repository at Yucca Mountain, Nevada, requires the determination of the rate of radionuclide transport via groundwater through the fractured zone to the accessible environment. An efficient methodology for the calculation of effective hydraulic properties is presented in this paper. The Real Space Renormalization Group (RSRG) approach is adapted and modified for application to fractured rock under unsaturated conditions. The conceptual models associated with this approach are discussed briefly and the implementation of the algorithm is presented in diagrammatic form. Some verification comparisons with direct numerical simulations are presented. The estimates of effective unsaturated hydraulic conductivity, as obtained with the RSRG method, compare very well with direct numerical simulation results for the fracture configurations considered in this work. The RSRG method also proves to be highly efficient in terms of computational requirements.

890 **Stochastic analysis of unsaturated flow and transport with the SUFLAT executive numerical code.** Bagtzoglou, A.C. (Southwest Research Institute, San Antonio, TX (United States)); Islam, M.R.; Muller, M. pp. 2669-2677 of High Level Radioactive Waste Management: Proceedings of the fifth annual international conference. Volume 4. American Nuclear Society, Inc., La Grange Park, IL (United States) (1994). pp. 1048 Contract NRC-02-88-005. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994.

A description of the executive numerical code SUFLAT, for stochastic analysis of unsaturated flow and transport, is presented in this paper. A brief introduction to the theory of cross-correlated random fields is given together with a verification test case, using data from the Las Cruces Trench. Finally, the SUFLAT methodology is applied to a hypothetical flow system analogous, in some respects, to the Yucca Mountain site. Flow and transport simulations are conducted for a two-layered system with stochastically generated hydraulic properties, similar to the Topopah Spring welded (TSw) and Calico Hills nonwelded-vitric (CHnv) interface. Various qualitative observations serve to build confidence in the results of these simulations. The high saturation values in the low part of the upper layer and extensive lateral flow along the interface are indeed consistent with numerous other simulation results and conceptual models. However, and in stark contrast with these conceptual models, highly focused preferential flow channels are developed and break the continuity of the "hypothesized" capillary barrier. These results serve to strongly emphasize the notion that analyses neglecting the effects of the inherent heterogeneity in the flow system are bound to underestimate the mass flux crossing a prescribed compliance boundary.

891 (CONF-940815–93) **Incentives and techniques for increasing the capacity of the geologic repository.** Cowell, B.S.; Fontana, M.H.; Michaels, G.E. Oak Ridge National Lab., TN (United States). [1994]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC05-84OR21400. From SPECTRUM '94: international nuclear and hazardous waste management conference; Atlanta, GA (United States); 14-18 Aug 1994. Order Number DE94018138. Source: OSTI; NTIS; INIS; GPO Dep.

Estimates of the materials potentially destined for emplacement in Yucca Mountain exceed the statutory repository capacity limit of 70,000 metric tons initial heavy metal. Removal and subsequent burning of the actinides in these materials can dramatically increase the repository capacity, postponing or perhaps eliminating the need for a second repository. The detailed calculations described herein verify portions of a promising actinide removal and waste emplacement concept, HEWEC. Results from heat transfer calculations indicate that more than 2.5 times the material may be emplaced using a combination of optimum geometry and actinide recycle. This optimum geometry includes additional drifts and closer borehole spacing within the drifts. Future work will quantify the additional benefits that may be derived from drift ventilation and staggered emplacement strategies.

892 **Evolving fracture arrays and associated changes in rock mass properties.** Piscoran, P.L. (Univ. of Nevada, Reno, NV (United States)); Schultz, R.A. pp. 6-8 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Using a boundary element technique, we relate changes in rock mass properties associated with an evolving fracture array by quantifying the effect of fracture network changes on rock mass strength and deformability. The growth of a crack array is modeled using a two-dimensional displacement discontinuity computer algorithm. During each iteration cycle, each crack in the network is evaluated against a propagation criterion, and changes in the elastic properties of the rock mass are monitored.

893 **Geological suitability studies as to burial of radioactive waste in salts and tuffs of the Transcarpathian depression.** Shestopalova, O.V. (Institute of Geochemistry & Ore Formation, Kiev (Ukraine)). pp. 36-38 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The Transcarpathian depression is considered as one of the promising regions as to selection of the sites for radioactive waste burial. The structures in the depression were analyzed having regard to flow conditions and the favorable reservoirs available. The Solotvino depression as the most favorable structure was examined in respect to its deposits and candidate sites for further research.

894 **Fracture permeability under effect of normal and shear stress: A preliminary experimental investigation.** Mohanty, S. (Southwest Research Institute, San Antonio, TX (United States)); Manteufel, R.D.; Chowdhury, A.H. pp. 41-43 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 Contract NRC-0293005. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The change in fracture permeability under mechanical loads have been investigated. An apparatus has been developed to measure change in fracture permeability, when a single fracture is subjected to normal and shear stress. Both radial and linear flow experiments have been conducted by modifying a direct shear test apparatus. Preliminary results suggest a 35-percent change in fracture permeability under normal stress to 8 MPa and nearly 350 percent under shear displacement of 9.9254 m (1 in.) at 5 MPa normal stress. Effort is underway to separate the permeability change due to gouge material production from that of due to dilation.

895 **Effect of environmental variables on CO_2 transport through USW-G4 tuffs.** Davis, K.T. (North Carolina A&T State Univ. (United States)); King, F.G.; Ali, M.S.; Ilias, S. pp. 53-55 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The purpose of this study was to provide effective diffusivity data for carbon dioxide that may be used to calculate the transport of carbon dioxide through Yucca Mountain tuff layers to the accessible environment. The study was done on twelve tuff samples from five different layers of the USW-G4 drillhole, which is located in the central part of the proposed repository envelope. The tuff samples studied were from the following layers: vapor phase zone, upper lithophysal zone, middle nonlithophysal zone, lower lithophysal zone and lower nonlithophysal zone. The depths of the samples ranged from 83.6-371.0 m. A steady-state counter diffusion method, using gas chromatographic analysis, was used to determine the effective diffusivity of carbon dioxide. For all samples, the diffusion was either in the transition regime or in the Knudsen regime. The effective diffusivity of carbon dioxide through the different layers was found to be in the range of 0.00012-0.0011 cm^2s. The CO_2 diffusion coefficient increased with temperature in the range from 25 °C to 125 °C. The effect of pressure on CO_2 diffusivity at 25 °C was also measured for pressures up to 4 atm. For most samples, effective diffusivity decreased with increasing pressure. The effect of differential pressure on CO_2 transport was also measured for differential pressures up to 4 atm. Mass transfer coefficients were log-linear with pressure increase and were substantially higher than effective diffusivity for all samples.

896 **Estimation of spatial distribution of recharge factors at Yucca Mountain, Nevada.** Stothoff, S.A. (Center for Nuclear Waste Regulatory Analyses, San Antonio, TX (United States)); Bagtzoglou, A.C.; Castellaw; H. pp. 69-71 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Determining compliance with the performance objectives for both the repository system and the Geologic Setting (GS) requires prediction of groundwater flow. Since infiltration is the primary source of water in the subsurface, the amounts and locations of infiltration are controlling factors in the movement of groundwater throughout the GS. In fractured, unsaturated rock, such as that found at the Yucca Mountain (YM) site, occurrence of infrequent, high-intensity rainfall events will modify, perhaps drastically, the subsurface flow regime from the one predicted by assuming that all rainfall events have averaged intensities. Indeed, the DOW has concluded that the spatial and temporal distribution of infiltration may be the most important factors influencing groundwater flow path development. Deep percolation fluxes are affected by processes active in the near-surface zone, including evaporation, transpiration, liquid water flow, and vapor flow. Each of these processes is governed by several factors. For example, precipitation has been found to vary substantially over the YM region, both spatially and temporally, and winter storms are, in general, more uniform and of longer duration than summer storms (Hevesi et al., 1992a,b; 1994). These observations indicate that, especially for summer storms, a spatially uniform precipitation pattern is clearly not applicable, even at the subregional scale. Similarly, evaporation from the ground surface is affected by air temperature, atmospheric vapor pressure, wind speed profile, incident solar radiation, surface soil and rock texture, plant activity, surficial temperature, and surficial moisture content. Many of these factors, such as surficial slope and orientation (related to incident solar radiation), surficial composition, and plant distributions, are or can be mapped at the YM site.

897 **Characterization of the potential for perched water development at Yucca Mountain, Nevada.** Turner, D.R. (Southwest Research Institute, San Antonio, TX (United States)); Bagtzoglou, A.C.; Foegelle, J. pp. 72-74 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 Contract NRC-0293005. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The potential for existing or future perched-water bodies is identified as a potentially adverse condition for the storage of high-level radioactive wastes (HLW) in a geologic repository. Identification and characterization of where perched-water zones exist in the present or may have existed in the past, placed in the context of a geologic framework, can help to constrain conceptual and mathematical models used to predict future hydrologic conditions. This paper presents initial results of current research efforts at the Center for Nuclear Waste Regulatory Analyses in developing geologic and geographic databases that are designed to support modeling efforts to evaluate the potential for development of perched-water zones at Yucca Mountain, Nevada.

898 **Proof-of-principle tests of the REKA method for in situ thermophysical property measurement.** Danko, G. (Univ. of Nevada, Reno (United States)); Emert, G. pp. 75-79 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

It would be advantageous to measure rock thermophysical properties at Yucca Mountain around the exploratory drifts at some 500-1000 points in standard rockbolt holes. The in situ values, being primary site characteristics, would be applicable to (1) validate highly speculative empirical models for rockmass effects, (2) analyze the variability of rock properties at low cost, (3) identify initial convective effects, (4) monitor rock dryout due to ventilation, and (5) support hydrothermal site characterization. A scaled version of the thermal probe method, called REKA (Rapid Evaluation of K and Alpha) has been tested in the Mackay School of Mines Thermophysical Laboratory under different, controlled conditions in order to evaluate its application potential for field measurements when rockmass effects are present. The REKA method involves a single borehole probe with a heater and temperature measurement section. An elliptical temperature field is generated by the heater, and the temperature distribution along the length of the probe is recorded at several locations and at given time intervals for a period of 24 hours. The scaled REKA probe requires an approximately 0.9 m-deep (3 ft) hole which is 0.013 m (1/2 in) in diameter. The full-size probe version that has been used in underground mines requires approximately 1.8 m-deep (6 ft) hole with (0.045 m 1 3/4 in) diameter. Other probe sizes can also be selected in order to apply the method to the standard drillholes that are used for rockbolt installations. Three laboratory test series were conducted using different, controlled conditions in two host test beds to determine the response of the REKA probe to conditions that may be present during actual in situ measurements.

899 **Calculation of thermal conductivity of unsaturated porous media based on microscopic fluid distribution.** Mohanty, S. (Southwest Research Institute, San Antonio, TX (United States)). pp. 80-82 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

In conduction dominated heat flow through porous media, the degree of fluid saturation may play an important role. In this paper, a numerical method has been proposed to study the effect of fluid saturation of thermal conductivity using a thin-section and microscopic fluid saturation distribution. This study suggests that the effect of fluid saturation on the overall thermal conductivity is non-monotonic and shows a percolation like behavior with respect to the fluid saturation.

900 **Potential fast paths along faults in the Calico Hills unit at Yucca Mountain.** Wang, J.S.Y. (Univ. of California, Berkeley (United States)); Aunzo, Z.; Flexser, S.; Cook, N.G.W. pp. 103-106 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 DOE Contract AC03-76SF00098. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Potential fast flow and transport paths comprising near vertical fractures or faults are one of the most important features affecting the suitability of Yucca Mountain as a site for a potential permanent repository of high-level radioactive waste. Of the unsaturated tuff units at Yucca Mountain, the Calico hills nonwelded tuff unit is relatively less fractured and is further away from repository-induced perturbations, in comparison with the Topopah Spring welded tuff units. Observations in the Tunnel Bed units from the Defense Nuclear Agency tunnels at Rainier Mesa indicate that major flow paths have short travel times for the transport of meteoric water through the vadose zone, and the potential fast path features are spatially infrequent. The presence of similiar fast paths cannot be ruled out by existing borehole data from Yucca Mountain. In this study, the vertical and lateral distribution of vitric and zeolitic tuff sections in the Calico Hills unit above the water table, and the vitrophyre at the base of the Topopah Spring unit are evaluated.

901 **A preliminary three-dimensional geological framework model for Yucca Mountain.** Stirewalt, G.L. (Center for Nuclear Waste Regulatory Analyses, Arlington, VA (United States)); Henderson, D.B. pp. 116-118 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

A preliminary three-dimensional geological framework model has been developed for the potential high-level radioactive waste disposal site at Yucca Mountain. The model is based on field data and was constructed using EarthVision (Version 2.0) software. It provides the basic geological framework in which variations in geological parameters and features in and adjacent to the repository block can be illustrated and analyzed. With further refinement and modification of the model through incorporation of additional data, it can be used by Nuclear Regulatory Commission (NRC) staff to determine whether representation of subsurface geological features in Department of Energy models is reasonable. Consequently, NRC staff will be able to use the model during pre-licensing and licensing phases to assess models for analyses of site suitability, design considerations, and repository performance.

902 **Evaluation of uncertainty in geological framework models at Yucca Mountain, Nevada.** Bagtzoglou, A.C. (Southwest Research Institute, San Antonio, TX (United States)); Stirewalt, G.L.; Henderson, D.B.; Seida, S.B. pp. 119-122 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 Contract NRC-0293005. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The first step towards determining compliance with the performance objectives for both the repository system and the geologic setting at Yucca Mountain requires the development of detailed geostratigraphic models. This paper proposes an approach for the evaluation of the degree of uncertainty inherent in geologic maps and associated three-dimensional geological models. Following this approach, an assessment of accuracy and completeness of the data and

evaluation of conceptual uncertainties in the geological framework models can be performed.

903 Amphibole in quaternary basalts of the Yucca Mountain region: Significance to volcanism models. Hill, B.E. (Center for Nuclear Waste, San Antonio, TX (United States)); Lynton, S.J.; Luhr, J.F. pp. 132-134 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 Contract NRC-0293005. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The purpose of this investigation is to gain an understanding of the origin of amphibole in Quaternary basalt in the Yucca Mountain region for use in constraining volcanism models. Heavy minerals were concentrated from relatively fresh scoriae at cones in the Yucca Mountain region. Electron microprobe analyses indicates that the amphiboles crystallized from basaltic magma with greater than 2 wt % but less than 5 wt % H_2O. Models of mafic volcanic processes for Yucca Mountain should consider that magmatic water contents slightly above 2 wt % may be characteristic of the Quaternary basaltic system. Petrogenetic models also must consider the effects of variable magmatic water contents on the stability of plagioclase and amphibole in differentiating systems.

904 Radiocarbon dating of fossil mollusk shells in the Yucca Mountain region. Brennan, R. (Univ. of Arizona, Tucson (United States)); Quade, J. pp. 182-184 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Fossil mollusk shells from late Quaternary deposits in Southern Nevada were radiocarbon dated to determine the age of paleogroundwater discharge events and to establish minimum ^{14}C ages of paleogroundwater. Shells of the terrestrial taxa Vallonia sp. and Succineidae returned ^{14}C dates consistent with those on organic material in the same stratigraphic position. The aquatic taxa Gyraulus parvus and Gyraulus circumstratus returned the oldest dates within each unit samples. These results show that (1) fossil Vallonia and Succineidae are useful in dating deposits in which no other radiocarbon-datable material is available, and (2) Gyraulus sp. select micro habitats with the most ^{14}C deficient water, providing minimum ages of groundwater in the area during the last glacial period.

905 Effects of alluvial depth on long-term infiltration at Yucca Mountain, NV. Stothoff, S.A. (Southwest Research Institute, San Antonio, TX (United States)). pp. 191-194 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Modeling long-term infiltration into the deep subsurface while including the effects of climatic variation poses a significant computational challenge. The top several meters of a porous matrix are strongly affected by atmospheric conditions over time scales on the order of a decade, although this influence decays with depth. First-order analytical results suggest that perturbations of the moisture content from the time-averaged moisture content profile yield a net infiltration flux which is always larger than the infiltration flux predicted from the time-averaged moisture content profile. Numerical results suggest the perturbation flux can be the same order of magnitude as the flux calculated from the time-averaged moisture content profile within a few meters of the ground surface. It is demonstrated that increasing depth of alluvial cover has an inhibiting effect on the time-averaged long-term infiltration for a less-permeable underlying non-welded tuff.

906 Compartmentalized saturated flow at Yucca Mountain. Lehman, L.L. (L. Lehman & Associates, Brunsville, MN (United States)); Brown, T.P. pp. 206-208 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

As a result of analyses done over the past few years, we have made several observations regarding the saturated zone flow system at Yucca Mountain, Nevada. Taken together, these observations suggest the formulation of a more complex conceptual model of the saturated zone than are currently being analyzed in performance assessments. Future performance assessments should include more closely coupled hydro-thermal and tectonic processes.

907 Numerical analysis of a proposed percolation experiment at the Pena Blanca natural analog site. Green, R.T. (Southwest Research Institute, San Antonio, TX (United States)); Rice, G. pp. 226-228 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 Contract NRC-0293005. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

A field-scale percolation test is proposed for the Pena Blanca natural analog site near Chihuahua, MX. To aid in design of the field test, the V-TOUGH two-phase flow simulator was applied to model percolation of water through 8 to 10 m of partially saturated fractured tuff. The rock was characterized as a composite medium using measured hydraulic properties for the rock matrix and estimated values for the fractures. Measured matrix permeability varied over four orders of magnitude and fracture apertures were estimated to range from 10 to 1,000 μm. Water arrival times were predicted to vary between one day to 10,000 yr. The utility of the composite model and other representations of flow through fractured porous media can be tested using results from the field scale infiltration test data.

908 The role of ground-water travel time in suitability and licensing. Murphy, M.R. (Regulatory and Licensing Advisor/Nye County NWRPO, Olympia, WA (United States)). pp. 229-230 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This paper examines the Department of Energy (DOE) guidelines and Nuclear Regulatory Commission (NRC) licensing criteria pertaining to groundwater travel time, and their impact on obtaining a license for Yucca Mountain. DOE

will be able to obtain a license for Yucca Mountain even if it is determined that there are some fast pathways along which groundwater travel time to the accessible environment is less than 1000 years. However, this will require DOE to gather and analyze a significant amount of firm data, rather than relying primarily on conservative assumptions and bounding calculations.

909 **The need to address enhanced radon emission in the environmental impact report of Yucca Mountain.** Spiegler, P. (State of Nevada, Carson City (United States)). pp. 284-286 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The enhanced emission of Radon 22 at Yucca Mountain, which will result from the heating of the rock by the decay heat of the spent fuel elements and the high-level waste, may significantly perturb background radiation around Yucca Mountain. The history and current status of requirements for addressing enhanced Radon 222 emissions in Environmental Impact Statements is detailed. The Department of Energy has indicated that enhanced Radon 222 emission is not a site characterization or a repository siting issue, and does not plan to address this issue in the environmental monitoring program. This paper concludes that such an approach may not be appropriate for Yucca Mountain.

910 **Future water table rise at Yucca Mountain: A regulatory perspective.** Coleman, N.M. (Nuclear Regulatory Commission, Washington, DC (United States)). pp. 287-289 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The U.S. Nuclear Regulatory Commission staff has developed a program of Systematic Regulatory Analysis (SRA). The purpose of this program is to ensure that important technical issues related to compliance with 10 CFR Part 60 will be identified before receipt of a license application. A plan is being developed to review the U.S. Department of Energy's (DOE's) demonstration of compliance in the license application for each part of the regulation. Under the siting criteria of NRC's Part 60, one of the potentially adverse conditions is the possibility that the water table may rise high enough to saturate a repository in the unsaturated zone. DOE must evaluate this and other conditions in a license application for a geologic repository site. DOE's evaluation must show compliance with the requirements of Part 60 with reasonable assurance. This paper describes the NRC staff's preliminary plans to review DOE's demonstration of compliance, including assumptions about a future rise of the water table.

911 **Site suitability evaluation process development, the situs jurisdiction's perspective.** Murphy, M.R. (Nye County NWRPO, Olympia, WA (United States)); Sims, S.H. pp. 357-358 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This paper presents the viewpoint of Nye County, the situs jurisdiction for the proposed Yucca Mountain repository, regarding the U.S. Department of Energy (DOE) site suitability evaluation. Nye County endorses the DOE process, but does not believe it can be completed to meet the target date of 1998. Difficulties in presenting the case for site suitability to the public are discussed. Nye County recommends that DOE clearly explain its process and governing definitions more clearly, and deliver a compelling technical argument to the public regarding safety at Yucca Mountain.

912 **Use of modeling in repository licensing.** McGarry, J.M. III (Winston & Strawn, Washington, DC (United States)); Echols, F.S. pp. 415-419 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

A review of the regulatory history of the Nuclear Regulatory Commission (NRC) regulations applicable to the licensing of a geologic repository, as well as a review of NRC administrative (licensing) decisions and federal case law, support the NRC's use of simplified models, in appropriate circumstances, which provide well-documented and reasonably conservative bounding assumptions, together with the use of expert judgement, natural analogues, and other aids to supplement available information, in reaching its reasonable assurance determination whether the public health and safety will be adequately protected if the Yucca Mountain, Nevada site should be licensed for development as a geologic repository. Specific examples are provided to assist the reader to better understand how such qualitative concepts as 'reasonable assurance', 'reasonably conservative', and 'adequate' protection are used in an administrative context to resolve technical issues.

913 **Assessing volcanic hazard at Yucca Mountain using expert judgment.** Coppersmith, K.J. (Geomatrix Consultants, Inc., San Francisco, CA (United States)); Perman, R.C.; Nesbit, J. pp. 464-465 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

A study to assess the probability of a future volcanic event disrupting the potential repository at Yucca Mountain, termed the Probabilistic Volcanic Hazard Analysis (PVHA) project, is being sponsored by the U.S. Department of Energy (DOE). This assessment, which is focused on the volcanic hazard at the site, expressed as the probability of disruption of the potential repository, will eventually provide input to an assessment of volcanic risk, which expresses the probability of radionuclide release due to volcanic disruption. To ensure that a wide range of approaches are considered in the hazard analysis, judgments of members of an expert panel will be elicited. The results of the individual elicitations will be combined to develop an integrated assessment of the volcanic hazard that reflects the diversity of scientific interpretations. This paper outlines the hazard model components and the procedures for eliciting expert judgments.

914 **Radionuclide releases from borosilicate and natural glasses.** Shettel, D.L. (Geosciences Management

Institute, Inc., Boulder City, NV (United States)); Morgenstein, M.E. pp. 597-599 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The recent availability of experimental data for drip tests on borosilicate glasses permits the calculation of realistic and conservative radionuclide releases. Source terms based on these data are an improvement over those based on static closed-system saturated experiments and solubility calculations for Yucca Mountain, Nevada.

915 **Actinide source term predictions for spent fuel at Yucca Mountain.** Shettel, D.L. (Geosciences Management Institute, Inc., Boulder City, NV (United States)). pp. 609-611 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

The recent availability of experimental data for unsaturated drip tests on spent nuclear fuel permit the calculation of realistic and conservative actinide source terms for these spent fuel samples. Source terms based on these data are an improvement over those based on static closed-system saturated experiments and solubility calculations for Yucca Mountain, Nevada.

916 **Probabilistic seismic risk at Yucca Mountain from published data.** Hofmann, R.B. (Center For Nuclear Waste Regulatory Analyses, San Antonio, TX (United States)); Ibrahim, A.K. pp. 688-690 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 Contract NRC-02-52-005. From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

Published data concerning earthquake recurrence, faults and their seismic potential in the Yucca Mountain area, were used as input to a revised Lawrence Livermore National Laboratory/Nuclear Regulatory Commission probabilistic seismic hazard analysis computer code. The unmodified code was used for the eastern U.S. seismic hazard characterization project. Calculations were made to test our revisions to permit western U.S. hazard analyses. Code capabilities were extended to provide a means of testing the effects of revised inputs or alternative expert opinions, (indicative of uncertainty), on seismic and fault displacement hazards. Such revisions or alternative opinions would be expected to arise during the licensing process for a potential U.S. high level radioactive waste repository site at Yucca Mountain, Nevada. The revised code functions properly. This analysis produced results comparable to those previously published.

917 **Institutional and technical integration.** Sims, S.H. (Nye County Nuclear Waste Repository Project Office, Pahrump, NV (United States)). pp. 723-724 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This summary outlines the Nye County Nuclear Waste Oversight group approach to public relations regarding the Yucca Mountain Project. The ultimate aim of this group is to assure the public that the Yucca Mountain project is "safe". Efforts to achieve institutional and technical integration are summarized.

918 **Using natural analogue studies in the secondary science curriculum.** Ebert, E.K. (Green Valley High School, Henderson, NV (United States)). pp. 739-740 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This paper discusses an atomic theory unit of a high school chemistry course taught in Nevada. The unit is based on the application of natural analogues to nuclear waste issues. The paper focuses on the students' reactions to the subject material.

919 **Education and Yucca Mountain.** Lamont, M.A. (Thurman White Middle School, Henderson, NV (United States)). pp. 748-749 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This paper outlines a middle school social studies curriculum taught in Nevada. The curriculum was designed to educate students about issues related to the Yucca Mountain project. The paper focuses on the activities used in the curriculum.

920 **Managing high level nuclear waste: Social, economic, and perceived risk issues.** Bassett, G.W. Jr. (Univ. of Illinois, Chicago, IL (United States)); Jenkins-Smith, H.; Silva, C. pp. 755-756 of High level radioactive waste management: Proceedings. American Nuclear Society, Inc.; American Society of Civil Engineers, La Grange Park, IL (United States) (1995). pp. 811 From 6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995.

This summary describes a research paper concerned with social, political, and economic consequences of leaving waste at power plants. Assessments were made by surveying residents in counties where nuclear waste is stored. The intent of the research is to compare attitudes in the surveyed counties with those of Nevada residents.

921 (CONF-9506115–, pp. 461-469) **Environmental ethics and professional practice: A case study of an environmental challenge for century 2000.** Malone, C. (Nuclear Waste Project Office, Carson City, NV (United States)). National Association of Environmental Professionals, Washington, DC (United States). 1995. From 20. National Association of Environmental Professionals annual conference and exposition: environmental challenges - the next twenty years; Washington, DC (United States); 10-13 Jun 1995. In *Environmental challenges: The next 20 years. Proceedings.* 932p. Source: NAEP Publications, 5165 MacAuthur Blvd., N.W., Washington, DC 20016 (United States).

Objective resolution of environmental issues involves questions of facts and values, and, for environmental issues to be resolved ethically, a proper synthesis of environmental

facts with questions of ethics must occur. In this case study, the proposal by the U.S. Department of Energy (DOE) to use the Yucca Mountain site in southwest Nevada as a deep geologic repository for the permanent disposal of the nation's high-level nuclear waste is examined in part in the context of the "Code of Ethics and Standards of Practice for Environmental Professionals" adopted by the National Association of Environmental Professionals (NAEP). Current plans are that a repository at the Yucca Mountain site would begin functioning in 2010 and would be sealed after about 150 years. The requirement that a geologic repository must isolate nuclear waste from the environment for at least 10,000 years poses unique challenges to environmental professionals. This case study also analyzes the challenges in terms of the implications of a new federal Executive Order on Ecosystem Management and corresponding internal orders within all federal agencies to conform to the Executive Order. The imposition of the principles and practices of ecosystem-based resource management on federal agencies provides an opportunity to also address, in the context of the DOE Yucca Mountain Project, (1) the ecosystem approach to environmental management, (2) concepts of holistic resource management planning, and (3) the concepts of sustainability and biodiversity. Within this framework there are important implications for environmental ethics and professional practice that must remain at the forefront of concerns of the NAEP over the next two decades.

922 (DOE–95007796) **1993 Annual progress report for subsidiary agreement No. 2 (1991–1996) between AECL and US/DOE for a radioactive waste management technical co-operative program.** Atomic Energy of Canada Ltd., Pinawa, MB (Canada). Whiteshell Labs.; US-DOE Yucca Mountain Site Characterization Project Office, Las Vegas, NV (United States). [1993]. 55p. Sponsored by USDOE, Washington, DC (United States);Atomic Energy of Canada Ltd., Ottawa, ON (Canada). Order Number DE95007796. Source: OSTI; NTIS; INIS; GPO Dep.

A coordinated research program on radioactive waste disposal is being carried out by the Atomic Energy of Canada Limited and the US Department of Energy. This annual report describes progress in the following eight studies: Fundamental materials investigations; In-situ stress determination; Development of a spent fuel dissolution model; Large block tracer test–Experimental testing of retardation models; Laboratory and field tests of in-situ hydrochemical tools; Cigar Lake–Analogue study, actinide and fission product geochemistry; Performance assessment technology exchange; and Development of multiple-well hydraulic test and field tracer test methods.

923 (DOE/EA–0532) **Environmental assessment for the Groundwater Characterization Project, Nevada Test Site, Nye County, Nevada: Revision 1.** USDOE Nevada Operations Office, Las Vegas, NV (United States). Aug 1992. 156p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94004388. Source: OSTI; NTIS; INIS; GPO Dep.

The US Department of Energy (DOE) proposes to conduct a program to characterize groundwater at the Nevada Test Site (NTS), Nye County, Nevada, in accordance with a 1987 DOE memorandum stating that all past, present, and future nuclear test sites would be treated as Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites (Memorandum from Bruce Green, Weapons Design and Testing Division, June 6, 1987). DOE has prepared an environmental assessment (DOE/EA-0532) to evaluate the environmental consequences associated with the proposed action, referred to as the Groundwater Characterization Project (GCP). This proposed action includes constructing access roads and drill pads, drilling and testing wells, and monitoring these wells for the purpose of characterizing groundwater at the NTS. Long-term monitoring and possible use of these wells in support of CERCLA, as amended by the Superfund Amendments and Reauthorization Act, is also proposed. The GCP includes measures to mitigate potential impacts on sensitive biological, cultural and historical resources, and to protect workers and the environment from exposure to any radioactive or mixed waste materials that may be encountered. DOE considers those mitigation measures related to sensitive biological, cultural and historic resources as essential to render the impacts of the proposed action not significant, and DOE has prepared a Mitigation Action Plan (MAP) that explains how such mitigations will be planned and implemented. Based on the analyses presented in the EA, DOE has determined that the proposed action is not a major Federal action significantly affecting the quality of the human environment, within the meaning of the National Environmental Policy Act of 1969 (NEPA). Therefore, preparation of an environmental impact statement is not required and the Department is issuing this FONSI.

924 (DOE/EIS–0203-D-Vol.1-App.F) **Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Draft Environmental Impact Statement: Volume 1, Appendix F, Nevada Test Site and Oak Ridge Reservation Spent Nuclear Fuel Management Programs.** USDOE Idaho Operations Office, Idaho Falls, ID (United States). Jun 1994. 456p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94014155. Source: OSTI; NTIS; INIS; GPO; GPO Dep.

This volume addresses the interim storage of spent nuclear fuel (SNF) at two US Department of Energy sites, the Nevada Test Site (NTS) and the Oak Ridge Reservation (ORR). These sites are being considered to provide a reasonable range of alternative settings at which future SNF management activities could be conducted. These locations are not currently involved in management of large quantities of SNF; NTS has none, and ORR has only small quantities. But NTS and ORR do offer experience and infrastructure for the handling, processing and storage of radioactive materials, and they do exemplify a broad spectrum of environmental parameters. This broad spectrum of environmental parameters will provide, a perspective on whether and how such location attributes may relate to potential environmental impacts. Consideration of these two sites will permit a programmatic decision to be based upon an assessment of the feasible options without bias, to the current storage sites. This volume is divided into four parts. Part One is the volume introduction. Part Two contains chapters one through five for the NTS, as well as references contained in chapter six. Part Three contains chapters one through five for the ORR, as well as references contained in chapter six. Part Four is summary information including the list of preparers, organizations contacted, acronyms, and abbreviations for both the NTS and the ORR. A Table of Contents, List of Figures, and List of Tables are included in parts Two, Three, and Four. This approach permitted the inclusion of both sites in one volume while maintaining consistent chapter numbering.

925 (DOE/EIS–0203-F-Vol.1-App.L) **Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs. Final Environmental Impact Statement: Volume 1, Appendix L, Environmental Justice.** USDOE Idaho Operations Office, Idaho Falls, ID (United States). Apr 1995. 46p. Sponsored by USDOE, Washington, DC (United States). Order Number DE95012042. Source: OSTI; NTIS; INIS; GPO Dep.

Appendix L provides an assessment of the areas surrounding the 10 sites under consideration for the management of spent nuclear fuels (SNF) under all programmatic alternatives considered in this volume. It is divided into two sections: (a) the five sites considered for the management of DOE naval SNF only (under the No Action and Decentralization alternatives, and (b) the five DOE sites being considered for the management of all types of DOE SNF under all alternatives. The five sites considered for the management of naval SNF only are the Norfolk Naval Shipyard, Portsmouth, Virginia; Portsmouth Naval Shipyard, Kittery, Maine; Pearl Harbor Naval Shipyard, Honolulu, Hawaii; Puget Sound Naval Shipyard, Bremerton, Washington; and Kesselring Site, West Milton, New York. The five DOE sites considered for the management of some portion or all DOE SNF are the Savannah River Site, Aiken, South Carolina; Oak Ridge Reservation, Oak Ridge, Tennessee; Idaho National Engineering Laboratory, Idaho Falls, Idaho; Hanford Site, Richland, Washington; and Nevada Test Site, Mercury, Nevada. This assessment includes potential adverse impacts resulting from both onsite activities and associated transportation of materials. Based on this assessment, it is concluded that none of the alternatives analyzed results in disproportionately high and adverse effects on minority populations or low-income communities surrounding any of the sites under consideration for the management of SNF or associated offsite transportation routes.

926 (DOE/EIS–0203-Vol.1-App.F) **Department of Energy Programmatic Spent Nuclear Fuel management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs: Final Environmental Impact Statement. Volume 1, Appendix F.** USAEC Idaho Operations Office, Idaho Falls, ID (United States). Apr 1995. 450p. Sponsored by USDOE, Washington, DC (United States). Order Number DE95012041. Source: OSTI; NTIS; INIS; GPO Dep.

This appendix addresses the interim storage of spent nuclear fuel at the Nevada Test Site and the Oak Ridge Reservation.

927 (DOE/ER/14352–1) **Rock mechanics in the 1990s: Proceedings: Volume 2.** Haimson, B. (ed.). Wisconsin Univ., Madison, WI (United States). 1993. 396p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FG02-93ER14352. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). Order Number DE94014602. Source: OSTI; NTIS; GPO Dep.

The 34th US Symposium on ROCK MECHANICS was held at the University of Wisconsin-Madison, Madison, WI June 27–30, 1993. Vol 2 contains 98 papers on acoustic emission and failure prediction, YUCCA MOUNTAIN project, numerical methods, constitutive models, role of pore pressure in some rock mechanical processes pertaining to the oil industry, coupled mechanical and hydrologic processes, in-situ stress measurement, rock fractures and joints, coal and metal mining and ground control, and large underground facilities. Individual papers have been entered separately into the data base.

928 (DOE/ER/14352–1, pp. 511-514) **Micromechanical modeling tuffaceous rock for application in underground nuclear waste storage.** Wang, Runqi (Univ. of Arizona, Tucson (United States)); Kemeny, J.M. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

Yucca Mountain, Nevada, is currently being considered as a potential site for the underground storage of high-level civilian radioactive wastes. The host rock surrounding the underground repository is Topopah Spring tuff. Previous experimental studies on tuffs have shown that pores are the primary microstructures of Topopah Spring and Apache Leap tuffs (an analog of for Topopah Spring tuff). Tuff is a kind of volcanic ash that has been compressed at high temperature, and pores have been found widely distributed in tuffs. The pores often appear to form at grain boundaries, and are considered an important flaw in initiating microcrack growth. Under compressive loading, microcracking will initiate from sharp corners of the pores and propagate subparallel to the maximum stress direction until interacting with other pores. Further loading may induce pore collapse which is a major contributor to rock deformation and dilatancy in Apache Leap tuff. Large macroscopic fractures in tuff are formed by the processes of crack growth, interaction, and pore linking. The linking crack is almost parallel to the maximum stress direction. The distance between pores in Topopah Spring tuff is 4-6 times the pore diameter. Detailed SEM observations indicate that macroscopic cracks tend to propagate along the path with the highest pore concentrations. Based on the specific micro-mechanisms for deformation in tuffs as described above, micromechanical models have ben developed. The next section of this paper describes these micromechanical models. The third section of the paper describes the use of these models to predict nonlinear rock deformation and failure in tuff under compressive stresses.

929 (DOE/ER/14352–1, pp. 661-664) **Assessment of conventional methodologies for joint roughness coefficient determination.** Hsiung, S.M. (Southwest Research Institute, San Antonio, TX (United States)); Ghosh, A.; Ahola, M.P.; Chowdhury, A.H. Wisconsin Univ., Madison, WI (United States). 1993. Contract NRC-02-88-005. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

A numerical description of rock joint roughness is necessary to describe adequately the pseudostatic and dynamic rock-joint behavior. The most commonly used measure of joint roughness in rock engineering practice is the joint roughness coefficient (JRC), proposed by Barton and adopted by the International Society for Rock Mechanics. Three basic methods for the determination of JRC have been proposed by various investigators - a tilt test on rock joints as proposed by Barton and Choubey, using an average deviation from the center line about which roughness is measured, and using the theory of fractal geometry. These methods are evaluated in this paper to determine their appropriateness for use in the assessment of rock-joint behavior of Apache Leap tuff joints by comparing the

estimates using these methods to the JRC values back-calculated from the laboratory direct shear test results.

930 (DOE/ER/14352–1, pp. 745-748) **Design methodology for rock excavations at the Yucca Mountain project.** Alber, M. (Pennsylvania State Univ., University Park (United States)); Bieniawski, Z.T. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

The problems involved in the design of the proposed underground repository for high-level nuclear waste call for novel design approaches. Guidelines for the design are given by the Mission Plan Amendment in which licensing and regulatory aspects have to be satisfied. Moreover, systems engineering was proposed, advocating a top-down approach leading to the identification of discrete, implementable system elements. These objectives for the design process can be integrated in an engineering design methodology. While design methodologies for some engineering disciplines are available, they were of limited use for rock engineering because of the inherent uncertainties about the geologic media. Based on the axiomatic design approach of Suh, Bieniawski developed a methodology for design in rock. Design principles and design stages are clearly stated to assist in effective decision making. For overall performance goals, the domain of objectives is defined through components (DCs) - representing a design solution - satisfy the FRs, resulting in discrete, independent functional relations. Implementation is satisfied by evaluation and optimization of the design with respect to the constructibility of the design components.

931 (DOE/ER/14352–1, pp. 749-752) **In situ flow testing of a cement borehole seal in welded tuff.** Crouthamel, D.R. (Stone & Webster Engineering, Inc., Boston, MA (United States)); Fuenkajorn, K.; Daemen, J.J.K. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

Exploratory boreholes, shafts and tunnels drilled or excavated prior to or during the construction of a subsurface nuclear repository may create direct passages for radionuclide transport to the biosphere. Waste isolation at the Yucca Mountain repository suite will require that penetrations (boreholes, shafts, etc.) of the geological barrier be sealed, primarily to prevent excessive flow of groundwater and/or air into the emplaced wastes and to retard the migration of radionuclides to the accessible environment. Cement is being considered as part of multicomponent seals or plugs for the repository due to its relatively low permeability, high strength, longevity, and swelling capacity. Cement or concrete has long been used as a hydrological barrier in underground mines and in the oil and gas industry. However, insufficient tests data exists about the hydraulic performance of cement plugs under in-situ conditions (i.e. as affected by scale, and field installation and environment), and particularly about their long-term sealing effectiveness. The objectives of the research are to determine the hydraulic conductivities of the cement plug, host stuff, and their interface, and to identify the effects of size and field installation on the borehole plug performance.

932 (DOE/FTR–94002466) **Travel to France and Switzerland to collaborate on radioactive waste storage: Foreign trip report, June 15–20, 1993.** Dockery, H.A. Sandia National Labs., Albuquerque, NM (United States). 28 Oct 1993. 47p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-76DP00789. Order Number DE94002466. Source: OSTI; NTIS (US Sales Only); GPO Dep.

The purpose of the visit to the Bureau de Recherches Geologiques et Minieres (BRGM) on June 16 was to determine if there might be common areas of interest of radioactive waste storage and isolation and to initiate contact between the Sandia National Laboratories (SNL) and BRGM in those areas. The informal visit included presentations about several of BRGM's activities. Of particular interest was information on the BRGM hydrologic and geochemical modeling effort for waste-disposal projects. The traveler made a presentation on Yucca Mountain total-system performance-assessment activities and applications for staff from both BRGM and ANDRA. On June 17 and 19, he attended a meeting of a working group to develop an international database of features, events, and processes (FEPs) to be considered in scenario development at the NEA offices in Paris, France. The primary result of the working group was to propose construction of a database of FEPs that would be of general use to the international community for both projects involved with high-level radioactive waste, as well as hazardous waste. The member countries will be working over the next year to incorporate all previously assimilated information into a joint database. The last part of the trip was made to visit NAGRA in Switzerland on June 22 and 23. The main purpose of that trip was to present information on Sandia's Total-System Performance-Assessment activities. The presentation was well received by the audience. The comment was made that the European community was not aware of the large amount of progress that had been made in the area of total-system performance assessment and that further exchanges of this nature would be welcomed.

933 (DOE/FTR–94006304) **Report on the nuclear waste program in Sweden: Foreign trip report, December 12–16, 1993.** Shephard, L.E. Sandia National Labs., Albuquerque, NM (United States). 27 Jan 1994. 13p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94006304. Source: OSTI; NTIS (US Sales Only); GPO Dep.

Dr. Shephard is one of two US representatives for the Scientific Advisory Committee (SAC) that has been formed by the Svensk Kaernbranslehantering AB (SKB) to provide review and advice on the technical program being planned or implemented at the Aespoe Hard Rock Laboratory (HRL), Oskarshamn, Sweden. The fifteenth meeting of the SAC was convened in Forsmark, Sweden, December 14 and 15, 1993 (Attachment 1 contains a list of participants). Several components of the HRL technical program were discussed (see Attachment 2: Agenda) including: (1) plans for initiating an evaluation of repository construction techniques comparing both drill and blast and tunnel boring machine construction approaches, (2) the results of a pre-investigation study that predicted conditions prior to construction of the HRL, (3) the status of a small-scale prototype repository simulation experiment (DOABLE), (4) important elements and characteristics of HRL conceptual models, and (5) preliminary modelling results and plans for the multi-well tracer experiment. Each of these discussion topics contained components with direct application to the Yucca Mountain Project.

934 (DOE-HMIP-RR-94.031) **Natural analogue studies in the geological disposal of radioactive wastes.** Miller, W. (Intera Information Technologies (United Kingdom)); Chapman, N.; Alexander, R.; McKinley, I.; Smellie, J. Department of the Environment, London (United Kingdom). Her Majesty's Inspectorate of Pollution. 1994. 395p. Contract PECD-7/9/631; PECD-7/9/553. Source: Available from the British Library Document Supply Centre, Boston Spa, Wetherby, West Yorks. LS23 7BQ.

Published by Elsevier as no. 57 in the series Studies in Environmental Science.

In this volume the concept of the geological disposal of radioactive wastes is discussed and repositories in Sweden, Switzerland and Britain described. The selection, status and relevance of studying natural analogues is discussed. Information on the performance of near-field materials in a repository gained from natural analogue studies is evaluated. Detailed descriptions of natural analogue sites such as Pocos de Caldas, Cigar Lake, Needle's Eye and Loch Lomond are given and their importance in advancing the understanding of processes such as radionuclide release and transport are discussed. Finally the application of the information gained from natural analogue studies to the performance assessment for the geological disposal of radioactive wastes is considered. Recommendations are made for future natural analogue studies. (UK).

935 (DOE/IG-0351) **Report on audit of costs and management of the Yucca Mountain Project.** USDOE Office of Inspector General, Washington, DC (United States). Capital Regional Audit Office. 23 Jun 1994. 31p. Sponsored by USDOE, Washington, DC (United States). Source: OSTI (Free of Charge).

Report to The Secretary.

The Department of Energy (Department) is responsible for establishing an underground waste repository to store high-level nuclear waste. To carry out this responsibility, the Department of Energy established the Office of Civilian Radioactive Waste Management (Waste Management Office). The Waste Management Office began characterization of the Yucca Mountain site to assess the feasibility of safely storing spent fuel and high level waste for 10,000 years. To date, the Department had spent about $1.5 billion on site characterization activities. The purpose of our audit was to examine how effectively these funds were spent and to examine the costs and management of contracting for the project. Our audit found that if procurement and fund allocation practices were streamlined, significant savings could be achieved over the remaining life of the project. Also, the anticipated reductions in the number of project participants had not materialized, nor had management and integration of the project been effectively implemented. In addition, the Waste Management Office's efforts to make major staffing reductions had not met the original goals, and sound cost reduction ideas advanced by the project's participants were not evaluated and implemented in a timely manner. Management agreed with our recommendations and is in the process of developing a program-wide strategic plan that recognizes funding constraints and has implemented a reorganization of the management structure at the Project Office.

936 (DOE/IG-0366) **Audit of management of the site characterization program at Yucca Mountain.** Layton, J.C. USDOE Office of Inspector General, Albuquerque, NM (United States). Western Regional Audit Office. 15 Feb 1995. 14p. Sponsored by USDOE, Washington, DC (United States). Source: OSTI (Free of Charge).

Report to The Secretary.

The Department of Energy (Department) is responsible for establishing an underground repository to store high-level nuclear waste. In accordance with the amended Nuclear Waste Policy Act of 1982, the Department began characterization of the Yucca Mountain site to assess the feasibility of safely storing spent fuel and high-level waste for 10,000 years. Site characterization was originally scheduled to be completed in 1995. Subsequently, your predecessor, Admiral Watkins, changed the plan completion date to 2001. The purpose of our audit was to determine if the Department is making adequate progress in characterizing the Yucca Mountain project.

937 (DOE/NV-376) **Waste minimization and pollution prevention awareness plan.** Department of Energy, Las Vegas, NV (United States). Nevada Operations Office. Aug 1994. 68p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94017512. Source: OSTI; NTIS; INIS; GPO Dep.

The primary mission of DOE/NV is to manage and operate the Nevada Test Site (NTS) and other designated test locations, within and outside the United States; provide facilities and services to DOE and non-DOE NTS users; and plan. coordinate, and execute nuclear weapons tests and related test activities. DOE/NV also: (a) Supports operations under interagency agreements pertaining to tests, emergencies, and related functions/activities, (b) Plans, coordinates, and executes environmental restoration, (c) Provides support to the Yucca Mountain Site Characterization Project Office in conjunction with DOE/HQ oversight, (d) Manages the Radioactive Waste Management Sites (RWMS) for disposal of low-level and mixed wastes received from the NTS and off-site generators, and (e) Implements waste minimization programs to reduce the amount of hazardous, mixed, radioactive, and nonhazardous solid waste that is generated and disposed The NTS, which is the primary facility controlled by DOE/NV, occupies 1,350 square miles of restricted-access, federally-owned land located in Nye County in Southern Nevada. The NTS is located in a sparsely populated area, approximately 65 miles northwest of Las Vegas, Nevada.

938 (DOE/NV/10630-28-Add.2) **Addendum to Environmental Monitoring Plan, Nevada Test Site and Support Facilities: Addendum 2.** Reynolds Electrical and Engineering Co., Inc., Las Vegas, NV (United States). Nov 1993. 95p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-89NV10630. Order Number DE94005932. Source: OSTI; NTIS; INIS; GPO Dep.

This 1993 Addendum to the "Environmental Monitoring Plan Nevada Test Site and Support Facilities – 1991," Report No. DOE/NV/10630-28 (EMP) applies to the US Department of Energy's (DOE's) operations on the Continental US (including Amchitka Island, Alaska) that are under the purview of the DOE Nevada Operations Office (DOE/NV). The primary purpose of these operations is the conduct of the nuclear weapons testing program for the DOE and the Department of Defense. Since 1951, these tests have been conducted principally at the Nevada Test Site (NTS), which is located approximately 100 miles northwest of Las Vegas, Nevada. In accordance with DOE Order 5400.1, this 1993 Addendum to the EMP brings together, in one document, updated information and/or new sections to the description of the environmental activities conducted at the NTS by user

organizations, operations support contractors, and the US Environmental Protection Agency (EPA) originally published in the EMP. The EPA conducts both the offsite environmental monitoring program around the NTS and post-operational monitoring efforts at non-NTS test locations used between 1961 and 1973 in other parts of the continental US. All of these monitoring activities are conducted under the auspices of the DOE/NV, which has the stated policy of conducting its operations in compliance with both the letter and the spirit of applicable environmental statutes, regulations, and standards.

939 (DOE/NV/10845–49) **Identification of potential groundwater flow paths using geological and geophysical data.** Pohlmann, K.; Andricevic, R. USDOE Economic Regulatory Administration, Washington, DC (United States). Office of Utility Systems. Sep 1994. 26p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-90NV10845. Order Number DE95006253. Source: OSTI; NTIS; INIS; GPO Dep.

This project represents the first phase in the development of a methodology for generating three-dimensional equiprobable maps of hydraulic conductivity for the Nevada Test Site (NTS). In this study, potential groundwater flow paths were investigated for subsurface tuffs at Yucca Flat by studying how these units are connected. The virtual absence of site-specific hydraulic conductivity data dictates that as a first step a surrogate attribute (geophysical logs) be utilized. In this first phase, the connectivity patterns of densely welded ash-flow tuffs were studied because these tuffs are the most likely to form zones of high hydraulic conductivity. Densely welded tuffs were identified based on the response shown on resistivity logs and this information was transformed into binary indicator values. The spatial correlation of the indicator data was estimated through geostatistical methods. Equiprobable three-dimensional maps of the distribution of the densely-welded and nonwelded tuffs (i.e., subsurface heterogeneity) were then produced using a multiple indicator simulation formalism. The simulations demonstrate that resistivity logs are effective as soft data for indicating densely welded tuffs. The simulated welded tuffs reproduce the stratigraphic relationships of the welded tuffs observed in hydrogeologic cross sections, while incorporating the heterogeneity and anisotropy that is expected in this subsurface setting. Three-dimensional connectivity of the densely welded tuffs suggests potential groundwater flow paths with lengths easily over 1 km. The next phase of this investigation should incorporate other geophysical logs (e.g., gamma-gamma logs) and then calibrate the resulting soft data maps with available hard hydraulic conductivity data. The soft data maps can then augment the hard data to produce the final maps of the spatial distribution of hydraulic conductivity that can be used as input for numerical solution of groundwater flow and transport.

940 (DOE/NV/11417–1) **Great Basin paleoenvironmental studies project: Technical progress report: First quarter (January–August 1993).** Nevada Univ., Reno, NV (United States). Desert Research Inst. [1993]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-93NV11417. Order Number DE94004562. Source: OSTI; NTIS; INIS; GPO Dep.

Project goals, project tasks, progress on tasks, and problems encountered are described and discussed for each of the studies that make up the Great Basin Paleoenvironmental Studies Project for Yucca Mountain. These studies are: Paleobotany, Paleofauna, Geomorphology, and Transportation. Budget summaries are also given for each of the studies and for the overall project.

941 (DOE/NV/11417–2) **Great Basin paleoenvironmental studies project: Technical progress report, second quarter, September–November, 1993.** Nevada Univ., Reno, NV (United States). Desert Research Inst. [1993]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-93NV11417. Order Number DE94004563. Source: OSTI; NTIS; GPO Dep.

Progress is described in the four tasks associated with this project. Task 1, Paleobotanical studies in the Great Basin, has as its objective the reconstruction of the response of vegetation to climate in order to identify periods of mesic climate at Yucca Mountain during the last 20,000 to 50,000 years. Past extremes in infiltration rates are expected to serve as estimates of climate that may be expected during the next 10,000 years at Yucca Mtn. Task 2, Paleofaunas, will construct a history of Great Basin vertebrates that will provide empirical evidence of past environmental and climatic conditions. The objective of Task 3, Geomorphology, is to document the responses of surficial processes and landforms to the climatic changes documented by studies of packrat middens, pollen, and faunal distributions. The goal of Task 4, Transportation, is to compare the results from three models that have been suggested as appropriate for evaluating flood flows on alluvial fans with the results obtained from the traditional one-dimensional, stochastic model used in previous research for Yucca Mountain. This research looked at three alluvial fans with rail transportation alignments crossing them.

942 (DOE/NV/11417–3) **Great Basin paleoenvironmental studies project: Third quarterly technical progress report, December 1993–February 1994.** Nevada Univ., Reno, NV (United States). Desert Research Inst. [1994]. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-93NV11417. Order Number DE94009652. Source: OSTI; NTIS; GPO Dep.

Examination of the paleolithic and geomorphic records to determine the local and regional impact of past climates will advance assessment of Yucca Mountain's suitability as a high-level nuclear waste repository. The project includes the integration of botanical, faunal, and geomorphic components to accomplish this goal. Paleobotanical studies will reconstruct the response of vegetation to climate change at the community and the organismal levels by integrating data obtained from nearly continuous sediment records of pollen, plant macrofossils, and stable isotopes from fossil woodrat middens. The goal of the paleofaunas study is to construct a history of Great Basin vertebrates, particularly mammals, that will provide empirical evidence of past environmental and climatic conditions within the Great Basin as it is recorded by the animals. Taxonomic composition of archaeological and paleontological faunas from various areas within the Great Basin and morphological change within individual mammalian taxa at specific localities are being investigated to monitor faunal response to changing environmental conditions. The objective of the geomorphology component of the paleoenvironmental program is to document the responses of surficial processes and landforms to the climatic changes documented by studies of packrat middens, pollen, and faunal distributions. The project will focus on: (1) stratigraphic relationships between lake deposits and aeolian or fluvial sediments and landforms; (2) cut and fill sequences in

floodplain and river-channel deposits; (3) identification of periods of dune mobility and stability; (4) documentation of episodes of alluvial fan and terrace development and erosion; and (5) correlation of (3) and (4) to climatically driven lake-level fluctuation as revealed by shoreline features such as strandlines and beach ridges. Accomplishments for this period are presented for these studies.

943 (DOE/RW–0253-Rev.5) **Program cost and schedule baseline. Revision 5, (A00000000-00811-1701-00001).** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). Sep 1995. 50p. Sponsored by USDOE, Washington, DC (United States). Order Number DE96000815. Source: OSTI; NTIS; GPO Dep.

The purpose of this document is to establish quantitative expressions of proposed costs and schedule to serve as a basis for measurement of Program performance. It identifies the components of the Program Cost and Schedule Baseline (PCSB) that will be subject to chance control by the Executive (Level 0) and Program (Level 1) Baseline Change Control Boards (BCCBs) and establishes their baseline values. The Program technical baseline is contained in the Civilian Radioactive Waste Management System (CRWMS) Requirements Document (CRD) and the System Requirement Documents (SRDs) for the individual system elements. Changes to the PCSB will be approved by the Program Baseline Change Control Board (PBCCB). In addition to the PBCCB, the Energy System Acquisition Advisory Board Baseline Change Control Board (ESAAB BCCB) will perform control functions relating to Total Project Cost (TPC) and major schedule milestones for the Yucca Mountain Site Characterization Project, the Waste Acceptance, Storage and Transportation (WAST) Project (formerly Monitored Retrievable Storage (MRS) Project), and Program Integration element.

944 (DOE/RW/00286–3) **Public involvement in radioactive waste management decisions.** Council of State Governments, Lombard, IL (United States). Midwestern Office. Apr 1994. 32p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC01-94RW00286. Order Number DE94011159. Source: OSTI; NTIS; INIS; GPO Dep.

Current repository siting efforts focus on Yucca Mountain, Nevada, where DOE's Office of Civilian Radioactive Waste Management (OCRWM) is conducting exploratory studies to determine if the site is suitable. The state of Nevada has resisted these efforts: it has denied permits, brought suit against DOE, and publicly denounced the federal government's decision to study Yucca Mountain. The state's opposition reflects public opinion in Nevada, and has considerably slowed DOE's progress in studying the site. The Yucca Mountain controversy demonstrates the importance of understanding public attitudes and their potential influence as DOE develops a program to manage radioactive waste. The strength and nature of Nevada's opposition – its ability to thwart if not outright derail DOE's activities – indicate a need to develop alternative methods for making decisions that affect the public. This report analyzes public participation as a key component of this openness, one that provides a means of garnering acceptance of, or reducing public opposition to, DOE's radioactive waste management activities, including facility siting and transportation. The first section, Public Perceptions: Attitudes, Trust, and Theory, reviews the risk-perception literature to identify how the public perceives the risks associated with radioactivity. DOE and the Public discusses DOE's low level of credibility among the general public as the product, in part, of the department's past actions. This section looks at the three components of the radioactive waste management program – disposal, storage, and transportation – and the different ways DOE has approached the problem of public confidence in each case. Midwestern Radioactive Waste Management Histories focuses on selected Midwestern facility-siting and transportation activities involving radioactive materials.

945 (DOE/RW–0441) **Regulatory guidance document.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). May 1994. 128p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94015371. Source: OSTI; NTIS; INIS; GPO Dep.

The Office of Civilian Radioactive Waste Management (OCRWM) Program Management System Manual requires preparation of the OCRWM Regulatory Guidance Document (RGD) that addresses licensing, environmental compliance, and safety and health compliance. The document provides: regulatory compliance policy; guidance to OCRWM organizational elements to ensure a consistent approach when complying with regulatory requirements; strategies to achieve policy objectives; organizational responsibilities for regulatory compliance; guidance with regard to Program compliance oversight; and guidance on the contents of a project-level Regulatory Compliance Plan. The scope of the RGD includes site suitability evaluation, licensing, environmental compliance, and safety and health compliance, in accordance with the direction provided by Section 4.6.3 of the PMS Manual. Site suitability evaluation and regulatory compliance during site characterization are significant activities, particularly with regard to the YW MSA. OCRWM's evaluation of whether the Yucca Mountain site is suitable for repository development must precede its submittal of a license application to the Nuclear Regulatory Commission (NRC). Accordingly, site suitability evaluation is discussed in Chapter 4, and the general statements of policy regarding site suitability evaluation are discussed in Section 2.1. Although much of the data and analyses may initially be similar, the licensing process is discussed separately in Chapter 5. Environmental compliance is discussed in Chapter 6. Safety and Health compliance is discussed in Chapter 7.

946 (DOE/RW–0448) **OCRWM Bulletin, summer/fall 1994.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). [1994]. 36p. Sponsored by USDOE, Washington, DC (United States). Source: OSTI; INIS; OSTI (Free of Charge).

This publication consists of two parts, OCRWM Bulletin, and Of Mountains & Science which is about the Yucca Mountain project. The OCRWM bulletin provides information about OCRWM activities, program update to Congress, reorganization, training provided on OCRWM database, OCRWM calendar, and exhibit schedule for 1994. Recent activities at the Yucca Mountain project such as the arrival of the tunnel boring machines is presented in layman's term.

947 (DOE/RW–0449) **FY1993 annual report to Congress.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). Sep 1994. 130p. Sponsored by USDOE, Washington, DC (United States). Order Number DE95003292. Source: OSTI; NTIS; INIS; GPO Dep.

As established by the Nuclear Waste Policy Act of 1982, as amended, the United States Department of Energy's

Office of Civilian Radioactive Waste Management is responsible for managing and disposing of the Nation's spent nuclear fuel from civilian nuclear power reactors and high-level radioactive waste from defense activities. The program will provide leadership in developing and implementing strategies that assure the health and safety of the public and workers, protect the environment, and merit public confidence, in an economically viable manner. To accomplish the program's mission, we are developing a waste management system culminating in a geologic repository for permanent disposal deep beneath the surface of the earth. Our goals include: (1) determining whether Yucca Mountain, Nevada, designated by the Nuclear Waste Policy Amendments Act of 1987 as the only site currently to be evaluated, is suitable for a geologic repository; (2) resolving the issue of acceptance of spent fuel from nuclear utilities in 1998; (3) developing more effective working relationships with external parties who have an interest in the waste disposal mission; and (4) establishing a new funding mechanism that will permit efficient and effective execution of our mission and achievement of our goals. This report contains details of the program's accomplishments and activities over the past fiscal year and the audited financial statements for the Nuclear Waste Fund.

948 (DOE/RW–0460) **OCRWM Bulletin, Winter 1995.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). [1995]. 24p. Sponsored by USDOE, Washington, DC (United States). Order Number DE95008452. Source: OSTI; NTIS; INIS; GPO Dep.

This publication describes activities associated with the United States Department of Energy's Office of Civilian Radioactive Waste Program. Activities at the Yucca Mountain Site Characterization Project are described.

949 (DOE/RW–0464) **Office of Civilian Radioactive Waste Management Fiscal Year 1994 annual report to Congress.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). May 1995. 110p. Sponsored by USDOE, Washington, DC (United States). Order Number DE95013657. Source: OSTI; NTIS; INIS; GPO Dep.

The events of Fiscal Year 1994 made it a notable year in OCRWN's history. Highlights include formulation of a new program approach; intensive consultation with other parties to build confidence in that approach; the delivery, assembly, and initial testing of the tunnel boring machine that is now digging into Yucca Mountain; steps toward acquisition of a standardized multipurpose canister system and planning for the accompanying environmental impact statement; and solicitation, through a Federal Register notice, of utilities' and other interested parties' recommendations toward resolving key waste-acceptance issues.

950 (DOE/RW–0476) **OCRWM Bulletin: Westinghouse begins designing multi-purpose canister.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). Sum 1995. 28p. Sponsored by USDOE, Washington, DC (United States). Order Number DE95017244. Source: OSTI; NTIS; INIS; GPO Dep.

This publication consists of two parts: OCRWM (Office of Civilian Radioactive Waste Management) Bulletin; and Of Mountains & Science which has articles on the Yucca Mountain project. The OCRWM provides information about OCRWM activities and in this issue has articles on multi-purpose canister design, and transportation cask trailer.

951 (DOE/RW–0478) **OCRWM test and evaluaton master plan. Revision 00.** TRW Environmental Safety Systems, Inc., Vienna, VA (United States). Aug 1995. 58p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE95017242. Source: OSTI; NTIS; INIS; GPO Dep.

The Office of Civilian Radioactive Waste Management (OCRWM) Test and Evaluation Master Plan (TEMP) describes the program Test and Evaluation (T&E) policy, objectives, requirements, general methodology (test flow and description of each T&E phase), responsibilities, and scheduling of test phases for the Civilian Radioactive Waste Management System (CRWMS). This TEMP is a program-level management planning document for al CRWMS T&E activities and will be used in conjunction with Section 11 of the Quality Assurance Requirements and Description (QARD), as appropriate, as a guide for the projects in developing their T&E plans. In the OCRWM document hierarchy, that is described in the OCRWM Systems Engineering Management Plan (SEMP), the TEMP is subordinate to the program SEMP. To ensure CRWMS operates as an integrated system, the plans for verifying the performance and evaluating the operational suitability and effectiveness of the overall system are also described. Test and evaluation is an integral part of the systems engineering process. Key aspects of the systems engineering process, more fully described in the OCRWM SEMP, are discussed in this TEMP to illustrate how T&E supports the overall systems engineering process.

952 (DOE/RW–0481) **OCRWM Bulletin: A report from the U.S. Department of Energy's Office of Civilian Radioactive Waste Management.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). Fal 1995. 24p. Sponsored by USDOE, Washington, DC (United States). Order Number DE96002257. Source: OSTI; NTIS; GPO Dep.

This document, entitled the OCRWM Bulletin, is a report from the U.S Department of Energy's Office of Civilian Radioactive Waste Management (OCRWM). This issue contains articles describing the following subjects: regulatory drop tests for spent nuclear fuel transportation casks; Environmental Impact Statement for a multi-purpose canister system for spent nuclear fuels; an update from the nuclear waste technical review board; a dry transfer system for spent nuclear fuels and other miscellaneous articles about spent nuclear fuels. Half of the publication is also devoted to articles involving the Yucca Mountain Project.

953 (EPRI-TR–104012) **A proposed public health and safety standard for Yucca Mountain: Presentation and supporting analysis. Final report.** Kessler, J.H. (Electric Power Research Inst., Palo Alto, CA (United States)); Yang, R.L. Electric Power Research Inst., Palo Alto, CA (United States); Risk Engineering, Inc., Boulder, CO (United States); Del Mar Consulting, Corpus Christi, TX (United States); Polestar Applied Technology, Inc., Los Altos, CA (United States). ©Dec 1994. 148p. Sponsored by Electric Power Research Inst., Palo Alto, CA (United States). Source: EPRI Distribution Center, 207 Coggins Drive, PO Box 23205, Pleasant Hill, CA 94523 (United States).

The National Academy of Science Subcommittee on the Technical Bases for Yucca Mountain Standards (TYMS Committee) requested public input on the technical bases for a performance standard for a potential geologic repository to dispose irradiated fuel and high-level radioactive waste at Yucca Mountain, Nevada. This report proposes a

standard for Yucca Mountain and provides the technical bases for the proposed Standard. EPRI's analysis of the earlier EPA standard found it inappropriate from both a practical and public health protection standpoint. The public health and safety standard that EPRI proposes for Yucca Mountain has two parts. The first part proposes essentially complete containment for 1000 years; the second part is regulatory guidance based on limiting health risk in the long term. This second part requires probabilistic analysis of dose estimates to future populations living in the Yucca Mountain vicinity. This two-part Standard recognizes the difficulties of model prediction in the long term while maintaining a focus on what is most important in any regulatory standard-minimization of long-term human health risk.

954 (EUR–14877) **Oklo working group meeting.** Von Maravic, H. (Commission of the European Communities, Brussels (Belgium)). Commission of the European Communities, Luxembourg (Luxembourg). 1993. 199p. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). Source: OSTI; NTIS (US Sales Only); INIS.

Natural analogue studies have been carried out for several years in the framework of the European Community's R and D programme on radioactive waste; and within its recent fourth five-year programme on 'Management and storage of radioactive waste (1990-94)' the Community is participating in the Oklo study, natural analogue for transfer processes in a geological repository. The Oklo project is coordinated by CEA-IPSN (F) and involves laboratories from several CEA directorates (IPSN, DTA and DCC) which collaborate with other institutions from France: CREGU, Nancy; CNRS, Strasbourg and ENSMD, Fontainebleau. Moreover, institutes from non-EC member States are also taking part in the Oklo study. The second joint CEC-CEA progress meeting of the Oklo Working Group was held in April 1992 in Brussels and gave the possibility of reviewing and discussing progress made since its first meeting in February 1991 at CEA in Fontenay-aux-Roses. About 40 participants from 15 laboratories and organizations coming from France, Canada, Gabon, Japan, Sweden and the USA underline the great interest in the ongoing research activities. The meeting focused on the different tasks within the CEC-CEA Oklo project concerning (i) field survey and sampling, (ii) characterization of the source term, (iii) studies of the petrographical and geochemical system, and (iv) studies of the hydrogeological system and hydrodynamic modelling. (author) 17 papers are presented.

955 (EUR–14877, pp. 9-14) **Oklo, natural analogue for transfer processes in a geological repository: an overview.** Chapuis, A.M. (CEA Centre d'Etudes de Fontenay-aux-Roses, 92 (France). Inst. de Protection et de Surete Nucleaire); Blanc, P.L. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

The uranium ore body in Oklo is a unique subject in the world, as natural fission reactions occurred there two billion years ago. It provides opportunities for the study of natural analogy with deep radioactive waste disposal, specially radionuclide mass transfer processes to the surface. The ongoing program is co-funded by the CEC, and it involves several directorates in the CEA, that is to say the IPSN, plus DTA and DCC. Other, non-CEC agencies also take part in the studies, such as SKB (Sweden), AECL and ONTARIO-HYDRO (Canada). It can be subdivided into several different tasks: (1) In situ sampling, in close collaboration with the mining company (C.O.M.U.F., Compagnie des Mines d'Uranium de Franceville, Mounana, Gabon). (2) Study and characterization of the source term (mostly in CEA laboratories). (3) Studies on the geochemical systems ruling the migrations, implying collaboration between CEA laboratories and other institutions: CREGU (Centre de Recherches sur la Geologie des matieres premieres minerales et energetiques, formerly "de l'Uranium", Nancy), Centre de Geochimie de la Surface (CNRS, Strasbourg), and Ecole Nationale Superieure des Mines de Paris (ENSMP, Centre de Geologie Generale et Miniere and Centre d'Informatique Geologique, Fontainebleau). (4) Modelling: Part of the modelling will take place in each laboratory involved, but the final coupling of models will be the responsibility of IPSN and ENSMP. (author). 1 fig.

956 (EUR–14877, pp. 15-24) **The reaction zones and the rock sampling in Oklo-Okelobondo.** Peycelon, H. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

Since 1972, 16 reaction zones have been discovered. Eleven of those are located in the Oklo open pit and are mined out. Nowadays the interesting zones for the natural analogue project are located underground and had been identified as zones 10, 13 and 16 in the mining works of Oklo and in the borehole OK 84 at Okelobondo. The sampling had been picked up in the reaction zones and in their peripheric areas. Far from the reaction zones fractures, falts, organic matters and dolerite have also been sampled. The aim of the sampling was to find rocks which shows fluid circulation evidence. Particular attention has been paid to: 1- The limits of layers. 2- The interlayers: pelitic and fine black sandstones where little veins of calcite was frequently found. 3- The fractures, falts and hydraulic fracturated rocks. Less systematically and to complete the sampling some samples have been taken in the layers and are representative of the common uranium ore. (author). 6 figs., 2 refs.

957 (EUR–14877, pp. 25-35) **Geochemical and isotopic characterization of the reaction zones (uranium, transuranium, lead and fission products).** Holliger, P. (CEA Centre d'Etudes de Grenoble, 38 (France)). Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

New in-situ isotopic studies have been carried out on polished sections from the Oklo nuclear reactor zones. Interpretations of U - Fission Products (F.P) analyses allow to calculate the main nuclear reaction parameters (fluence, neutron spectrum, conversion factor, fission proportion of ^{235}U, ^{238}U and ^{239}Pu, lifetime of the reactors,...) of the newly discovered reactor zones. U-Pb measurements on uranium oxides and galenas show that 1.95 billion years is the primary age of the Oklo uranium deposit and 750 million years is the time of an episodic disturbance with U and Pb local isotopic homogenization and redistribution. This major episode of U and Pb migration was probably caused by the

intrusion of a dolerite dyke which cuts across the Oklo deposit near to the reactor zone 13. Samples from parts of reactor zones 10 and 13, located in sandstone and massive uraninite respectively, were studied in order to examine the stability of fission products relative to uranium. Ion microprobe images show a good retention of numerous FP (e.g Rare Earth Elements) and transuranium elements in the UO_2 matrix and the existence of tiny inclusions containing Ru, (Tc), Rh, Pd, Mo and Te together with Pb, As and S. (author). 4 refs., 6 figs., 3 tabs.

958 (EUR–14877, pp. 37-44) **Migration of radioelements around the new nuclear reactors at Oklo: petrological and geochemical results.** Menet-Dressayre, C. (CEA Centre d'Etudes de la Vallee du Rhone, 30 - Marcoule (France). Direction du Cycle du Combustible); Menager, M.T. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

Samples from a new natural reactor of Oklo (zone 10) have been investigated with the aim of specifying possible elemental migrations into its close surroundings. The mineralogy demonstrates the occurrence of a redox front at the boundary of the reactor. We show first that significant migration of rare earths and uranium took place on a decimetric scale around the reactor and that secondary phases (both clay minerals, carbonates filling fissures and accessory minerals such as zircon) are responsible for their subsequent immobilization within the rock. (author). 2 refs., 1 fig., 3 tabs.

959 (EUR–14877, pp. 45-55) **Geochemistry of apatites, pyrites and galenas in near- and far-field veins and sandstones around the Oklo fossil reactors (Gabon): identification of ancient hydrothermal circulations.** Raimbault, L. (Ecole Nationale Superieure des Mines, 77 -Fontainebleau (France). Centre d'Informatique Geologique). Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

The identification and the modelling of fission-product transfer from reactor cores to near-and far-field surrounding rocks, are a prerequisite to the use of the Oklo fossil reactors as a natural analogue of radioactive waste disposal. It is thus necessary to characterize the different hydrothermal circulation stages which occurred in the deposit, for their ability to carry away radionuclides to be assessed. The problems to be solved are as follows:(1) to identify each stage, (2) to constrain the chemical composition of these fluids as precisely as possible, (3) to determine fluid pathways, and if possible, (4) to assign the source(s) of matter carried by each fluid, and the source of energy needed for fluid convection. This paper presents the geochemistry of apatites, pyrites and galenas. (author). 3 refs., 4 figs., 2 tabs.

960 (EUR–14877, pp. 57-65) **Dating of the Francevillian sedimentary series and mineralogic and isotopic (Sm, Nd, Rb, Sr, K, Ar, U, O and C) characterization of the gangue of the reactors 10 and 13. Preliminary report.** Gautier-Lafaye, F. (Centre National de la Recherche Scientifique (CNRS), 67 - Strasbourg (France). Centre de Sedimentologie et Geochimie de la Surface); Stille, P.; Bros, R.; Taieb, R. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

This paper summarizes the various ages reported for the diagenetic events in the Francevillian sedimentary series (Precambrian era) and the fission reactors of Oklo. Obviously, differences exist between the ages obtained on the silicate minerals and the ages obtained on the Uranium ores and on the reactors. Clay minerals which crystallized during the fission reactions yield younger ages than the reactors themselves. Similarly, the diagenetic clays (1870 Ma) show younger ages than the Uranium ores (2000 Ma). This is in contrast to mineralogical and field evidence indicating that Uranium mineralization occurred during diagenesis of the Francevillian sediments. These antithetical results give rise to several questions. Does the age obtained on the diagenetic clays date a late thermal event or does the age of the Uranium mineralization reflect a multistage U-Pb history. This work tries to bring answers with the help of new isotopic analysis and studies mineralogy of the gangue of reactors and isotopic compositions in Uranium ores. 8 refs., 4 figs.

961 (EUR–14877, pp. 67-70) **Natural analogues of bitumen matrices in a deep repository.** Petit, J.C. (CEA, 75 - Paris (France)); Landais, P. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

Bitumens are used for the solidification of low-activity alpha-containing wastes and their long-term behaviour in geological conditions remain questionable. It is thus proposed in this work to gain some understanding on this issue by studying natural analogues of technological bitumens which have been poorly investigated, from this viewpoint, until now. In particular, we intend to characterize the organic matter associated with the Oklo nuclear reactors (Gabon) and to estimate the specific consequences of radiation damages, notably radiolytic effects, by comparison with organic matter collected outside the reaction zones and having variable uranium concentrations. The work will concentrate on two distinct aspects: firstly, the structural and chemical modifications induced by the radiation damages in the organic matter; secondly, the changes in the leaching behaviour of various elements (e.g. U, REE, etc.) possibly deriving from these radiation-induced alterations. The Oklo reactors are a priori favourable, as natural analogues, because of the long time scale involved, the association of bitumen and uraninite (UO_2), the presence of daughters of fission products and transuranium elements generated by the nuclear reactions which induced various radiation effects. (author).

962 (EUR–14877, pp. 71-80) **Hydrogeology of the Oklo-Okelobondo site.** Gurban, I. (Ecole Nationale Superieure des Mines, 75 - Paris (France)); Ledoux, E.; Blanc, P.L.; Escalier des Orres, P.; Bourguet, L. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

This study gives an account of all the hydrogeological data from the Oklo-Okelobondo site obtained so far. This hydrogeological overview has led to the proposal of a hydrodynamic flow pattern for the system and the choice of a study area as a basis for a preliminary modelling of groundwater flow and solute transport in the far field. (author). 5 refs., 4 figs.

963 (EUR–14877, pp. 81-99) **Far field hydrogeochemistry in the Oklo reactor area (Gabon).** Toulhoat, P. (CEA Centre d'Etudes de Cadarache, 13 - Saint-Paul-lez-Durance (France). Dept. Stockage Dechets); Gallien, J.P.; L'Henoret, P. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

In the frame of a general study of the Oklo natural reactor, which takes into account the natural analogue aspect, a complete hydrogeological and hydrogeochemical study is undertaken. The partners of this study are the following: - Section de geochimie, CEA (France): P. Toulhoat, J.P. Gallien, P. L'Henoret, V. Moulin (groundwater chemistry and colloids). - Ecole des Mines de Paris (CIG, Fontainebleau) E. Ledoux, I. Gurban (hydrogeology and modelling) - SKB and Conterra AB (Sweden) J.A.T. Smellie, A. Winberg (hydrogeology, isotope geochemistry). The aim of this study is to try to understand and to characterize the possible mobilization of elements or isotopes when groundwaters come in contact with nuclear reaction zones. The first step of the study is presented here, which comprises a general geochemical and hydrodynamical characterization of the site. In this presentation, the site of Bagombe is also mentioned as it has been confirmed as sector in which nuclear fission reactions occurred as in Oklo. (author). 10 refs., 6 figs., 6 tabs.

964 (EUR–14877, pp. 101-116) **Analysis of waters from the Oklo reactor area: preliminary results on the content of organic substances and colloids.** Moulin, V. (CEA Centre d'Etudes de Cadarache, 13 - Saint-Paul-lez-Durance (France). Dept. Stockage Dechets); Vilarem, J.P. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

The migration of radionuclides, in a nuclear waste disposal in geological formation, depends in part on the physico-chemical forms of the radioelements present in the natural aquifer. In particular, the presence of colloids (entities defined as dispersed particles with size of 1 nm-1 μm) may alter the speciation of radioelements and hence, change their behaviour. Their mobility may be enhanced or decreased by sorption or complexation reactions. These colloids may be inorganic particles (silicates, silico-aluminates, metallic hydroxides, etc) or organic particles (such as humic substances constituted by humic and fulvic acids). Moreover, these colloids may exist in different natural systems (e.g. surface, marine and groundwaters) often associated with humic substances. The evaluation of the importance of colloids in the dissemination of radioactivity necessitates, in particular, the determination of their concentration in the waters sampled on the site, and their characterization (composition, size). In the framework of a general study of the Oklo natural reactor, a complete hydrogeochemical and hydrogeological study is undertaken. Preliminary studies on the colloid content of different water samples from the Oklo reactor area have been performed to complete the study of the groundwater chemistry presented by Toulhoat et al. (1991, 1992). These complementary studies have, as objectives, to evaluate: - the occurrence of colloids by scanning electron microscopy (after ultrafiltration) and by photon correlation spectroscopy, -the occurrence of organic materials by the analysis of the total organic carbon content. (author). 4 refs., 8 figs.

965 (EUR–14877, pp. 117-129) **A first attempt at modelling groundwater flow and mass transport in the far field.** Gurban, I. (Ecole Nationale Superieure des Mines, 75 - Paris (France)); Ledoux, E.; Raimbault, I.; Blanc, P.L.; Escalier des Orres, P. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

The purpose of this study is to identify and then to model the present transfer of groundwater which might set in motion elements produced in the reaction zone. Consequently, the first stage of this study consisted of a hydrochemical overview of the Oklo-Okelobondo site into which all previous and current information, gathered during missions in September 1990 and June 1991 was integrated. In the second stage of the study, a preliminary hydrodynamic model was built. In a plausible context and based on the collected data, the study area, the drainage of the domain and the aquifer layers were defined and a conceptual hydrogeological flow pattern proposed. The data made it possible to begin the hydrodynamic modelling of current migration basing it on a pattern of groundwater circulation and bearing in mind the morphology of the soil surface and of the geological strata and taking into account the first results of the hydrochemical analyses. (author). 7 refs., 1 tab.

966 (EUR–14877, pp. 131-141) **Swedish activities in the Oklo natural analogue project.** Smellie, J.A.T. (Conterra AB, Uppsala (Sweden)); Winberg, A.; Karlsson, F. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

Presently, many countries are concerned about the need for a safe method to dispose of high-level nuclear wastes. The various national regulatory agencies involved generally require quantitative predictions for at least the first 10^4 years after disposal, and qualitative predictions of repository safety performance for up to 10^6 years. Predicting what this future behaviour will be can be considerably facilitated by comparison with the evolution of parallel natural geochemical systems, particularly those rich in radioelements. Such natural systems provide a unique opportunity to test, by observation and measurement, many of the geochemical processes that are expected to influence the predicted reliability of high-level radioactive waste containment deep in the bedrock for long periods of geological time, providing direct and indirect validation support for some of the models and data used in performance assessment. Oklo, by virtue of representing a fossil natural reactor which achieved criticality some 2 000 Ma ago, provides a unique opportunity to

show whether the stable nuclear fission end-products have remained, in the near-vicinity of the reactor zone subsequent to fission. Furthermore, the materials found in the Oklo reactors resemble closely important waste forms such as spent nuclear fuel and bitumised residue and have been subject to extreme geochemical reactions and radiolysis when related to expected site disposal conditions, and for a much longer time. In order to study such effects, not only do the reactor zones require further detailed mineralogical, geochemical and radiochemical study, but equally the geological setting and hydrological environment of the reactor zones also need to be understood. For this reason SKB are interested to study the spatial distribution of the reactor zones at Oklo, Okelobondo and Bagombe in the context of the large-and small-scale groundwater hydraulics of the host sedimentary rocks. (author). 7 refs., 1 fig.

967 (EUR–14877, pp. 143-152) **Oklo stable isotopes.** Jakubick, A.T. (Ontario Hydro Research Lab., Toronto, ON (Canada)); O'Neill, J.A.; Gnoyke, R.; Thomas, G.F. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204265–: Migration of radionuclides in the geosphere meeting, Brussels (Belgium), 9-10 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

It is generally accepted that the fission reactions at Oklo resulted in convective circulation of the water heated up in the reactor zones. These convective currents were likely the main cause for the redistribution of some of the uranium of the reactor zones and most of the migration of the fission products possibly occurred at this stage. In order to derive generic conclusions applicable to the problems of nuclear waste disposal one has to identify the pattern of circulation of the convective currents and relate the observed distribution of elements around the reactor zones to the patterns left behind by the paleohydrogeological regime. The objective of this project is to discern and delineate the pathways of elemental migration by determining the deuterium and oxygen signature in the rocks confining the reactor zones. Furthermore the stable isotope analysis provides insights regarding water-rock interaction. In pursuit of this objective the Toronto team is concentrating on measurements of deuterium while F. Gauthier-Lafaye of Strasbourg is responsible for the analysis of the oxygen isotopes. In the final synthesis of the results beyond the main objective we intend to evaluate the differences in migration between the various members of the decay chains by means of a semi-analytical 3 dimensional model. (author). 8 refs., 1 fig., 1 tab., 2 appendices.

968 (EUR–14877, pp. 153-166) **X-ray photoelectron spectroscopic study of a sample from a natural fission reactor at Oklo, Gabon.** Sunder, S. (Atomic Energy of Canada Ltd., Pinawa, MB (Canada). Whiteshell Nuclear Research Establishment); Sargent, F.P.; Miller, N.H. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

X-ray photoelectron spectroscopy (XPS) was used to study a sample from a natural fission reactor, reaction zone number 13, at Oklo (Gabon). Peaks due to uranium, oxygen, carbon, lead, silicon, calcium, aluminum, sulfur thorium and bismuth were seen in the XPS spectra. High-resolution spectra were recorded for the U, Pb, O, and C bands to determine the chemical state of these elements. The oxidation state of uranium in the sample is predominantly U^{4+}, with a U^{6+}/U^{4+} ratio of about 0.11. Lead was in the +2 oxidation state. The carbon signal indicated the presence of organic carbon, while the oxygen bands indicated the presence of water. The significance of the results for nuclear fuel waste management is discussed. (author). 27 refs., 7 figs., 2 tabs.

969 (EUR–14877, pp. 167-175) **Geochemical behaviour of fissiogenic Rb, Sr, Cs and Ba in SF84 (zone 10).** Hidaka, H. (Tokyo Metropolitan Univ. (Japan)); Holliger, P. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

In order to estimate the geochemical behaviour of fission products in the Oklo reactor and to determine the various characteristics of the reactor, isotopic measurements of many elements (Rb, Sr, Zr, Mo, Ru, Pd, Ag, Cd, In, Sn, Te, Ba and REE) are being carried out with thermal ionization mass spectrometer. Our attention in this report is focused only on alkali and alkaline earth elements from SF84 (Zone 10) samples. Until now, some isotopic studies have been performed to search for fissiogenic Rb, Sr, Cs and Ba of Oklo samples, but with little success. The extremely low retentivity in the reactor and the presence of high abundances of natural elements make the isotopic compositions of Rb, Sr and Ba little anomalous. (author). 7 refs., 3 figs., 2 tabs.

970 (EUR–14877, pp. 177-188) **Heterogeneity and alteration of uraninite from the natural fission reactor 10 at Oklo, Gabon.** Ewing, R.C. (New Mexico Univ., Albuquerque, NM (United States). Dept. of Geology); Janeczek, J. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

A mineralogical study of uranium ore from reactor zone 10 revealed that uraninite in the natural reactors at Oklo, Gabon, has been altered through partial dissolution, Pb loss, and replacement by coffinite, $USiO_4.nH_2O$. The dissolution occurred during formation of the clay mantle surrounding the ore body and was probably caused by hydrothermal saline solutions under reducing conditions. The loss of lead (up to 11 wt%) from uraninite occurred approximately one billion years after the operation of the reactors. As a result, there are two generations of uraninite in the reactor zone that differ in chemical composition and unit cell parameters [a_1 = 0.5495(2) and a_2 = 0.5455(2) nm]. Minor coffinitization of uraninite has also occurred. Thus, the Oklo deposit has been altered since the event of nuclear criticality. This provides several distinct geochemical environments in which one may analyze the corrosion of uraninite and the subsequent retention or migration of fission products. (author). 20 refs., 3 figs., 1 tab.

971 (EUR–14877, pp. 189-194) **Effects of organic matter on the containment of uranium and fissiogenic isotopes in the Oklo natural reactors.** Nagy, B. (Arizona Univ., Tucson, AZ (United States). Dept. of Geosciences). Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA

Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

Several of the Proterozoic natural fission reactors at Oklo in the Republic of Gabon contain abundant organic matter. Organic petrography including reflectance measurements, Rock-Eval pyrolysis, microfocused-laser Raman spectrometry, pyrolysis-gas chromatography-organic mass spectrometry, pyrolysis-high resolution organic mass spectrometry, ion microprobe and thermal ionization isotope mass spectrometry, backscattered scanning electron microscopy and electron microprobe analyses were used to characterize the organic matter and its associated minerals in and in the vicinity of the organic-rich reactors 7-9. Nonuraniferous organic samples distant from the reactors were also examined by most of these analytical techniques. There are two types of organic matter in the natural reactors and in the distant sedimentary rocks: solid bitumen and kerogen. Both of these organic substances consist of a condensed aromatic hydrocarbon macromolecular matrix which contains dispersed fine-grain size, cryptocrystalline graphite. Liquid bitumen was generated during criticality through reaction mechanisms involving water at elevated temperatures. Later the liquid bitumen became a solid. The liquid bitumen helped to reduce U(VI) to U(IV) from aqueous solutions, resulting in the precipitation of uraninite which incorporated fissiogenic isotopes. These uraninite crystals were coated and enclosed in bitumen, which held them immobile after its solidification. This mechanism prevented ^{235}U and fission product losses for long periods of time. Organic matter in the natural reactors and uranium ores have a less tightly bound macromolecular matrix than organics in the nonuraniferous and distant sedimentary rocks, but the looser molecular matrix did not hinder ^{235}U and fission product retention. (author). 19 refs., 2 tabs.

972 (FRCEA-TH–486) **Radioactive waste storage: historical outlook and socio technical analysis.** Petit, J.C. CEA Centre d'Etudes Nucleaires de Saclay, 91 - Gif-sur-Yvette (France). Direction du Cycle du Combustible; Ecole Nationale Superieure des Mines, 75 - Paris (France). Jul 1993. 356p. (In French). Order Number DE95631542. Source: OSTI; NTIS; INIS.

The radioactive waste storage remains, in most of the industrialized concerned countries, one extremely debated question. This problem may, if an acceptable socially answer is not found, to create obstacles to the whole nuclear path. This study aim was to analyze the controversy in an historical outlook. The large technological plans have always economical, political, sociological, psychological and so on aspects, that the experts may be inclined to neglect. "Escape of radioactivity is unlikely, as long as surveillance of the waste is maintained, that is, as long as someone is present to check for leaks or corrosion or malfunctioning of and to take action, if any of these occur. 444 refs., 32 figs.

973 (IAEA-TECDOC–732, pp. 119-128) **United States high-level radioactive waste management program: Current status and plans.** Williams, J. (Department of Energy, Washington, DC (United States). Office of Civilian Radioactive Waste Management). International Atomic Energy Agency, Vienna (Austria). Feb 1994. (CONF-9308225–: Regular advisory group meeting on spent fuel management: Current status and prospects, Vienna (Austria), 31 Aug - 3 sep 1993). In *Spent fuel management: Current status and prospects 1993: Proceedings of a regular advisory group meeting held in Vienna, 31 August-3 September 1993.* 131p. Order Number DE94623709. Source: OSTI; NTIS (US Sales Only); INIS.

Over 20% of the electricity generated in the United States is produced by 108 commercial nuclear reactors. U.S. commercial nuclear utilities are currently storing spent nuclear fuel at the reactor sites. Spent fuel is stored in fuel pools at 70 sites around the country, in addition to several utility at-reactor dry storage installations. To date, the total quantity of spent fuel accumulated at reactor sites is approximately 24,000 metric tons of heavy metal (MTHM). According to current projections, by the time the last license for the current generation of nuclear reactors expires, the estimated total quantity of spent fuel requiring disposal will reach about 86,000 MTHM. We have been conducting a program directed at developing a waste-management system consisting of a geologic repository, with a projected start date of 2010; a monitored retrievable storage facility (MRS); and a transportation system to support storage and disposal operations. Until the Federal system starts to accept spent fuel for storage and disposal, commercial utilities are responsible for managing their spent fuel. To facilitate spent-fuel management at reactor sites and in the Federal system, we are evaluating the development and use of multipurpose canisters. These metal canisters would be used with appropriate overpacks for (1) storage, at reactor sites or at a Federal facility; (2) transportation; and (3) permanent disposal. Our repository program remains focused on the scientific investigations needed to determine whether the candidate site (Yucca Mountain in Nevada) is suitable. For the MRS, we remain optimistic that a volunteer site will be found through the efforts of the Nuclear Waste Negotiator. With a conceptual design completed, we are deferring major new MRS activities until a site has been identified. Our transportation strategy is directed at being able to transport spent fuel as soon as a storage facility is ready to accept it. (author).

974 (INIS-mf–13846, pp. 2.51-2.61) **Nuclear waste disposal and the environment.** Torgerson, D.F. (Atomic Energy of Canada Ltd., Pinawa, MB (Canada). Whiteshell Nuclear Research Establishment); Soonawala, N.M. Canadian Nuclear Association, Toronto, ON (Canada). 1990. 245p. (CONF-900621–: 30. annual conference of the Canadian Nuclear Association and the 11th annual conference of the Canadian Nuclear Society, Toronto (Canada), 3-7 Jun 1990). In *Proceedings of the 30. Annual Conference of the Canadian Nuclear Association.* Order Number DE94622203. Source: OSTI; NTIS (US Sales Only); INIS.

The Canadian Nuclear Fuel Waste Management Program, under which research has been carried out for more than a decade, is assessing the concept of deep geological disposal of nuclear fuel waste. The quantity of used fuel produced after a century of nuclear power production will be comparable to the uranium content of a large uranium ore body. The research has assessed engineered and natural systems for containing and retarding radionuclides that may be released from the vault. The geology of Precambrian rocks has been studied in detail. Extensive hydrogeological research has been carried out to study the flow and chemistry of groundwater up to a kilometer below the surface. Studies have been carried out on the behaviour of radionuclides in the surface waters, soils, the atmosphere, and the food chain. Mathematical modelling is being carried out to assess the environmental impact and safety of the disposal system. Studies of natural analogs, such as the uranium ore body at Cigar Lake have provided information on important

processes over very long times. These results will be submitted for review under the federal Environmental Assessment and Review Process. Acceptance and implementation of the concept for nuclear fuel waste disposal would demonstrate final closure of the nuclear fuel cycle. 15 refs.

975 (INIS-mf-13849, pp. 113-135) **Design considerations at the Cigar Lake project.** Peebles, G.A. (Cigar Lake Mining Corporation, Cigar Lake, Saskatchewan (Canada)). Canadian Nuclear Association, Toronto, ON (Canada). 1988. 413p. (CONF-880662--: 28. annual conference of the Canadian Nuclear Association and the 9. annual conference of the Canadian Nuclear Society, Winnipeg (Canada), 12-15 Jun 1988). In *Proceedings of the Canadian Nuclear Association 28. annual conference.* Order Number DE94622204. Source: OSTI; NTIS (US Sales Only); INIS.

The Cigar lake uranium deposit in northern Saskatchewan is the largest high grade uranium deposit in the world with a total reserve of 385 million pounds U_3O_8. The main section of the deposit has a total geological reserve of 285 million pounds at an average grade of 14% U_3O_8. This paper describes the geological characteristics of the deposit and the development of the test mining program.

976 (INIS-mf-14377) **Alligator Rivers Analogue project - Geologic Setting: Final Report - Volume 2.** Snelling, A.A. Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 118p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95606001. Source: OSTI; NTIS (US Sales Only); INIS.

In this volume the author synthesizes the results of the investigations carried over more than 20 years in the Koongarra area. It describes its regional geologic setting, geological evolution and the exploration activities carried out to date. The secondary ore of the Koongarra No. 1 uranium orebody provides a natural analogue suitable for validation of models for radionuclide transport. Although the primary uranium mineralisation occurs as uraninite veins and veinlets in fractures and brecciated zones that cross cut the steeply dipping (55 deg.C) host schists, weathering and dispersion of uranium within the zone of weathered schists has formed this secondary ore. The interaction of the weathering processes with the mineralogy and geochemistry of the unweathered host schists, and the primary hydrothermal alteration halo with and around the primary uranium mineralisation, has also been critical in the development of the secondary ore. This secondary ore natural analogue being at a shallow depth, plus the availability of open boreholes and drill core/borehole samples, has facilitated groundwater and rock investigations. 49 refs., 4 tabs., 42 figs.

977 (INIS-mf-14378) **Alligator Rivers Analogue project. Geomorphology and paleoclimatic history: Final Report - Volume 3.** Wyrwoll, K.H. (Univ. of Western Australia, Nedlands, WA (Australia)). Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 93p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95606009. Source: OSTI; NTIS (US Sales Only); INIS.

The aim of this volume is to discuss the likely influence of geomorphological and palaeoclimatic controls on the development of the secondary dispersion fan at Koongarra. For the Koongarra area the Phanerozoic was a time of tectonic stability and predominantly subaerial denudation. The structural geology of the region facilitated the erosion of the Kombolgie Formation, setting in train the development of Koongarra Valley. With the removal of the Kombolgie cover the surface of the Cahill Formation could then be eroded. The geochemical controls on the development of the secondary dispersion fan require the orebody to be located in an oxidising weathering environment. Under the present weathering regimes it seems that this implies that the orebody is located at a depth of less than 30 m. From estimates of the present regional denudation rates of the area and wider geomorphological considerations, it is concluded that the top of the orebody would have reached such a depth at some time in the last 1-6 million years. The climates of the Late Quaternary provide some guide to Pleistocene climatic events. The most intense aridity coincided with times of global glacial maxima. There is also evidence that in the Late Cenozoic there were times of elevated rates of chemical weathering. However, the timing, nature and duration of such events is unclear. 171 refs., 4 tabs., 35 refs.

978 (INIS-mf-14379) **Alligator Rivers Analogue project. Geophysics, petrophysics and structure: Final Report - Volume 4.** Emerson, D.W. (Sydney Univ., NSW (Australia). Dept. of Geology and Geophysics); Mills, K.J.; Hallett, M.S.; Cao, L.Q.; Miyakawa, K. Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 125p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95606010. Source: OSTI; NTIS (US Sales Only); INIS.

The geophysical and geological field work at Koongarra (including borehole core logging) showed that the site itself is a folded, faulted, variably fractured Precambrian psammitic and pelitic schist sequence with a quasi-horizontal weathered zone superimposed on the steeply dipping rock fabric. The site is flanked by a high resistivity younger sandstone unit to the northwest and by a magnetic amphibolite/ferricrete sequence to the far southeast. The data interpretations elicited the essential structural and broad lithological elements. Gravity, magnetic and electrical laboratory and field studies confirmed a broad folded fractured sequence of dipping layered host rocks weathered in their upper parts and trending in a southwest-northeast direction. Qualitatively interpreted anomalies indicated the trend of the main groundwater movement to the south where dolomites are thought to act as a sink. These drainage features have SP, resistivity and radiometric expression. The roles of the Kombolgie Sandstone as a source of water and the Koongarra Fault as a barrier or otherwise were not established owing to the lack of sufficient samples for testing and also on account of the difficulty of geophysical access over the site's rugged escarpment. 40 refs., 13 tabs., 69 figs.

979 (INIS-mf-14380) **Alligator Rivers Analogue project. Groundwater Chemistry: Final Report - Volume 7.** Edis, R. (Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia)); Waite, D.; Herczeg, A.L.; Sekine, Keiichi; Yanase, Nobuyuki; Seo, Toshihiro. Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 185p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95605960. Source: OSTI; NTIS (US Sales Only); INIS.

The objective of this volume is to provide an account of the groundwater sampling and analysis program undertaken at Koongarra, as part of the Alligator Rivers Analogue Project. Chemical parameters were investigated in groundwaters at various locations and depths in the vicinity of the Koongarra orebody. Measurements of the pH, redox state, conductivity, and bicarbonate alkalinity provided a starting

point for interpreting water chemistry. Groundwater samples were obtained using submersible pumps, or, in a few cases, bailers. The concentrations of major cations and anions, such as magnesium and phosphate, were determined using a variety of standard techniques. Numerous elements were routinely analysed using quantitative or semi-quantitative ICPMS. Uranium series radionuclides and environmental isotopes were measured using radiochemical techniques and mass spectrometry. The distributions of isotopes such as deuterium, tritium, ^{210}Pb, ^{13}C and ^{14}C enabled groundwater mixing and flow-paths to be studied. The occurrence and distributions of major species at Koongarra are presented in this volume, using both cross-sections and contour plans. Chemical and isotopic data for groundwater analyses carried out during the project are included in the Appendices. 47 refs., 16 tabs., 58 figs.

980 (INIS-mf-14381) **Alligator Rivers Analogue project. Weathering and its effects on uranium redistribution: Final Report - Volume 9.** Isobe, H. (Japan Atomic Energy Research Inst., Tokai, Ibaraki (Japan). Tokai Research Establishment); Ohnuki, T.; Yanase, N.; Sato, T.; Kimura, H.; Sekine, K.; Nagano, T.; Edis, R.; Klessa, D.A.; Conoley, C.; Nakashima, S.; Ewing, R.C. Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 138p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95605961. Source: OSTI; NTIS (US Sales Only); INIS.

In the vicinity of the uranium ore deposit at Koongarra, quartz-chlorite schist, the ore host rock, has been subjected to weathering. Although quartz is resistant to weathering, chlorite has been altered to clays and iron minerals. The chlorite weathering and the uranium association with the weathered minerals are the main topics of this study. In order to clarify the weathering of chlorite and its effects on the redistribution of uranium, the processes, mechanisms, and kinetics of the chlorite weathering, and the uranium concentrations in minerals were examined by various methods: X-ray diffraction analysis, scanning electron microscopy, electron microprobe analysis, transmission electron microscopy, autoradiography, visible spectroscopy, alpha and gamma spectrometry. The observed results were compared to those calculated, based on two different models developed for the present study. Water-rock interactions have resulted in the weathering of chlorite and precipitation and sorption of uranyl from the groundwaters with the weathering products. It is concluded that the chlorite weathering affects the uranium retardation factor, and thus uranium redistribution at Koongarra. 55 refs., 20 tabs., 120 figs.

981 (INIS-mf-14382) **Alligator Rivers Analogue project. Geochemical Data Bases: Final Report - Volume 10.** Bennett, D.G. (W.S. Atkins Environment, Epsom, Surrey (United Kingdom)); Read, D. Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 56p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95605962. Source: OSTI; NTIS (US Sales Only); INIS.

The Koongarra uranium deposit in the Northern Territory of Australia is being studied to evaluate the processes involved in the geochemical alteration of the ore body and the formation of the uranium dispersion fan. A broad range of research is being undertaken into the geochemistry and hydrology of the site with the aim of understanding the transport of radionuclides through the system. During the project a range of geochemical and hydrogeochemical models have been developed to account for measured data from the site and with which to predict site evolution. The majority of these models are based on the premise of thermodynamic chemical equilibrium and employ fundamental thermodynamic data to characterise the chemistry of the system. From the differences which exist between the thermodynamic data bases (Appendices I and II) it is possible to gain a view of the level of uncertainty associated with thermodynamic data in each set of calculations. This report gives a brief introduction to the geochemical processes underlying the models, and details the equations used to quantify the more common of these processes (e.g. aqueous speciation and mineral solubility). A description is given of the computer codes (EQ3/6, PHREEQE, MINTEQ) most commonly used during the project for geochemical modelling. Their key features are highlighted and comparisons made. It is concluded that the degree of uncertainty in geochemical modelling studies arising as a result of using one code rather than another is relatively insignificant when compared to that related to differences in the underlying data bases. 73 refs., 3 figs.

982 (INIS-mf-14383) **Alligator Rivers Analogue project. Geochemistry of ^{239}Pu, ^{129}I, ^{99}Tc and ^{36}Cl: Final Report - Volume 15.** Fabryka-Martin, J.T. (Los Alamos Scientific Lab., NM (United States)); Curtis, D.B. Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 82p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95605963. Source: OSTI; NTIS (US Sales Only); INIS.

One objective of this research programme has been to evaluate the applicability of uranium orebodies as natural analogues for testing radionuclide release-rate models used in performance assessment activities. The investigated nuclides included three of the most persistent radioactive constituents of high-level wastes from nuclear fission power reactors: plutonium-239, iodine-129, and technetium-99. The feasibility of uranium minerals as analogues for the behavior of these nuclear reaction products (NRP) in spent fuel relies upon a capability to characterise NRP concentrations in the source minerals. Measured abundances of natural ^{239}Pu, ^{99}Tc and ^{129}I in uranium ores are compared to calculated abundances in order to evaluate the degree to retention of these radionuclides by the ore. This modelling study also shows the extent to which various NRP are correlated, such that one provides a constraint on the production rates of others. Under most conditions, ^{36}Cl, another long-lived neutron-capture product found in uranium ores, is shown to be an ideal in-situ monitor of the ^{235}U fission rate, which is the dominant source term for ^{129}I and possibly a significant one for ^{99}Tc. Similarly, $^{239}Pu/U$ ratios can be used to establish limits on the ^{238}U neutron-induced fission rate; the ratios measured in this study suggest that ^{238}U induced fission comprises $< 4\%$ of the total fissions in most of the ore samples studied and hence can be neglected as a source of ^{129}I and ^{99}Tc. 79 refs., 21 tabs., 18 figs.

983 (INIS-mf-14384) **The effect of weathering on the distribution of uranium and associated elements at Koongarra, Northern Territory, Australia.** Edis, Robert (Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia)). Sydney Univ., NSW (Australia). Mar 1992. 162p. Sponsored by Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). Order Number DE95605964. Source: OSTI; NTIS (US Sales Only); INIS.

A thesis submitted to the Faculty of Agriculture of the University of Sydney in fulfilment of the requirements for the degree of Master of Science in Agriculture.

The aim of work described in this thesis was to investigate some aspects of the redistribution of U and other elements, at the Koongarra No.1 U ore deposit in the Northern Territory of Australia. Aspects of the redistribution of U which are considered in this thesis include the spatial patterns of remobilised U; the associations of U with minerals and elements and how these change with weathering, and transport of material by colloids present in the groundwater. The Koongarra No.1 U ore deposit is currently being studied as a natural analogue of a high level radioactive waste repository, as part of the Alligator Rivers Analogue Project. As spent fuel is a proposed waste form for geological burial, the study of uraninite leaching in an ore body makes a very good analogue of a breached repository. Work presented in this thesis was undertaken as part of that study. Aspects of the redistribution considered here include spatial patterns of redistributed U, associations between U, other elements and minerals, and transport of material by groundwater colloids. Techniques employed include:- thin section analyses (optical analysis, autoradiography, electron microprobe, and scanning electron microscopy); mineralogical and chemical analyses (x-ray diffraction, x-ray fluorescence, PIXE-PIGME, neutron activation, and infra-red spectrophotometry); groundwater colloid sampling and concentrating (tangential and stirred cell ultrafiltration); transmission electron microscopy for the examination of colloids and scanning electron microscopy for the examination of prefilters. The redistribution of U during weathering appeared to follow the distribution of Fe oxides. Uranium present in the groundwater responsible for the weathering would then have absorbed onto the freshly precipitated and highly sorptive Fe oxides. Uranium concentrations appeared to be correlative to the degree of weathering, and the corresponding amount of Fe oxides. 339 refs., 36 tabs., 83 figs.

984 (INIS-XN–505) **The International Intraval project: to study validation of geosphere transport models for performance assessment of nuclear waste disposal. Phase 1, summary report.** Nuclear Energy Agency, 75 - Paris (France). Dec 1993. 135p. Order Number DE94629680. Source: OSTI; NTIS (US Sales Only); INIS.

Intraval is an international project that addresses the validation of models of transport of radionuclides through groundwater in the geosphere. Such models are used in assessment of the long-term safety of nuclear waste disposal systems. The present report summarises the results for the test cases and presents some additional remarks.

985 (JAB–10733-TM12) **Processed seismic motion records from earthquakes (1982–1993): Recorded at Scotty's Castle, California.** Lum, P.K.; Honda, K.K. URS/John A. Blume and Associates, Engineers, San Francisco, CA (United States). Oct 1993. 311p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-89NV10733. Order Number DE94001371. Source: OSTI; NTIS; GPO Dep.

As part of the contract with the US Department of Energy, Nevada Operations Office (DOE/NV), URS/John A. Blume & Associates, Engineers (URS/Blume) maintained a network of seismographs to monitor the ground motion generated by the underground nuclear explosions (UNEs) at the Nevada Test Site (NTS). The seismographs were located in the communities surrounding the NTS and the Las Vegas valley. When these seismographs were not used for monitoring the UNE generated motions, a limited number of seismographs were maintained for monitoring motion generated by other than UNEs (e.g. motion generated by earthquakes, wind, blast). Scotty's Castle was one of the selected earthquake monitoring station. During the period from 1982 through 1993, numerous earthquakes with varied in magnitudes and distances were recorded at Scotty's Castle. The records from 24 earthquakes were processed and included in this report. Tables 1 and 2 lists the processed earthquakes in chronological order and in the order of epicentral distances, respectively. Figure 1 shows these epicenters and magnitudes. Due to the potential benefit of these data for the scientific community, DOE/NV and the National Park Service authorize the release of these records.

986 (JAERI-M–94-061) **Status of natural analogue studies: Based on the results obtained by JAERI.** Sekine, Keiichi (Japan Atomic Energy Research Inst., Tokai, Ibaraki (Japan). Tokai Research Establishment). Japan Atomic Energy Research Inst., Tokyo (Japan). Mar 1994. 26p. (In Japanese). Order Number DE94785243. Source: OSTI; NTIS; INIS.

This report is based on the materials for the meeting at the Nuclear Safety Commission of Japan held on September 1993. Details are as follows: Alteration of glass as the study of alteration of natural minerals; alteration of uranium minerals, migration of uranium and thorium series radionuclides, alteration of chlorite, fixation of uranium alteration of minerals and migration of uranium as the study of alligator rivers analogue project held at Koongarra uranium deposit, Australia. (author).

987 (LA–12968-MS) **The unsaturated hydraulic characteristics of the Bandelier Tuff.** Rogers, D.B.; Gallaher, B.M. Los Alamos National Lab., NM (United States). Sep 1995. 138p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE96000894. Source: OSTI; NTIS; GPO Dep.

Report includes diskette designed to run on IBM PC compatible equipment.

This report summarizes the physical and, unsaturated hydraulic properties of the Bandelier Tuff determined from laboratory measurements made on core samples collected at Los Alamos National Laboratory. We fit new van Genuchten-type moisture retention curves to this data, which was categorized according to member of the Bandelier Tuff and subunit of the Tshirege Member. Reasonable consistency was observed for hydraulic properties and retention curves within lithologic units, while distinct differences were observed for those properties between units. With the moisture retention data, we constructed vertical profiles of in situ matric suction and hydraulic head. These profiles give an indication of the likely direction of liquid water movement within the unsaturated zone and allow comparison of core-scale and field-scale estimates of water flow and solute transport parameters. Our core-derived transport velocities are much smaller than values estimated from tritium, Cl, and NO_3 contamination found recently in boreholes. The contaminant tracer-derived transport velocities from Los Alamos Canyon are greater than corederived values found for the Otowi Member, and for Mortandad Canyon, greater than core-derived values for that borehole. The significant difference found for Mortandad Canyon suggests that fracture or other fast-path transport may be important there. The relatively small difference between observed and predicted velocities at Los Alamos Canyon may mean that vadose zone transport there occurs by unsaturated matrix flow.

988 (LA-UR–93-4253) **Radionuclide releases from natural analogues of spent nuclear fuel.** Curtis, D.B. (Los Alamos National Lab., NM (United States)); Fabryka-Martin, J.; Dixon, P.; Aguilar, R.; Rokop, D.; Cramer, J. Los Alamos National Lab., NM (United States). [1993]. 12p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-931201–6: 4. international conference on chemistry and migration behavior of actinides and fission products in the geosphere, Charleston, SC (United States), 12-17 Dec 1993). Order Number DE94004989. Source: OSTI; INIS; NTIS; GPO Dep.

Measures of ^{99}Tc, ^{129}I, ^{239}Pu and U concentrations in rock samples from uranium deposits at Cigar Lake and Koongarra have been used to study processes of radionuclide release from uranium minerals. Rates of release have been immeasurably slow at Cigar Lake. At Koongarra release rates appear to have been faster, producing small deficiencies of ^{99}Tc, and larger ones of ^{129}I. The inferred differences in radionuclide release rates are consistent with expected differences in uranium mineral degradation rates produced by the differing hydrogeochemical environments at the two sites.

989 (LA-UR–94-2245) **Vadose zone drilling at the NTS.** Efurd, D.W. Los Alamos National Lab., NM (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94016080. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Project has an opportunity to evaluate possible mobilization and transport of radioactive materials away from the storage horizon in the proposed repository. One scenario by which such transport could occur involves water leaving the storage area and carrying radioactive particulates of colloidal size. The colloids could move along the gas-liquid interface in partially filled fractures within the vadose zone. It should be possible to check the reality of this proposed scenario by examining "anthropogenic analogs" of the repository. These are sites of nuclear tests conducted in unsaturated tuff at the Nevada Test Site (NTS). We propose to drill under one or more such sites to determine if radionuclides have moved from their original confinement in the puddle- glass at the bottom of the cavity. This document examines the characteristics of an ideal test site for such a study, suggests several possible locations that have some of the desired characteristics, and recommends one of these sites for the proposed drilling.

990 (LA-UR–95-1792) **AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.** Schriber, S.O.; Arthur, E.; Rodriguez, A.A. Los Alamos National Lab., NM (United States). [1995]. 958p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). Order Number DE95014018. Source: OSTI; NTIS; INIS; GPO Dep.

This conference was the first to bring together US and foreign researchers to define Accelerator Driven Transmutation Technology (ADTT) concepts in several important national and international application areas - nuclear waste transmutation, minimizing of world plutonium inventories, and long-term energy production. The conference covered a number of diverse technological areas - accelerators, target/blankets, separations, materials - that make up ADTT systems. The meeting provided one of the first opportunities for specialists in these technologies to meet together and learn about system requirements, components, and interface issues. It was also an opportunity to formulate plans for future developments in ADTT. During the conference over one hundred technical presentations were made describing ADTT system and technology concepts as well as the impact of ADTT on issues related to global plutonium management and the high-level nuclear waste problem areas. Separate abstracts have been entered into the database for articles from this report.

991 (LA-UR–95-1792, pp. 1-7) **A long view of global plutonium management.** Wagner, R.L. Jr. (Kaman Sciences Corporation, Alexandria, VA (United States)). Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

Dealing with the large and growing world inventories of fissile materials from all sources is a major part of the long term challenge of limiting the danger from nuclear weapons. Providing clean, safe nuclear power may also be needed to prevent conditions from arising which could lead to large scale nuclear weapon (re)armament. ADTT technologies might reconcile the seeming dilemma of providing nuclear power while maintaining a very low world inventory of nuclear materials which can be used in weapons. This vision for ADTT should be tested in a variety of ways, including comparisons with competing approaches and with other objectives. Such testing is one part of constructing a path for a decades-long, worldwide implementation campaign for ADTT.

992 (LA-UR–95-1792, pp. 8-21) **Potential benefits of waste transmutation to the U.S. high-level waste respository.** Michaels, G.E. (Oak Ridge National Laboratory, TN (United States)). Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

This paper reexamines the potential benefits of waste transmutation to the proposed U.S. geologic repository at the Yucca Mountain site based on recent progress in the performance assessment for the Yucca Mountain base case of spent fuel emplacement. It is observed that actinides are assumed to have higher solubility than in previous studies and that Np and other actinides now dominate the projected aqueous releases from a Yucca Mountain repository. Actinides are also indentified as the dominant source of decay heat in the repository, and the effect of decay heat in perturbing the hydrology, geochemistry, and thermal characteristics of Yucca Mountain are reviewed. It is concluded that the potential for thermally-driven, buoyant, gas-phase flow at Yucca Mountain introduces data and modeling requirements that will increase the costs of licensing the site and may cause the site to be unattractive for geologic disposal of wastes. A transmutation-enabled cold repository is proposed that might allow licensing of a repository to be based upon currently observable characteristics of the Yucca Mountain site.

993 (LA-UR–95-1792, pp. 44-53) **A high gain energy amplifier operated with fast neutrons.** Rubbia, C. (CERN, Geneva (Switzerland)). Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

The basic concept and the main practical considerations of an Energy Amplifier (EA) have been exhaustively described elsewhere. Here the concept of the EA is further explored and additional schemes are described which offer a higher gain, a larger maximum power density and an extended burn-up. All these benefits stem from the use of fast neutrons, instead of thermal or epithermal ones, which was the case in the original study. The higher gain is due both to a more efficient high energy target configuration and to a larger, practical value of the multiplication factor. The higher power density results from the higher permissible neutron flux, which in turn is related to the reduced rate of ^{233}Pa neutron captures (which, as is well known, suppress the formation of the fissile ^{233}U fuel) and the much smaller k variations after switch-off due to ^{233}Pa decays for a given burn-up rate. Finally a longer integrated burn-up is made possible by reduced capture rate by fission fragments of fast neutrons. In practice a 20 MW proton beam (20 mA @ 1 GeV) accelerated by a cyclotron will suffice to operate a compact EA at the level of $\approx$ 1 GW_e. The integrated fuel burn-up can be extended in excess of 100 GW d/ton, limited by the mechanical survival of the fuel elements. Radio-Toxicity accumulated at the end of the cycle is found to be largely inferior to the one of an ordinary Reactor for the same energy produced. Schemes are proposed which make a "melt-down" virtually impossible. The conversion ratio, namely the rate of production of ^{233}U relative to consumption is generally larger than unity, which permits production of fuel for other uses. Alternatively the neutron excess can be used to transform unwanted "ashes" into more acceptable elements.

994 (LA-UR–95-1792, pp. 83-92) **Development of advanced technological systems for accelerator transmutation.** Batskikh, G.I. (Russian Academy of Sciences, Moscow (Russian Federation)); Bondarev, B.I.; Durkin, A.P. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

A development concept of the accelerator nuclear energy reactors is considered for energy generation and nuclear power plant waste conversion into short-lived nuclides along with the requirements imposed on the technological systems necessary for implementation of such projects. The state of art in the field is discussed.

995 (LA-UR–95-1792, pp. 93-104) **Introduction to spallation physics and spallation-target design.** Russell, G.J. (Los Alamos National Laboratory, NM (United States)); Pitcher, E.J.; Daemen, L.L. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

When coupled with the spallation process in appropriate target materials, high-power accelerators can be used to produce large numbers of neutrons, thus providing an alternate method to the use of nuclear reactors for this purpose. Spallation offers exciting new possibilities for generating intense neutron fluxes for a variety of applications, including: (a) spallation-neutron sources for materials science research; (b) accelerator-based production of tritium; (c) accelerator-based transmutation of waste; (d) accelerator-based destruction of plutonium; and (e) radioisotope production for medical and energy applications. Target design plays a key role in these applications, with neutron production/leakage being strongly dependent on the incident particle type and energy, and target material and geometry.

996 (LA-UR–95-1792, pp. 116-136) **The physics design of accelerator-driven transmutation systems.** Venneri, F. (Los Alamos National Laboratory, NM (United States)). Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

Nuclear systems under study in the Los Alamos Accelerator-Driven Transmutation Technology program (ADTT) will allow the destruction of nuclear spent fuel and weapons-return plutonium, as well as the production of nuclear energy from the thorium cycle, without a long-lived radioactive waste stream. The subcritical systems proposed represent a radical departure from traditional nuclear concepts (reactors), yet the actual implementation of ADTT systems is based on modest extrapolations of existing technology. These systems strive to keep the best that the nuclear technology has developed over the years, within a sensible conservative design envelope and eventually manage to offer a safe, less expensive and more environmentally sound approach to nuclear power.

997 (LA-UR–95-1792, pp. 235-246) **Potential role of ABC-assisted repositories in U.S. plutonium and high-level waste disposition.** Berwald, D. (Grumman Aerospace Corporation, Bethpage, NY (United States)); Favale, A.; Myers, T. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

This paper characterizes the issues involving deep geologic disposal of LWR spent fuel rods, then presents results of an investigation to quantify the potential role of Accelerator-Based Conversion (ABC) in an integrated national nuclear materials and high level waste disposition strategy. The investigation used the deep geological repository envisioned for Yucca Mt., Nevada as a baseline and considered complementary roles for integrated ABC transmutation systems. The results indicate that although a U.S.

geologic waste repository will continue to be required, waste partitioning and accelerator transmutation of plutonium, the minor actinides, and selected long-lived fission products can result in the following substantial benefits: plutonium burndown to near zero levels, a dramatic reduction of the long term hazard associated with geologic repositories, an ability to place several-fold more high level nuclear waste in a single repository, electricity sales to compensate for capital and operating costs.

998 (LA-UR–95-1792, pp. 247) **Status of electronuclear facilities development in ITEP.** Chuvilo, I.V. (ITEP, Moscow (Russian Federation)). Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

The concept of plutonium management, both weapon-grade and power, should be developed taking into account the history of previous stages of the nuclear industry and ideas which guided the process of their implementation. Theoretical studies of several versions of a neutron multiplying subcritical system based on thermal and epithermal neutrons are conducted in ITEP. Systems with several neutron multiplying subcritical sections are considered connected by neutron flux propagation from a previous section to subsequent one. This could be implemented by the use of neutron valves separating these sections that permits to decrease the requirements imposed upon proton beam power significantly. Heterogeneous and homogeneous approaches to implementation of such systems are studied. There are many problems associated with nuclear constants and their classification. Measurements are performed of thermal effects in various materials under proton beam irradiation. Problems associated with materials are in the process of investigation too. Joint programs and division of labour should be organized.

999 (LA-UR–95-1792, pp. 255-263) **An overview of Russian experience and capabilities for development of ATW/ABC systems.** Kazaritsky, V.D. (Institute for Theoretical and Experimental Physics, Moscow (Russian Federation)). Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

Several Russian institutes are expected to undertake a feasibility study of nuclear power systems based on proton accelerators. The examined systems are intended for conversion of surplus Pu and transmutation of long-lived radioactive waste. This research motivated by the demilitarisation agreements and criticism of traditional nuclear power is focused on environmental protection.

1000 (LA-UR–95-1792, pp. 264-267) **On the ATW-concepts: ITP approach and opportunities.** Simonenko, V.A. (Institute of Technical Physics, Chelyabinsk (Russian Federation)); Gregyonkin, K.F. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

It is discussed the interest of Russian Federal Nuclear Center - Institute of Technical Physics at Chelyabinsk-70 in the research of Accelerator Driven Technologies applications for radioactive waste transmutation, cumulated actinides burning, energy production. The ITP background and opportunities for this research are presented. It is shown the ITP possibilities for testing and experimental development of Accelerator Driven Technologies.

1001 (LA-UR–95-1792, pp. 268-273) **Accelerator-driven nuclear synergetic systems-an overview of the research activities in Sweden.** Conde, H. (Uppsala Univ. (Sweden)); Baecklin, A.; Carius, S. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

The rapid development of the accelerator technology which enables the construction of reliable and very intense neutron sources has initiated a growing interest for accelerator driven transmutation systems in Sweden. After the Specialist Meeting on Accelerator-Driven Transmutation Technology for Radwaste and other Applications on 24-28 June 1991 at Saltsjoebaden, Sweden, the research activities oriented towards accelerator-driven systems have been started at several research centers in Sweden. Also the governmental agencies responsible for the spent fuel policy showed a positive attitude to these activities through a limited financial support, particularly for studies of the safety aspects of these systems. Also the nuclear power industry and utilities show a positive interest in the research on these concepts. The present paper presents an overview of the Swedish research activities on accelerator-driven systems and the proposed future coordination, organizations and prospects for this research in the context of the national nuclear energy and spent fuel policy. The Swedish perspective for international cooperation is also described.

1002 (LA-UR–95-1792, pp. 274-280) **Specific contributions of the Dutch programme "RAS" towards accelerator-based transmutation.** Abrahams, K. (Netherlands Energy Research Foundation (ECN), Petten (Netherlands)); Franken, W.M.P.; Bultman, J.H. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

Accelerator-based transmutation is being studied by ECN within its general nuclear waste transmutation programme RAS. In this paper the following contributions are presented: (1) Evaluation of cross sections at intermediate energies, within an international frame given by NEA, (2) Cell calculations on the equilibration of transuranium actinides in thermal molten-salt transmuters, (3) Irradiation facilities at the European research reactor HFR in Petten, which have

been constructed with the purpose to demonstrate and investigate the transmutation of waste in a high neutron flux, (4) Studies of accelerator-based neutron generating systems to transmute neptunium and technetium, (5) Comparison of several systems on the basis of criteria for successful nuclear waste-management.

1003 (LA-UR–95-1792, pp. 281-288) **Site layout and balance of plant design for an accelerator-driven materials processing complex.** Cunliffe, J. (Bechtel Corporation, San Francisco, CA (United States)); Taussig, R.; Ghose, S. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

High energy proton beam accelerators are under consideration for use in radioisotope production, surplus weapons material destruction, radioactive waste transmutation, and thorium-based energy conversion cycles. While there are unique aspects to each of these applications that must be accommodated in the design of the associated facility, all share a set of fundamental characteristics that in large measure dictate the site layout features and many balance-of-plant (BOP) design requirements found to be common to all. This paper defines these key design determinants and goes on to discuss the manner in which they have been accommodated in the pre-conceptual design for a particular materials production application. An estimate of the costs associated with this BOP design is also presented with the aim of guiding future evaluations where the basic plant designs are similar to that of this specific case.

1004 (LA-UR–95-1792, pp. 299-306) **Accelerator driven reactors and nuclear waste management projects in the Czech Republic.** Janouch, F. (Royal Institute of Technology, Stockholm (Sweden)); Mach, R. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

The Czech Republic is almost the only country in the central Europe which continues with the construction of nuclear power reactors. Its small territory and dense population causes public worries concerning the disposal of the spent nuclear fuel. The Czech nuclear scientists and the power companies and the nuclear industries are therefore looking for alternative solutions. The Los Alamos ATW project had received a positive response in the Czech mass-media and even in the industrial and governmental quarters. The recent scientific symposium "Accelerator driven reactors and nuclear waste management" convened at the Liblice castle near Prague, 27-29. 6. 1994 and sponsored by the Czech Energy Company CEZ, reviewed the competencies and experimental basis in the Czech republic and made the first attempt to formulate the national approach and to establish international collaboration in this area.

1005 (LA-UR–95-1792, pp. 307-313) **Benefits and risks of P & T of nuclear waste.** Abrahams, K. (Netherlands Energy Research Foundation, Petten (Netherlands)). Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

Efforts on waste transmutation are coordinated in a research programme called RAS. One of the aims of this RAS program is to inform the public and advise the authorities on methods for transmutation/conditioning of nuclear waste, and on techniques which are being developed. Such new procedures for the treatment of waste should of course not lead to significant risks for the present population. Small risks might be accepted, but these should sufficiently be compensated for by favours to future generations.

1006 (LA-UR–95-1792, pp. 346-362) **Combining a gas turbine modular helium reactor and an accelerator and for near total destruction of weapons grade plutonium.** Baxter, A.M. (General Atomics, San Diego, CA (United States)); Lane, R.K.; Sherman, R. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

Fissioning surplus weapons-grade plutonium (WG-Pu) in a reactor is an effective means of rendering this stockpile non-weapons useable. In addition the enormous energy content of the plutonium is released by the fission process and can be captured to produce valuable electric power. While no fission option has been identified that can accomplish the destruction of more than about 70% of the WG-Pu without repeated reprocessing and recycling, which presents additional opportunities for diversion, the gas turbine modular helium-cooled reactor (GT-MHR), using an annular graphite core and graphite inner and outer reflectors combines the maximum plutonium destruction and highest electrical production efficiency and economics in an inherently safe system. Accelerator driven sub-critical assemblies have also been proposed for WG-Pu destruction. These systems offer almost complete WG-Pu destruction, but achieve this goal by using circulating aqueous or molten salt solutions of the fuel, with potential safety implications. By combining the GT-MHR with an accelerator-driven sub-critical MHR assembly, the best features of both systems can be merged to achieve the near total destruction of WG-Pu in an inherently safe, diversion-proof system in which the discharged fuel elements are suitable for long term high level waste storage without the need for further processing. More than 90% total plutonium destruction, and more than 99.9% Pu-239 destruction, could be achieved. The modular concept minimizes the size of each unit so that both the GT-MHR and the accelerator would be straightforward extensions of current technology.

1007 (LA-UR–95-1792, pp. 525) **The concept of electro-nuclear facility for useful power generation and minor actinides transmutation.** Bergelson, B.R. (ITEP, Moscow (Russian Federation)); Balyuk, S.A. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV

(United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

The possibility is shown to design in principle the double-purpose liquid fuel electro nuclear facility for useful power generation and minor actinides transmutation in U-Pu fuel cycle conditions. D_2O and a melt of fluorine salts are considered as a working media for liquid fuel. Such facility replenished with depicted or natural uranium only makes it possible to generate power of 900 MW (c) for external consumers and serve 20 WWER-1000 reactors for transmutation of MA. The facility could be thought as an alternative to fast reactors since appr. 30% of the total power confined in uranium is utilized in it.

1008 (LA-UR–95-1792, pp. 627-637) **Brief overview of the long-lived radionuclide separation processes developed in France in connection with the SPIN program.** Madic, C. (DRDD, Fontenay-aux-Roses (France)); Bourges, J.; Dozol, J.F. Los Alamos National Lab., NM (United States). [1995]. Contract F12W-CT-0112; Contract F12W-CT-90-0062. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

To reduce the long-term potential hazards associated with the management of nuclear wastes generated by nuclear fuel reprocessing, one alternative is the transmutation of long-lived radionuclides into short-lived radionuclides by nuclear means (P & T strategy). In this context, according to the law passed by the French Parliament on 30 December 1991, the CEA launched the SPIN program for the design of long-lived radionuclide separation and nuclear incineration processes. The research in progress to define separation processes focused mainly on the minor actinides (neptunium, americium and curium) and some fission products, like cesium and technetium. To separate these long-lived radionuclides, two strategies were developed. The first involves research on new operating conditions for improving the PUREX fuel reprocessing technology. This approach concerns the elements neptunium and technetium (iodine and zirconium can also be considered). The second strategy involves the design of new processes; DIAMEX for the co-extraction of minor actinides from the high-level liquid waste leaving the PUREX process, An(III)/Ln(III) separation using tripyridyltriazine derivatives or picolinamide extracting agents; SESAME for the selective separation of americium after its oxidation to Am(IV) or Am(VI) in the presence of a heteropolytungstate ligand, and Cs extraction using a new class of extracting agents, calixarenes, which exhibit exceptional Cs separation properties, especially in the presence of sodium ion. This lecture focuses on the latest achievements in these research areas.

1009 (LA-UR–95-1792, pp. 744-750) **Plutonium (TRU) transmutation and ^{233}U production by single-fluid type accelerator molten-salt breeder (AMSB).** Furukaw, Kazuo (Tokai Univ., Kanagawa (Japan)); Kato, Yoshio; Chigrinov, Sergey E. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

For practical/industrial disposition of Pu(TRU) by accelerator facility, not only physical soundness and safety but also the following technological rationality should be required: (1) few R&D items including radiation damage, heat removal and material compatibility; (2) few operation/maintenance/processing works: (3) few reproduction of radioactivity; (4) effective energy production in parallel. This will be achieved by the new modification of Th-fertilizing Single-Fluid type Accelerator Molten-Salt Breeder (AMSB), by which a global nuclear energy strategy for next century might be prepared.

1010 (LA-UR–95-1792, pp. 769-775) **The concept of the double-purpose electro-nuclear facility.** Bergelson, B.P. (Institute of theoretical and experimental physics, Moscow (Russian Federation)); Balyuk, S.A. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

The parameters have been determined on a conceptual level of the electro-nuclear facility intended for electric power generation and minor actinide transmutation. Electro-nuclear facilities (ENFs) have been developed without apparent success for many years. The main difficulties are associated with high accelerator cost and absence of their own clearly defined place for ENFs in the nuclear-power complex. In recent years, however, the situation has changed in many aspects in connection with the rise in safety requirements for nuclear power industry and because of the necessity to decrease the equilibrium level of the long-lived radiotoxicity in particular. In the authors opinion double-purpose ENFs designed for power generation and tansmutation of minor actinides are promising. The results of conceptual investigations for such a facility being operated on liquid fuel in the condition of a uranium-plutonium fuel cycle are given here.

1011 (LA-UR–95-1792, pp. 776-782) **The influence of external source intensity in accelerator/target/blanket system on conversion ratio and fuel cycle.** Kochurov, B.P. (Institute for Theoretical and Experimental Physics, Moscow (Russian Federation)). Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

The analysis of neutron balance relation for a subcritical system with external source shows that a high ratio of neutron utilization (conversion ratio, breeding ratio) much exceeding similar values for nuclear reactors (both thermal or fast spectrum) is reachable in accelerator/target/blanket system with high external neutron source intensity. An accelerator/target/blanket systems with thermal power in blanket about 1850 Mwt and operating during 30 years have been investigated. Continual feed up by plutonium (fissile material) and Tc-99 (transmuted material) was assumed. Accelerator beam intensity differed 6.3 times (16 mA - Case 1, and 100 mA-Case 2). Conversion ratio (CR) was defined as

the ratio of Tc-99 nuclei transmuted to the number of Pu nuclei consumed. High value of conversion ratio considerably exceeding 1 (CR=1.66) was obtained in the system with high source intensity as compared with low source system (CR=0.77). Net output of electric power of high source intensity system is about twice lower due to consumption of electric power for accelerator feed up. The loss of energy for Tc-99 transmutation is estimated as 40 Mev(el)/nuclei. Yet high conversion ratio (or breeding ratio) achievable in electronuclear installations with high intensity of external source can effectively be used to close fuel cycle (including incineration of wastes) or to develop growing nuclear power production system.

1012 (LA-UR–95-1792, pp. 783) **Chemistry of pyroprocessing for nuclear waste transmutation.** Ackerman, J.P. (Argonne National Laboratory, IL (United States)). Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

Pyrochemical treatment of spent nuclear fuel is an attractive approach for separating the transuranium (TRU) elements neptunium, plutonium, americium, and curium because of its simplicity, diversion resistance, and potentially low cost.

1013 (LA-UR–95-1792, pp. 798-823) **Centrifugal separation for miscible solutions: Fundamentals and applications to separation of molten salt nuclear material.** Ning Li (Los Alamos National Laboratory, NM (United States)); Camassa, R.; Ecke, R.E. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

The authors report on the physical separation of dilute solutions using centrifugal techniques. They use numerical simulations of the diffusion and sedimentation dynamics of centrifugation to model the approach to an equilibrium concentration profile. They verify experimentally the equilibrium profiles for aqueous solutions of different salts under rotation at 25000 rpm corresponding to centrifugal accelerations of about 57,000 g and 75,000 g in two different commercial centrifuges. These measurements provide ratios of sedimentation and diffusion coefficients. The authors show experimental results for the dynamics of separation that confirm the predictions of the theoretical model. They also measure the mass diffusion coefficient for several solutions. Although the relaxation to equilibrium is long, they have determined a method for efficiently extracting enriched components from a ternary mixture based on fast dynamics at early times. These dynamics are modeled in numerical simulations with realistic fluid parameters. Based on these studies the authors show that a multistage centrifugal separation process could provide efficient physical separation of actinides and fission products from a molten-salt solution in proposed transmutation/energy-production systems. The authors consider technical issues in the design of such a separation system.

1014 (LA-UR–95-1792, pp. 824) **Convective instabilities in liquid centrifugation for nuclear wastes separation.** Camassa, R. (Los Alamos National Laboratory, NM (United States)). Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

The separation of fission products from liquid solutions using centrifugal forces may prove an effective alternative to chemical processing in cases where radioactive materials necessitate minimal mixed-waste products or when allowing access to sophisticated chemical processing is undesirable. This investigation is a part of the effort to establish the feasibility of using liquid centrifugation for nuclear waste separation in the Accelerator Driven Energy Production (ADEP) program. A number of fundatmental issues in liquid centrifugation with radioactive elements need to be addressed in order to validate the approach and provide design criteria for experimental liquid salt (LiF and BeF_2) centrifuge. The author concentrates on one such issue, the possible onset of convective instabilities which could inhibit separation.

1015 (LA-UR–95-1792, pp. 825) **Subcritical neutron generator-test facility for nuclear waste transmutation studies.** Chuvilo, I.V. (ITEP, Moscow (Russian Federation)); Kolomiets, A.A.; Kozodaev, A.M. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

The development of the optimal design of high power facility for NPP transmutation and for a number of applications can not be carried out without preliminary tests of much cheaper prototypes. It has been proposed to combine in new test facility 36 MeV Linac ISTRA constructed in ITEP, original Be target and subcritical blanket that will be mounted on the place of partly disassembled heavy water ITEP experimental reactor. The basic parameters of Linac, schemes of the target and blanket are described. It will provide the direct experiments on installation which can be considered as prototype for future linac driven high power facilities.

1016 (LA-UR–95-1792, pp. 858-863) **Some basic advantages of accelerator-driven transmutation of minor actinides and iodine-129.** Shmelev, A.N. (Moscow Engineering Physics Institute (Russian Federation)); Apse, V.A.; Kulikov, G.G. Los Alamos National Lab., NM (United States). [1995]. (CONF-9407103–: International conference on accelerator-driven transmutation technologies and applications, Las Vegas, NV (United States), 25 Jul - 1 aug 1994). In *AIP conference on accelerator driven transmutation technologies and applications, Las Vegas, Nevada, July 25-29, 1994.* 958p. Order Number DE95014018. Source: OSTI; NTIS; INIS.

The blanket of accelerator-driven facility designed for I-129 transmutation doesn't contain fissile and fertile materials. So the overheating of iodine compounds transmuted is practically excluded. The efficacy of I-129 transmutation is estimated. Curium being accumulated in nuclear reactors can be incinerated in blanket of accelerator-driven facility.

The deep depletion of curium diluted with inert material can be achieved.

1017 (LA-UR–95-2086) **Intracaldera volcanism and sedimentation-Creede caldera, Colorado.** Heiken, G. (Los Alamos National Lab., NM (United States)); Krier, D.; Snow, M.G.; McCormick, T. Los Alamos National Lab., NM (United States). [1994]. 53p. Sponsored by USDOE, Washington, DC (United States);Los Alamos National Lab., NM (United States). DOE Contract W-7405-ENG-36. (CONF-941088–2: Annual meeting of the Geological Society of America, Seattle, WA (United States), 24-27 Oct 1994). Order Number DE95015300. Source: OSTI; NTIS; GPO Dep.

Within the Creede caldera, Colorado, many of the answers to its postcaldera volcanic and sedimentary history lie within the sequence of tuffaceous clastic sedimentary rocks and tuffs known as the Creede Formation. The Creede Formation and its interbedded ash deposits were sampled by research coreholes Creede 1 and 2, drilled during the fall of 1991. In an earlier study of the Creede Formation, based on surface outcrops and shallow mining company coreholes, Heiken and Krier (1987) concluded that the process of caldera structural resurgence was rapid and that a caldera lake had developed in an annulus ("moat") located between the resurgent dome and caldera wall. So far we have a picture of intracaldera activity consisting of intermittent hydrovoleanic eruptions within a caldera lake for the lower third of the Creede Formation, and both magmatic and hydrovolcanic ash eruptions throughout the top two-thirds. Most of the ash deposits interbedded with the moat sedimentary rocks are extremely fine-grained. Ash fallout into the moat lake and unconsolidated ash eroded from caldera walls and the slopes of the resurgent dome were deposited over stream delta distributaries within relatively shallow water in the northwestern moat; and in deeper waters of the northern moat, where the caldera was intersected by a graben. Interbedded with ash beds and tuffaceous siltstones are coarse-grained turbidites from adjacent steep slopes and travertine from fissure ridges adjacent to the moat. Sedimentation rates and provenance for clastic sediments are linked to the frequent volcanic activity in and near the caldera; nearly all of the Creede Formation sedimentary rocks are tuffaceous.

1018 (LBL–30043, pp. 19-32) **Geoscience technical support for nuclear waste geologic repositories.** Mangold, D.C.; Tsang, C.F. Lawrence Berkeley Lab., CA (United States). Dec 1990. In *Geotechnical support and topical studies for nuclear waste geologic repositories: Annual report, fiscal year 1989.* 186p. Order Number DE94003377. Source: OSTI; NTIS; INIS.

The Geoscience Technical Support activities in the Geologic Repository Project (GRP) at LBL covered a range of reports and reviews in FY89, particularly reviews of Study Plans of the Yucca Mountain site and their associated Comment Resolution Workshops. LBL sought to be responsive and active in meeting DOE's need for geoscience technical support for nuclear waste repositories. In addition, in consultation with DOE/HQ, the authors investigated and presented DOE with well-considered scientific inputs to program directions and new areas of needed work. This included the development of a white paper and proposed work plan on preclosure monitoring and performance confirmation that grew out of a request made by DOE to LBL to consider such studies for a repository in the unsaturated zone. This year also saw the beginning of a quality assurance program for GRP.

1019 (LBL–30043, pp. 33-41) **Radionuclides in hydrothermal systems as indicators of repository conditions.** Wollenberg, H.A.; Flexser, S.; Smith, A.R. Lawrence Berkeley Lab., CA (United States). Dec 1990. In *Geotechnical support and topical studies for nuclear waste geologic repositories: Annual report, fiscal year 1989.* 186p. Order Number DE94003377. Source: OSTI; NTIS; INIS.

Hydrothermal systems in tuffaceous and older sedimentary rocks contain evidence of the interaction of radionuclides in fluids with rock matrix minerals and with materials lining fractures, in settings somewhat analogous to the candidate repository site at Yucca Mountain, NV. Earlier studies encompassed the occurrences of U and Th in a "fossil" hydrothermal system in tuffaceous rock of the San Juan Mountains Volcanic Field, CO. More recent and ongoing studies examine active hydrothermal systems in calderas at Long Valley, CA and Valles, NM. At the Nevada Test Site, occurrences of U and Th in fractured and unfractured rhyolitic tuff that was heated to simulate the introduction of radioactive waste are also under investigation. Observations to date suggest that U is mobile in hydrothermal systems, but that localized reducing environments provided by Fe-rich minerals and/or carbonaceous materials concentrate U and thus attenuate its migration.

1020 (LBL–30043, pp. 100-113) **Mass transport with chemical reactions in a varying thermal field.** Carnahan, C.L. Lawrence Berkeley Lab., CA (United States). Dec 1990. DOE Contract AC03-76SF00098. In *Geotechnical support and topical studies for nuclear waste geologic repositories: Annual report, fiscal year 1989.* 186p. Order Number DE94003377. Source: OSTI; NTIS; INIS.

The work described here is part of a task to theoretically and numerically analyze effects of varying thermal fields on transport of radionuclides and ground water components in fracture filling materials in the near field at Yucca Mountain, and to numerically estimate the sensitivity of the effects to magnitudes of controlling parameters. A computer program, THCVP, simulates coupling between advective/diffusive solute transport and chemical reactions, coupling of the reactions to heat transport, and feedback from precipitation/dissolution reactions to fluid flow. A simple simulation of transport of dissolved silicic acid along a gradient of temperature shows how precipitation of quartz at low temperatures can drastically reduce advective transport of all solution components including trace contaminants.

1021 (MIC–94-04011/XAB) **Uranium mining developments in northern Saskatchewan: Dominique-Janine extension, McClean Lake project and midwest joint venture: Report.** AEA Environment and Energy, Harwell (United Kingdom). ©1993. 71p. (SSC-EN–106-21/1993E). Source: NTIS Prices: PC E07/MF E02.

Cover title: Dominique-Janine Extension, McClean Lake Project, and Midwest Joint Venture: Report. French ed. : 94-04012/1.

In April 1991, the governments of Canada and Saskatchewan announced a joint federal-provincial environmental assessment review to study uranium mine developments in northern Saskatchewan. To be included in the review were proposals for the Dominique-Janine extension of an existing mine, a proposed new mine at McClean Lake, and a proposed new mine, the Midwest Joint Venture, at South McMahan Lake, as well as proposals for operating mines at McArthur River and at Cigar Lake. This report assessed the acceptability of the first three proposed ventures. It addressed general issues such as the participation of the

northern people, biophysical and related concerns, health issues, sustainable development, alternative energy sources, local and global aspects of uranium mining, regulatory agencies, and the nuclear fuel cycle; and the biophysical, socio-economic, and health concerns for each proposed project.

1022 (MIC–95-00953/XAB) **Final report of the AECL/SKB Cigar Lake analog study. AECL research No. AECL-10851.** Atomic Energy of Canada Ltd., Pinawa, MB (Canada). Whiteshell Labs. ©1994. 403p. Source: NTIS Prices: PC E19/MF E01.

AECL has conducted natural analog studies on the Cigar Lake uranium deposit in northern Saskatchewan since 1984 as part of the Canadian Nuclear Fuel Waste Management Program. This report provides background information and summarizes the results of the study, emphasizing the analog aspects and the implications of modelling activities related to the performance assessment of disposal concepts for nuclear fuel wastes developed in both Canada and Sweden. The study was undertaken to obtain an understanding of the process involved in, and the effects of, steady-state water-rock interaction and trace-element migration in and around the deposit, including paleo-migration processes since the deposit was formed. To achieve these objectives, databases and models were produced to evaluate the equilibrium thermodynamic codes and databases; the role of colloids, organics, and microbes in transport processes for radionuclides; and the stability of UO2 and the influence of radiolysis on UO2 dissolution and radionuclide migration.

1023 (NUREG–1464) **NRC iterative performance assessment Phase 2. Development of capabilities for review of a performance assessment for a high-level waste repository.** Wescott, R.G. (Nuclear Regulatory Commission, Washington, DC (United States)); Lee, M.P.; Eisenberg, N.A. (eds.); McCartin, T.J.; Baca, R.G. Nuclear Regulatory Commission, Washington, DC (United States). Office of Nuclear Material Safety and Safeguards; Nuclear Regulatory Commission, Washington, DC (United States). Office of Nuclear Regulatory Research. Oct 1995. 515p. Sponsored by Nuclear Regulatory Commission, Washington, DC (United States). Source: OSTI; NTIS; INIS; GPO.

In order to better review a potential license application to construct and operate a geologic repository for spent nuclear fuel and high-level radioactive waste (HLW), the Nuclear Regulatory Commission staff (and its contractor) has expanded and improved its capability to conduct performance assessments. This report documents the demonstration of the second phase of this capability. The demonstration made use of the scenario selection procedure developed by Sandia National Laboratories to provide a set of scenarios, with corresponding probabilities, for use in the consequence analysis of a potential HLW disposal site in unsaturated tuff. Models of release of radionuclides from the waste form and transport in ground water, air and by direct pathways provided preliminary estimates of releases to the accessible environment for a 10,000 year period. The input values of parameters necessary for the consequence models were sampled numerous times using Latin Hypercube Sampling from assumed probability distributions. The results from the consequence models were then used to generate Complementary Cumulative Distribution Functions (CCDFs) for either release to the accessible environment or effective dose equivalents to a target population. CCDFs were calculated for probabilistically significant combinations (scenarios) of four disruptive events; drilling, pluvial climate, seismicity and magmatism. Sensitivity and uncertainty analyses of the calculated releases and effective dose equivalents were also used to determine the importance of the parameters. Because of the preliminary nature of the analysis and the lack of an adequate data base, the results and conclusions presented in this report should be carefully interpreted. They should not be misconstrued to represent the actual performance of the proposed Yucca Mountain repository nor serve as an endorsement of the methods used.

1024 (NUREG/CR–6203) **Validation studies for assessing unsaturated flow and transport through fractured rock.** Bassett, R.L. (Arizona Univ., Tucson, AZ (United States). Dept. of Hydrology and Water Resources); Neuman, S.P.; Rasmussen, T.C.; Guzman, A.; Davidson, G.R.; Lohrstorfer, C.F. Nuclear Regulatory Commission, Washington, DC (United States). Div. of Regulatory Applications; Arizona Univ., Tucson, AZ (United States). Dept. of Hydrology and Water Resources. Aug 1994. 210p. Sponsored by Nuclear Regulatory Commission, Washington, DC (United States). Source: OSTI; NTIS; INIS; GPO.

*The objectives of this contract are to examine hypotheses and conceptual models concerning unsaturated flow and transport through heterogeneous fractured rock and to design and execute confirmatory field and laboratory experiments to test these hypotheses and conceptual models. Important new information is presented such as the application and evaluation of procedures for estimating hydraulic, pneumatic, and solute transport coefficients for a range of thermal regimes. A field heater experiment was designed that focused on identifying the suitability of existing monitoring equipment to obtain required data. A reliable method was developed for conducting and interpreting tests for air permeability using a straddle-packer arrangement. Detailed studies of fracture flow from Queen Creek into the Magina Copper Company ore haulage tunnel have been initiated. These studies will provide data on travel time for transport of water and solute in unsaturated tuff. The collection of rainfall runoff, and infiltration data at two small watersheds at the Apache Leap Tuff Site enabled us to evaluate the quantity and rate of water infiltrating into the subsurface via either fractures or matrix. Characterization methods for hydraulic parameters relevant to Weigh-level waste transport, including fracture apertures, transmissivity, matrix porosity, and fracture wetting front propagation velocities, were developed.

1025 (NUREG/CR–6221) **The Valles natural analogue project.** Stockman, H. (Sandia National Labs., Albuquerque, NM (United States)); Krumhansl, J.; Ho, C.; McConnell, V. Nuclear Regulatory Commission, Washington, DC (United States). Div. of Engineering; Sandia National Labs., Albuquerque, NM (United States). Dec 1994. 122p. Sponsored by Nuclear Regulatory Commission, Washington, DC (United States). DOE Contract AC04-94AL85000. (SAND–94-0650). Source: OSTI; NTIS; GPO; INIS.

The contact between an obsidian flow and a steep-walled tuff canyon was examined as an analogue for a highlevel waste repository. The analogue site is located in the Valles Caldera in New Mexico, where a massive obsidian flow filled a paleocanyon in the Battleship Rock tuff. The obsidian flow provided a heat source, analogous to waste panels or an igneous intrusion in a repository, and caused evaporation and migration of water. The tuff and obsidian samples were analyzed for major and trace elements and mineralogy by INAA, XRF, X-ray diffraction; and scanning electron microscopy and electron microprobe. Samples were also analyzed for

D/H and $^{39}Ar/^{40}$ isotopic composition. Overall,the effects of the heating event seem to have been slight and limited to the tuff nearest the contact. There is some evidence of devitrification and migration of volatiles in the tuff within 10 meters of the contact, but variations in major and trace element chemistry are small and difficult to distinguish from the natural (pre-heating) variability of the rocks.

1026 (NUREG/CR–6288) **Geochemical investigations related to the Yucca Mountain environment and potential nuclear waste repository.** Murphy, W.M. (Southwest Research Institute, San Antonio, TX (United States). Center for Nuclear Waste Regulatory Analyses); Pabalan, R.T. Nuclear Regulatory Commission, Washington, DC (United States). Div. of Regulatory Applications; Southwest Research Inst., San Antonio, TX (United States). Center for Nuclear Waste Regulatory Analyses. Nov 1994. 192p. Sponsored by Nuclear Regulatory Commission, Washington, DC (United States). Source: OSTI; NTIS; GPO; INIS.

This report presents final results of the Geochemistry Research Project conducted at the Center for Nuclear Waste Regulatory Analyses (CNWRA) for the Nuclear Regulatory Commission (NRC) Office of Nuclear Regulatory Research. The study focused on experimental determinations and theoretical interpretations of fundamental thermodynamic and kinetic properties of minerals and reactions that characterize geochemical processes at the proposed nuclear waste repository site at Yucca Mountain and that could affect the capacity of the site to isolate nuclear waste. Technical results are presented in three major sections covering (i) cation exchange studies on clinoptilolite, (ii) kinetic and solubility studies on analcime and Na-clinoptilolite, and (iii) conceptual and numerical geochemical modeling of natural and repository systems. Experimental studies were designed to advance knowledge of the fundamental properties of the zeolite minerals clinoptilolite and analcime through controlled tests at 25°C, and to interpret the data in the context of the geochemical system at Yucca Mountain. Cation exchange equilibria were determined for clinoptilotite and binary solutions of Na^+ with K^+, Ca^{2+}, and Sr^{2+} at several solution concentrations. Results were interpreted using a Margules solid solution model for clinoptilolite coupled with a Pitzer activity coefficient model for aqueous solutions. Experimental data for analcime and clinoptilolite dissolution rates were interpreted using postulated rate mechanisms, and corresponding rate constants were determined. Dissolution rate data for analcime can be rationalized by alternate mechanisms which invoke either the presence of ultrareactive material or rate dependence on aqueous aluminum. Reversed solubility determinations were interpreted to obtain equilibrium constants for dissolution reactions and standard state Gibbs free energies of formation of the minerals.

1027 (NUREG/CR–6308) **An overview of instability and fingering during immiscible fluid flow in porous and fractured media.** Chen, G. (Univ. of Arizona, Tucson, AZ (United States). Dept. of Hydrology and Water Resources); Neuman, S.P.; Taniguchi, M. Nuclear Regulatory Commission, Washington, DC (United States). Div. of Regulatory Applications; Arizona Univ., Tucson, AZ (United States). Dept. of Hydrology and Water Resources. Apr 1995. 135p. Sponsored by Nuclear Regulatory Commission, Washington, DC (United States). Source: OSTI; NTIS; GPO.

Wetting front instability is an important phenomenon affecting fluid flow and contaminant transport in unsaturated soils and rocks. It causes the development of fingers which travel faster than would a uniform front and thus bypass much of the medium. Water saturation and solute concentration in such fingers tend to be higher than in the surrounding medium. During infiltration, fingering may cause unexpectedly rapid arrival of water and solute at the water-table. This notwithstanding, most models of subsurface flow and transport ignore instability and fingering. In this report, we survey the literature to assess the extent to which this may or may not be justified. Our overview covers experiments, theoretical studies, and computer simulations of instability and fingering during immiscible two-phase flow and transport, with emphasis on infiltration into soils and fractured rocks. Our description of instability in an ideal fracture (Hele-Shaw cell) includes an extension of existing theory to fractures and interfaces having arbitrary orientations in space. Our discussion of instability in porous media includes a slight but important correction of existing theory for the case of an inclined interface. We conclude by outlining some potential directions for future research. Among these, we single out the effect of soil and rock heterogeneities on instability and preferential flow as meriting special attention in the context of nuclear waste storage in unsaturated media.

1028 (NUREG/CR–6347) **Multi-phase reactive transport theory.** Lichtner, P.C. (Southwest Research Inst., San Antonio, TX (United States). Center for Nuclear Waste Regulatory Analyses). Nuclear Regulatory Commission, Washington, DC (United States). Div. of Regulatory Applications; Southwest Research Inst., San Antonio, TX (United States). Center for Nuclear Waste Regulatory Analyses. Jul 1995. 82p. Sponsored by Nuclear Regulatory Commission, Washington, DC (United States). (CNWRA–94-018). Source: OSTI; NTIS; INIS; GPO.

Physicochemical processes in the near-field region of a high-level waste repository may involve a diverse set of phenomena including flow of liquid and gas, gaseous diffusion, and chemical reaction of the host rock with aqueous solutions at elevated temperatures. This report develops some of the formalism for describing simultaneous multicomponent solute and heat transport in a two-phase system for partially saturated porous media. Diffusion of gaseous species is described using the Dusty Gas Model which provides for simultaneous Knudsen and Fickian diffusion in addition to Darcy flow. A new form of the Dusty Gas Model equations is derived for binary diffusion which separates the total diffusive flux into segregative and nonsegregative components. Migration of a wetting front is analyzed using the quasi-stationary state approximation to the Richards' equation. Heat-pipe phenomena are investigated for both gravity- and capillary-driven reflux of liquid water. An expression for the burnout permeability is derived for a gravity-driven heat-pipe. Finally an estimate is given for the change in porosity and permeability due to mineral dissolution which could occur in the region of condensate formation in a heat-pipe.

1029 (NUREG/CR–6356) **Hydraulic characterization of hydrothermally altered Nopal tuff.** Green, R.T. (Southwest Research Institute, San Antonio, TX (United States)); Meyer-James, K.A.; Rice, G. Electric Power Research Inst., Palo Alto, CA (United States); Southwest Research Inst., San Antonio, TX (United States). Center for Nuclear Waste Regulatory Analyses. Jul 1995. 40p. Sponsored by Nuclear Regulatory Commission, Washington, DC (United States). (CNWRA–94-027). Source: OSTI; NTIS; INIS; GPO.

Understanding the mechanics of variably saturated flow in fractured-porous media is of fundamental importance to evaluating the isolation performance of the proposed high-level radioactive waste repository for the Yucca Mountain

site. Developing that understanding must be founded on the analysis and interpretation of laboratory and field data. This report presents an analysis of the unsaturated hydraulic properties of tuff cores from the Pena Blanca natural analog site in Mexico. The basic intent of the analysis was to examine possible trends and relationships between the hydraulic properties and the degree of hydrothermal alteration exhibited by the tuff samples. These data were used in flow simulations to evaluate the significance of a particular conceptual (composite) model and of distinct hydraulic properties on the rate and nature of water flow.

1030 (PB–94-113636/XAB) **Underground exploration and testing at Yucca Mountain: A report to Congress and the Secretary of Energy.** Nuclear Waste Technical Review Board, Arlington, VA (United States). Oct 1993. 38p. Source: NTIS Prices: PC A03/MF A01; INIS.

Also available from Supt. of Docs. See also DE88009788.

Underground exploration and testing are major components of the DOE's site-characterization efforts at Yucca Mountain, Nevada. During the past four years, the DOE's plans for exploration and testing in an underground facility have evolved substantially, and many improvements have been made. The report reviews the status of the DOE's underground exploration and testing project at Yucca Mountain, Nevada; it suggests strategies to improve both the exploration and testing program and the approach to designing and excavating the exploratory facility. The Board makes several recommendations it believes will speed progress and improve cost-effectiveness. The Board believes the changes it is recommending can and should be made without slowing the momentum of important site-characterization activities currently under way at Yucca Mountain.

1031 (PB–94-116886/XAB) **NWTRB special report to congress and the Secretary of Energy.** Nuclear Waste Technical Review Board, Washington, DC (United States). Mar 1993. 28p. Source: NTIS Prices: PC A03/MF A01; INIS.

The Nuclear Waste Technical Review Board (the Board) was created by Congress in 1987 to review the scientific and technical validity of the Department of Energy's (DOE) civilian radioactive waste management program. The goal of the DOE's program is to design and develop a system to manage and safely dispose of the spent nuclear fuel being produced at the nation's 108 commercial nuclear power plants along with some high-level reprocessing wastes from defense-related activities. During its review of the program, the Board has witnessed considerable progress, especially in site characterization and data collection at Yucca Mountain, and, given existing data, this NWTRB Special Report to Congress and the Secretary of Energy briefly outlines three of the Board's major concerns: (1) the program's unrealistic deadlines, (2) the need for an integrated overall waste management plan, and (3) the effectiveness of program management. The Board believes that these concerns should be addressed immediately, concurrent with ongoing site-characterization work, to ensure that the program has a strong technical and scientific base and to facilitate program progress.

1032 (PB–94-174133/XAB) **US nuclear waste technical review board report to the US Congress and the Secretary of Energy, January to December 1993.** Nuclear Waste Technical Review Board, Arlington, VA (United States). Dec 1993. 178p. Source: NTIS Prices: PC A09/MF A02; INIS.

Also available from Supt. of Docs. See also NUREG-1046, PB–93-141620 and PB–94-113636.

This report reviews conclusions and recommendations that have resulted from the Board's activities primarily during 1993. In a few cases, activities that took place during 1992 and 1994 also are discussed. Since its last report on the exploratory studies facility, in October 1993, the Board has continued its interactions with the DOE, the state of Nevada, and with others involved in or concerned about the civilian radioactive waste management program. In this report, the Board makes a number of technical recommendations that it believes will aid the DOE in its endeavors to design and implement a safe and efficient radioactive waste disposal system. The report also discusses briefly some of the insights the Board gained during its interactions in June 1993 with experts from high-level waste management programs in Belgium, France, and the United Kingdom.

1033 (PNL–8659) **AREST model description.** Engel, D.W.; McGrail, B.P. Pacific Northwest Lab., Richland, WA (United States). Nov 1993. 87p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94004566. Source: OSTI; NTIS; INIS; GPO Dep.

The Office of Civilian Radioactive Waste Management and the Power Reactor and Nuclear Fuel Development Corporation of Japan (PNC) have supported the development of the Analytical Repository Source-Term (AREST) at Pacific Northwest Laboratory. AREST is a computer model developed to evaluate radionuclide release from an underground geologic repository. The AREST code can be used to calculate/estimate the amount and rate of each radionuclide that is released from the engineered barrier system (EBS) of the repository. The EBS is the man-made or disrupted area of the repository. AREST was designed as a system-level models to simulate the behavior of the total repository by combining process-level models for the release from an individual waste package or container. AREST contains primarily analytical models for calculating the release/transport of radionuclides to the lost rock that surrounds each waste package. Analytical models were used because of the small computational overhead that allows all the input parameters to be derived from a statistical distribution. Recently, a one-dimensional numerical model was also incorporated into AREST, to allow for more detailed modeling of the transport process with arbitrary length decay chains. The next step in modeling the EBS, is to develop a model that couples the probabilistic capabilities of AREST with a more detailed process model. This model will need to look at the reactive coupling of the processes that are involved with the release process. Such coupling would include: (1) the dissolution of the waste form, (2) the geochemical modeling of the groundwater, (3) the corrosion of the container overpacking, and (4) the backfill material, just to name a few. Several of these coupled processes are already incorporated in the current version of AREST.

1034 (PNL–8853) **Software requirements specification document for the AREST code development.** Engel, D.W. (Pacific Northwest Lab., Richland, WA (United States)); McGrail, B.P.; Whitney, P.D.; Gray, W.J.; Williford, R.E.; White, M.D.; Eslinger, P.W.; Altenhofen, M.K. Pacific Northwest Lab., Richland, WA (United States). Nov 1993. 54p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94004586. Source: OSTI; NTIS; INIS; GPO Dep.

The Analysis of the Repository Source Term (AREST) computer code was selected in 1992 by the U.S. Department of Energy. The AREST code will be used to analyze the performance of an underground high level nuclear waste repository. The AREST code is being modified by the Pacific Northwest Laboratory (PNL) in order to evaluate the engineered barrier and waste package designs, model regulatory compliance, analyze sensitivities, and support total systems performance assessment modeling. The current version of the AREST code was developed to be a very useful tool for analyzing model uncertainties and sensitivities to input parameters. The code has also been used successfully in supplying source-terms that were used in a total systems performance assessment. The current version, however, has been found to be inadequate for the comparison and selection of a design for the waste package. This is due to the assumptions and simplifications made in the selection of the process and system models. Thus, the new version of the AREST code will be designed to focus on the details of the individual processes and implementation of more realistic models. This document describes the requirements of the new models that will be implemented. Included in this document is a section describing the near-field environmental conditions for this waste package modeling, description of the new process models that will be implemented, and a description of the computer requirements for the new version of the AREST code.

1035 (PNL–9415) **Regional forecasting with global atmospheric models: Fourth year report.** Crowley, T.J. (Applied Research Corp., College Station, TX (United States)); North, G.R.; Smith, N.R. Pacific Northwest Lab., Richland, WA (United States); Applied Research Corp., College Station, TX (United States). May 1994. 60p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94013957. Source: OSTI; NTIS; INIS; GPO Dep.

The scope of the report is to present the results of the fourth year's work on the atmospheric modeling part of the global climate studies task. The development testing of computer models and initial results are discussed. The appendices contain studies that provide supporting information and guidance to the modeling work and further details on computer model development. Complete documentation of the models, including user information, will be prepared under separate reports and manuals.

1036 (RIVM–715206005) **INTRAVAL phase 2, test case 8, Alligator Rivers Natural Analogue: Modelling of uranium transport in the weathered zone at Koongarra (Australia).** Van de Weerd, H.; Leijnse, A.; Hassanizadeh, S.M.; Richardson-van der Poel, M.A. Rijksinstituut voor Volksgezondheid en Milieuhygiene, Bilthoven (Netherlands). Apr 1994. 88p. Source: Available from RIVM, P.O. Box 1, 3720 BA Bilthoven (Netherlands).

The title research is part of the project 'International Model Validation' which is carried out within the framework of the phase 1A program of the Dutch Committee 'Opberging te Land' (OPLA) (Land Storage). Within the OPLA program the title study is part of the program 'Risks of Radioactive Waste Storage'.

The purpose of this study is to test the simulation package METROPOL, developed at RIVM to simulate transport of radionuclides over large time scales. At the Koongarra site secondary uranium mineralization and dispersed uranium is present from the surface down to the base of weathering. Field data are analyzed to choose a modelling approach, to estimate model inputs and to test model results. Field data show that three layers can be distinguished in the Koongarra area: (1) a top layer which is fully weathered, (2) an intermediate layer which is partially weathered (the transition zone) and (3) a lower layer which is unweathered. The groundwater velocities are largest in the transition zone which has been moving downward as the weathering process proceeds. The finite element code METROPOL has been adapted to account for the movement of the transition zone and to describe the dissolution of uranium in the orebody by a non-equilibrium relation. In simulations taking into account the downward movement of the transition zone, the dispersion patterns at all depths are simulated. These simulations result in a pseudo steady state situation. Despite the fact that the model results presented are not fully in agreement with the dispersion patterns, it is expected that the present situation may be obtained by changing some of the model parameters. In this study it was shown that over large timescales geologic processes may have an impact on the transport of radionuclides, and the movement of the transition zone will have an impact on the uranium concentration distribution. The simulation results are influenced by the parameters values, which are difficult to estimate for a period of some million years. The largest uncertainties are associated with the boundary conditions. Continuation of natural analogue studies in the framework of nuclear waste disposal research is highly recommended. 24 figs., 13 tabs., 2 appendices, 39 refs.

1037 (RIVM–725206010) **INTRAVAL phase 2, test case 8. Alligator Rivers Natural Analogue. Modelling of uranium transport in the weathered zone at Koongarra, Australia.** Hassanizadeh, S.M. (National Inst. of Public Health and Environmental Protection RIVM, Bilthoven (Netherlands)); Van de Weerd, H.; Richardson-Van der Poel, M.A. Rijksinstituut voor Volksgezondheid en Milieuhygiene, Bilthoven (Netherlands). Jan 1993. 48p. Source: Available from RIVM, P.O. Box 1, 3720 BA Bilthoven (Netherlands).

The title research is part of the project 'International Model Validation' which is carried out within the framework of the phase 1A program of the Dutch Committee 'Opberging te Land' (OPLA) (Land Storage). Within the OPLA program the title study is part of the program 'Risks of Radioactive Waste Storage'.

Preliminary results of modelling of the dispersion of uranium in the weathered and transition zones are given. In the course of the Alligator Rivers Analogue Project (ARAP) more insight was gained about the formation of the dispersion fan and about the hydrology at Koongarra. The here applied transport modelling strategy takes into account those results. First, a general explanation of Natural Analogue is given, next to a brief description of the ARAP test case, carried out within the INTRAVAL phase 2. INTRAVAL is an international project concerned with the use of mathematical models for predicting the potential transport of radioactive solutes in the geosphere. Following is the analysis of chemical data, necessary for the choice of the modelling approach, for estimation of model inputs and for testing model results. Subsequently, the modelling strategy is expounded and a description is given of METROPOL, the transport code, used for modelling. 11 figs., 2 tabs., 1 appendix, 17 refs.

1038 (SAND–92-0984) **Measuring the dynamic compression and release behavior of rocks and grouts associated with HYDROPLUS.** Furnish, M.D. Sandia National Labs., Albuquerque, NM (United States). Oct 1993. 162p. Sponsored by USDOE, Washington, DC (United

States);Department of Defense, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94003312. Source: OSTI; NTIS; GPO Dep.

Gas-gun impact tests were performed on twelve rocks and rock simulants pertinent to the HYDROPLUS nuclear yield measurement program: A variety of tuffs, rhyolites, carbonates, grouts, an epoxy-alumina mixture and quartzite permafrost samples recovered in an apparently preserved frozen state from northern Canada. The present report presents results for all of these materials except for the carbonates. Two classes of impact techniques were employed for measuring equation-of-state properties for these materials. Both use velocity interferometry diagnostics. One, employing a sample-in-projectile geometry, provides high-precision Hugoniot data and continuous release trajectories for dry or water-saturated materials. The majority of the experiments were performed with this geometry. The other, employing a sample-in-target geometry, provides loading path and Hugoniot data as well as limited release data. Uncertainties in the results have been estimated by analyzing the effects of errors in observables and ancillary material properties.

1039 (SAND–93-2240C) **Using performance assessment for radioactive waste disposal decision making – implementation of the methodology into the third performance assessment iteration of the Greater Confinement Disposal site.** Gallegos, D.P. (Sandia National Labs., Albuquerque, NM (United States)); Conrad, S.H.; Baer, T.A. Sandia National Labs., Albuquerque, NM (United States). [1993]. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-76DP00789. (CONF-940553–8: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94006583. Source: OSTI; NTIS; INIS; GPO Dep.

The US Department of Energy is responsible for the disposal of a variety of radioactive wastes. Some of these wastes are prohibited from shallow land burial and also do not meet the waste acceptance criteria for proposed waste repositories at the Waste Isolation Pilot Plant (WIPP) and Yucca Mountain. These have been termed "special-case" waste and require an alternative disposal method. From 1984 to 1989, the Department of Energy disposed of a small quantity of special-case transuranic wastes at the Greater Confinement Disposal (GCD) site at the Nevada Test Site. In this paper, an iterative performance assessment is demonstrated as a useful decision making tool in the overall compliance assessment process for waste disposal. The GCD site has been used as the real-site implementation and test of the performance assessment approach. Through the first two performance assessment iterations for the GCD site, and the transition into the third, we demonstrate how the performance assessment methodology uses probabilistic risk concepts to guide affective decisions about site characterization activities and how it can be used as a powerful tool in bringing compliance decisions to closure.

1040 (SAND–94-2348C) **Use of a scenario-development procedure to identify potentially disruptive scenarios, Greater Confinement Disposal facility, Area 5, Nevada Test Site.** Guzowski, R.V. (Science Applications International Corp., San Diego, CA (United States)). Sandia National Labs., Albuquerque, NM (United States). [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-950216–59: Waste management '95, Tucson, AZ (United States), 26 Feb - 2 mar 1995). Order Number DE95007730. Source: OSTI; NTIS; INIS; GPO Dep.

The Greater Confinement Disposal (GCD) facility includes four boreholes that contain transuranic (TRLT) waste. Presence of the TRU waste means that this facility must comply with the US Environmental Protection Agency's Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Waste-Final Rule 40 CFR Part 191. To comply with the Containment Requirements of this rule, all potentially disruptive events and processes, and by implication all potentially disruptive combinations of events and processes (scenarios), must be identified for possible inclusion in performance assessments. Screening of the FEPs identified four events for scenario development: exploratory drilling for natural resources, drilling withdrawal wells, irrigation, and subsidence. Recent environmental-isotope analyses of the vadose zone suggest that radionuclide transport from the boreholes to the water table by infiltration is not a feasible transport mechanism within the time frame of regulatory concern. For this reason, the event of drilling withdrawal wells was merged with exploratory drilling for resources. The descriptions of the remaining three events were modified slightly to aid in estimation of event probabilities and consequence analyses. The three events are: exploratory drilling for resources penetrates a TRU borehole, irrigation occurs at the Radioactive Waste Management Site (RWMS), and subsidence occurs at the RWMS. Use of a logic diagram with these three events resulted in the construction of eight scenarios, including base-case (undisturbed) conditions. Screening these scenarios at this stage of scenario development was beyond the scope of this task. Based on the implementation assumptions, this scenario-development procedure produced a comprehensive set of mutually exclusive scenarios that are reproducible and auditable for use in GCD performance assessments.

1041 (SAND–94-2563/3) **Performance assessment of the direct disposal in unsaturated tuff of spent nuclear fuel and high-level waste owned by US Department of Energy. Volume 3, Appendices.** Rechard, R.P. (ed.). Sandia National Labs., Albuquerque, NM (United States). Feb 1995. 714p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95010452. Source: OSTI; NTIS; INIS; GPO Dep.

This assessment studied the performance of high-level radioactive waste and spent nuclear fuel in a hypothetical repository in unsaturated tuff. The results of this 10-month study are intended to help guide the Office of Environment Management of the US Department of Energy (DOE) on how to prepare its wastes for eventual permanent disposal. The waste forms comprised spent fuel and high-level waste currently stored at the Idaho National Engineering Laboratory (INEL) and the Hanford reservation. About 700 metric tons heavy metal (MTHM) of the waste under study is stored at INEL, including graphite spent nuclear fuel, highly enriched uranium spent fuel, low enriched uranium spent fuel, and calcined high-level waste. About 2100 MTHM of weapons production fuel, currently stored on the Hanford reservation, was also included. The behavior of the waste was analyzed by waste form and also as a group of waste forms in the hypothetical tuff repository. When the waste forms were studied together, the repository was assumed also to contain about 9200 MTHM high-level waste in borosilicate glass from three DOE sites. The addition of the borosilicate glass, which has already been proposed as a final waste form, brought the total to about 12,000 MTHM.

1042 (SAND–95-0271C) **A natural analogue for high-level waste in tuff: Chemical analysis and modeling of the Valles site.** Stockman, H.W. (Sandia National Labs., Albuquerque, NM (United States)); Krumhansl, J.L.; Ho, C.K.; Kovach, L.; McConnell, V.S. Sandia National Labs., Albuquerque, NM (United States). [1995]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-950216–76: Waste management '95, Tucson, AZ (United States), 26 Feb - 2 mar 1995). Order Number DE95008533. Source: OSTI; NTIS; INIS; GPO Dep.

The contact between an obsidian flow and a steep-walled tuff canyon was examined as an analogue for a high-level waste repository. The analogue site is located in the Valles Caldera in New Mexico, where a massive obsidian flow filled a paleocanyon in the Battleship Rock Tuff. The obsidian flow provided a heat source, analogous to waste panels or an igneous intrusion in a repository, and caused evaporation and migration of water. The tuff and obsidian samples were analyzed for major and trace elements and mineralogy by INAA, XRF, x-ray diffraction, and scanning electron microscopy and electron microprobe. Samples were also analyzed for D/H and $^{39}Ar/^{40}Ar$ isotopic composition. Overall, the effects of the heating event seem to have been slight and limited to the tuff nearest the contact. There is some evidence of devitrification and migration of volatiles in the tuff within 10 m of the contact, but variations in major and trace element chemistry are small and difficult to distinguish from the natural (pre-heating) variability of the rocks.

1043 (SAND–95-1270C) **Consideration of criticality in a nuclear waste repository.** Rechard, R.P.; Sanchez, L.C.; Stockman, C.T.; Ramsey, J.L. Jr.; Martell, M. Sandia National Labs., Albuquerque, NM (United States). [1995]. 8p. Sponsored by USDOE, Washington, DC (United States). (CONF-9509100–4: 5. international conference on nuclear criticality safety, Albuquerque, NM (United States), 17-22 Sep 1995). Order Number DE95014893. Source: OSTI; NTIS; INIS; GPO Dep.

The preliminary criticality analysis that was done suggests that the possibility of achieving critical conditions cannot be easily ruled out without looking at the geochemical process of assembly or the dynamics of the operation of a critical assembly. The evaluation of a critical assembly requires an integrated, consistent approach that includes evaluating the following: (1) the alteration rates of the layers of the container and spent fuel, (2) the transport of fissile material or neutron absorbers, and (3) the assembly mechanisms that can achieve critical conditions. The above is a non-trivial analysis and preliminary work suggests that with the loading assumed, enough fissile mass will leach from the HEU multi-purpose canisters to support a criticality. In addition, the consequences of an unpressurized Oklo type criticality would be insignificant to the performance of an unsaturated, tuff repository.

1044 (SKB-TR–93-17) **Oxidation of uraninite.** Janeczek, J. (Univ. of New Mexico, Albuquerque, NM (United States). Dept. of Earth and Planetary Science); Ewing, R.C. Swedish Nuclear Fuel and Waste Management Co., Stockholm (Sweden). Jun 1993. 30p. Order Number DE94620288. Source: OSTI; NTIS; INIS.

Samples of uraninite and pitchblende annealed at 1200 degrees C in H_2, and untreated pitchblende were sequentially oxidized in air at 180-190 degrees C, 230 degrees C, and 300 degrees C. Uraninite and untreated pitchblende oxidized to the U_4O_9-type oxide, and their x-ray symmetry remained isometric up to 300 degrees C. Reduced pitchblende, after oxidation to UO_{2+x} and U_4O_9-type oxides, transformed into α-U_3O_8 at 300 degrees C. Two major mechanisms control uraninite and untreated pitchblende stability during oxidation: 1. Th and/or lanthanide elements maintain charge balance and block oxygen interstitials near impurity cations; 2. the uraninite structure saturates with respect to excess and radiation-induced oxygen interstitials. Untreated pitchblende during oxidation behaved similarly to irradiated UO_2 in spent nuclear fuel; whereas, reduced pitchblende resembled non-irradiated UO_2. An analysis of the data in the literature, as well as our own efforts (XRD, EMPA, SEM, AEM) to identify U_3O_7 in samples form Cigar Lake, Canada, failed to provide conclusive evidence of the natural occurrence of tetragonal αU_3O_7. Most probably, reported occurrences of U_3O_7 are mixtures of isometric uraninites of slightly different compositions, 45 refs.

1045 (SKB-TR–93-21) **Development of 'CHEMFRONTS' a coupled transport and geochemical program to handle reaction fronts.** Baeverman, C. (Royal Inst. of Tech., Stockholm (Sweden). Dept. of Chemical Engineering). Swedish Nuclear Fuel and Waste Management Co., Stockholm (Sweden). Oct 1993. 254p. Order Number DE94621512. Source: OSTI; NTIS; INIS.

A computer program to calculate coupled mass transport and fluid rock interactions has been developed. The program, CHEMFRONTS, is based on the quasi-stationary state approximation and uses a kinetic expression for the mineral dissolution and precipitation coupled to a transport model. It is adapted to handle sharp reaction fronts. Such fronts evolve in the ground and typical examples are redox fronts and dissolution and precipitation fronts. CHEMFRONTS calculates the chemical reactions for one-dimensional advective flow through a porous medium. Reactions between the water and the solid phase such as dissolution and precipitation are included in the model. In the water phase, complexation and redox reactions are also computed. To verify the program, comparisons have been made with results obtained with other computer programs, CHEQMATE, PHASEQL/FLOW, and DYNAMIX. Natural analogues, such as Pocos de Caldas and Cigar Lake, are also studied. The results from the simulations and comparisons are encouraging. 37 refs.

1046 (SKB-TR–94-04) **Final report of the AECL/SKB Cigar Lake analog study.** Cramer, J. (ed.) (Atomic Energy of Canada Ltd. Research, Pinawa, MB (Canada). Whiteshell Labs.); Smellie, J. (ed.). Swedish Nuclear Fuel and Waste Management Co., Stockholm (Sweden). May 1994. 402p. (AECL–10851; COG–93-147.). Order Number DE95613252. Source: OSTI; NTIS; INIS.

The Cigar Lake uranium deposit is located in northern Saskatchewan, Canada. The 1.3-billion-year-old deposit is located at a depth of about 450 m below surface in a water-saturated sandstone at the unconformity contact with the high-grade metamorphic rocks of the Canadian Shield. The Cigar Lake deposit has many features that parallel those being considered within the Canadian concept for disposal of nuclear fuel waste. The study of these natural structures and processes provides valuable insight toward the eventual design and site selection of a nuclear fuel waste repository. The main feature of this analog is the absence of any indication on the surface of the rich uranium ore 450 m below. This indicates that the combination of natural barriers has been effective in isolating the uranium ore from the surface environment. More specifically, the deposit provides analog

information relevant to the stability of UO_2 fuel waste, the performance of clay-based barriers, radionuclide migration, colloid formation, radiolysis, fission-product geochemistry and general aspects of water-rock interaction. The main geochemical studies on this deposit focus on the evolution of groundwater compositions in the deposit and on their redox chemistry with respect to the uranium, iron and sulphide systems. Since 1984, through cooperation from the owners of the Cigar Lake deposit, analog studies have been conducted. AECL, with support from Ontario Hydro under the auspices of the CANDU Owners Group, initiated international participation in 1989 through collaboration with the Swedish Nuclear Fuel and Waste Management Company (SKB) and, more recently, with the Los Alamos National Laboratory (LANL).

1047 (SKI-R–94-19) **The Alligator rivers natural analogue - Modelling of uranium and thorium migration in the weathered zone at Koongarra.** Skagius, K. (Kemakta, Stockholm (Sweden)); Lindgren, M.; Boghammar, A.; Brandberg, F.; Pers, K.; Widen, H. Swedish Nuclear Power Inspectorate, Stockholm (Sweden). Aug 1993. 95p. Order Number DE95631036. Source: OSTI; NTIS; INIS.

The Koongarra Uranium Deposit in the Alligator Rivers Region in the Northern Territory of Australia is a natural analogue being investigated with the aim to contribute to the understanding of the scientific basis for the long term prediction of radionuclide migration within geological environments relevant to radioactive waste repositories. The dispersion of uranium and decay products in the weathered zone has been modelled with a simple advection-dispersion-reversible sorption model and with a model extended to also consider α-recoil and transfer of radionuclides between different mineral phases of the rock. The modelling work was carried out in several iterations, each including a review of available laboratory and field data, selection of the system to be modelled and suitable model, and a comparison of modelling results with field observations. Uranium concentrations in bulk rock calculated with the simple advection-dispersion-reversible sorption model were in fair agreement with observed data using parameter values within ranges recommended based on independent interpretations. The advection-dispersion-reversible sorption model is a large simplification of the system among other things because the partitioning of radionuclides between water and solid phase is described with a sorption equilibrium term only. Although the results from this study not are enough to validate simple performance assessment models in a strict sense, it has been shown that even simple models are able to describe the present day distribution of uranium in the weathered zone at Koongarra. 23 refs, 61 figs.

1048 (UCRL-ID–116122) **Preliminary on the isotope hydrology investigations at the Nevada test site: Hydrologic resources management program: FY 1992–1993.** Davisson, M.L.; Kenneally, J.M.; Smith, D.K.; Hudson, G.B.; Nimz, G.J.; Rego, J.H. Lawrence Livermore National Lab., CA (United States). Jan 1994. 83p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE94011538. Source: OSTI; NTIS; GPO Dep.

A comprehensive isotope data base of the NTS groundwaters collected during FY 92-93 is presented with preliminary interpretations. Multiple samples were collected from over 30 sites on pumped wells and open-holes by wireline bailing. Field water level measurements indicate essentially a bimodal distribution separated by water levels at higher elevations (e.g. Pahute Mesa) from water levels of lower elevations (e.g. Yucca and Frenchman Flats). Down hole temperature measurements have confirmed anomalous temperature gradients in the eastern Yucca Flat area and on Pahute Mesa, where horizontal temperature gradients up to 0.33°F/100ft are found. Consistent with previous reports by others, the major ion geochemistry of the NTS groundwater are dominated by Na-K-HCO_3 and Ca-Mg-HCO_3 water types, where the Na-rich water appears to be related to dissolution in the volcanic tuffs and the Ca-rich water to the Paleozoic carbonates. Increases in dissolved Si also seems to be indicative of groundwater that resides in the volcanic tuffs. Processes controlling the Na/Ca ratios are complex and may include ion exchange reactions with clays, evaporative concentration in the vadose zone, and lithological heterogeneities in addition to simple differential dissolution between the volcanic tuffs and the Paleozoic carbonates. Apparent ^{14}C ages range between 4000 and 38,000 years for groundwaters at the NTS. The uncertainty is large for exact age determinations at this time. The ^{14}C abundance decreases with increased dissolved HCO_3, and ^{13}C suggests dissolution of the "dead" Paleozoic carbonates significantly influence the ages, but more work is needed to investigate the influence of vadose zone carbonate.

1049 (UCRL-JC–114686) **Technical changes that would contribute to success in the civilian radioactive waste management program.** Ramspott, L.D. Lawrence Livermore National Lab., CA (United States). 1 Oct 1993. 30p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-9309295–3: Nuclear as a large-scale global option conference, Oak Ridge, TN (United States), 28-30 Sep 1993). Order Number DE94007381. Source: OSTI; NTIS; INIS; GPO Dep.

Many changes have taken place since the SCP safety strategy was formulated; it needs to be revised or replaced. Four concepts would aid in the shift from a rigid, ecelctic, schedule-driven, all-or-nothing program to an incremental, evolving, and experimental but integrated program. These are a simple safety case, reversability, demonstrability, and decoupling operations of a repository from operation of reactors. A simple safety case based on containment can be made for a repository at Yucca Mountain. This containment strategy is based on the dryness of openings at Yucca Mountain, Extended Dry heat management, and long-lived containers. Reversibility is technically believable at Yucca Mountain because of extended retrievability and drift emplacement, if an MRS were co-located with the repository. Because the rock is unsaturated, extended retrievability is technically feasible at Yucca Mountain. Demonstrability could be improved at Yucca Mountain by planning for incremental progression toward operation and closure of a repository, possibly including a shift to underground retrievable storage. Demonstrability can also be improved by using natural analogs. Repository operation can be decoupled from reactor operation by use of an unconstrained MRS facility or at-reactor dry storage and multipurpose storage canister/casks.

1050 (UCRL-JC–115255) **Seismic design and analysis considerations for high level nuclear waste repositories.** Hossain, Q.A. Lawrence Livermore National Lab., CA (United States). 30 Sep 1993. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-9310102–42: 4. energy natural phenomena hazards mitigation conference, Atlanta, GA

(United States), 19-22 Oct 1993). Order Number DE94005817. Source: OSTI; NTIS; INIS; GPO Dep.

A high level nuclear waste repository, like the one at Nevada's Yucca Mountain that is being investigated for site suitability, will have some unique seismic design and analysis considerations. These are discussed, and a design philosophy that can rationally account for the unique performance objectives of such facilities is presented. A case is made for the use of DOE's performance goal-based seismic design and evaluation methodology that is based on a hybrid "deterministic" and "probabilistic" concept. How and to what extent this methodology should be modified to adopt it for a potential site like Yucca Mountain is also outlined. Finally, the issue of designing for seismic fault rupture is discussed briefly, and the desirability of using the proposed seismic design philosophy in fault rupture evaluation is described.

1051 (UCRL-JC-116349) **A performance goal-based seismic design philosophy for waste repository facilities.** Hossain, Q.A. Lawrence Livermore National Lab., CA (United States). Feb 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553-23: ... International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94009105. Source: OSTI; NTIS; INIS; GPO Dep.

A performance goal-based seismic design philosophy, compatible with DOE's present natural phenomena hazards mitigation and "graded approach" philosophy, has been proposed for high level nuclear waste repository facilities. The rationale, evolution, and the desirable features of this method have been described. Why and how the method should and can be applied to the design of a repository facility are also discussed.

1052 (UCRL-JC-120389) **Challenges in defining a radiologic and hydrologic source term for underground nuclear test centers, Nevada Test Site, Nye County, Nevada.** Smith, D.K. Lawrence Livermore National Lab., CA (United States). Jun 1995. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-950868-3: ER '95: environmental remediation conference: committed to results, Denver, CO (United States), 13-18 Aug 1995). Order Number DE95015887. Source: OSTI; NTIS; INIS; GPO Dep.

The compilation of a radionuclide inventory for long-lived radioactive contaminants residual from nuclear testing provides a partial measure of the radiologic source term at the Nevada Test Site. The radiologic source term also includes potentially mobile short-lived radionuclides excluded from the inventory. The radiologic source term for tritium is known with accuracy and is equivalent to the hydrologic source term within the saturated zone. Definition of the total hydrologic source term for fission and activation products that have high activities for decades following underground testing involves knowledge and assumptions which are presently unavailable. Systematic investigation of the behavior of fission products, activation products and actinides under saturated or Partially saturated conditions is imperative to define a representative total hydrologic source term. This is particularly important given the heterogeneous distribution of radionuclides within testing centers. Data quality objectives which emphasize a combination of measurements and credible estimates of the hydrologic source term are a priority for near-field investigations at the Nevada Test Site.

1053 (USGS/OFR-94-491) **Meteorological data for four sites at surface-disruption features in Yucca Flat, Nevada Test Site, Nye County, Nevada, 1985-1986.** Carman, R.L. Geological Survey, Carson City, NV (United States). 1994. 46p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-91NV11040. Order Number DE95004391. Source: OSTI; NTIS; INIS; GPO Dep.

Surface-disruption features, or craters, resulting from underground nuclear testing at the Nevada Test Site may increase the potential for ground-water recharge in an area that would normally produce little, if any, recharge. This report presents selected meteorological data resulting from a study of two surface-disruption features during May 1985 through June 1986. The data were collected at four adjacent sites in Yucca Flat, about 56 kilometers north of Mercury, Nevada. Three sites (one in each of two craters and one at an undisturbed site at the original land surface) were instrumented to collect meteorological data for calculating bare-soil evaporation. These data include (1) long-wave radiation, (2) short-wave radiation, (3) net radiation, (4) air temperature, and (5) soil surface temperature. Meteorological data also were collected at a weather station at an undisturbed site near the study craters. Data collected at this site include (1) air temperature, (2) relative humidity, (3) wind velocity, and (4) wind direction.

1054 (USGS/WRIR-95-4177) **Water-level data from wells and test holes through 1991 and potentiometric contours as of 1991 for Yucca Flat, Nevada Test Site, Nye County, Nevada.** Hale, G.S.; Trudeau, D.A.; Savard, C.S. Geological Survey, Carson City, NV (United States). 1995. 15p. Sponsored by Department of the Interior, Washington, DC (United States). DOE Contract AI08-91NV11040. Order Number DE96002802. Source: OSTI; NTIS; GPO Dep.

The underground nuclear testing program of the US Department of Energy (USDOE) takes place at the Nevada Test Site (NTS), about 65 mi north-west of Las Vegas, Nevada. Underground nuclear tests at Yucca Flat, one of the USDOE test areas at NTS, have affected hydrologic conditions, including groundwater levels. The purpose of this map report, prepared in cooperation with USDOE, is to present selected water-level data collected from wells and test holes through December 1991, and to show potentiometric contours representing 1991 water-table conditions in the Yucca Flat area. The more generic term, potentiometric contours, is used herein rather than "water-table contours" because the hydrologic units contributing water to wells and test holes may not accurately represent the water table. The water table is that surface in an unconfined water body at which the pressure is atmospheric. It is defined by the altitude at which nonperched ground water is first found in wells and test holes. Perched ground water is defined as unconfined ground water separated from an underlying body of ground water by an unsaturated zone. This map report updates information on water levels in some wells and test holes and the resulting water-table contours in rocks of Cenozoic and Paleozoic age shown by Doty and Thordarson for 1980 conditions.

1055 Public reactions to nuclear waste: Citizens' views of repository siting. Dunlap, R.E.; Kraft, M.E.; Rosa, E.A. (eds.). [10p.] Duke University Press, Durham, NC (United States) ([1995]).

From review in Risk Analysis, Vol. 15, No. 1 (Feb 1995).

This book explores the apparent close inverse relationship between trust in government and perceptions of risk by the

public, focusing on the current controversy over siting of a high-level nuclear waste repository at Yucca Mountain.

1056 Nuclear waste disposal: Gambling on Yucca Mountain. Ginsburg, S. 153p. Aegean Park Press, Laguna Hills, CA (United States) (1995).

This document describes the historical aspects of nuclear energy ,nuclear weapons usage, and development of the nuclear bureaucracy in the United States, and discusses the selection and siting of Yucca Mountain, Nevada for a federal nuclear waste repository. Litigation regarding the site selection and resulting battles in the political arena and in the Nevada State Legislature are also presented. Alternative radioactive waste disposal options, risk assessments of the Yucca Mountain site, and logistics regarding the transportation and storage of nuclear waste are also presented. This document also contains an extensive bibliography.

1057 Public reactions to nuclear waste: Citizens' views of repository siting. Dunlap, R.E.; Kraft, M.E.; Rosa, E.A. (eds.). 332p. Duke University Press, Durham, NC (United States) ([1995]).

From review by Carl Gertz, Department of Energy and Michelle Ulick, Science Applications International Corporation in Forum, Vol. 10, No. 2 (Sum 1995).

This book compiles and examines a wide, but not exhaustive, array of survey work conducted between 1986 and 1991, though many of the public reactions are geared to Yucca Mountain. Included is an historic and social overview of nuclear power and events leading to concerns over waste-disposal methods. Other chapters present viewpoints of rural Nevadans living near Yucca Mountain, a cross-section of citizens nationwide and convention planners and participants.

1058 H.R. 2081: A Bill to prohibit site characterization of the Yucca Mountain site in the State of Nevada during fiscal years 1994 through 1998, and for other purposes. Introduced in the House of Representatives, One Hundred Third Congress, First Session, May 11, 1993. 4p. Government Printing Office, Washington, DC (United States) (1994).

This bill provides that no amount of money may be expended from the Nuclear Waste Fund during fiscal years 1994-1998 for site characterization of the Yucca Mountain site in Nevada in conjunction with a nuclear waste policy reassessment.

1059 Natural analogue studies in the geological disposal of radioactive wastes. Studies in Environmental Science, No. 57. Miller, W. (Intera Information Technologies (United Kingdom)); Chapman, N.; Alexander, R.; McKinley, I.; Smellie, J. 401p. Elsevier, Amsterdam (Netherlands) (1994). (NAGRA-NTB-93-03.).

The book deals with the concepts of radioactive waste disposal in Switzerland, Sweden and England, with analogue studies, radionuclide release and transport, applying natural analogue information, and the status of natural analogue studies. It contains descriptions of fourteen natural analogue studies.

1060 Thermoluminescence dating techniques at the Alligator Rivers Region Research Institute. Technical Memorandum 41. Roberts, R.G.; Uren, C.J.; Murray, A.S. 56p. Australian Government Publishing Service, Canberra (Australia) (1993).

Techniques for dating Quaternary sediments have been developed, with specific application to fluvial and colluvial sand deposits in tropical northern Australia. In thermoluminescence (TL) dating, the age of the deposit is determined as a function of the 'equivalent dose' (ED), the quantity of ionizing radiation required to produce the observed natural TL intensity and the dose rate. To determine the ED, the 90-125 μm diameter quartz fraction of each deposit was used (following conventional quartz-inclusion pretreatment procedures) and adopted a combined additive-dose and regenerative methodology. For unheated sediments, the TL clock is reset by exposure to sunlight, but an unbleachable (residual) TL signal remains even after prolonged exposure. The residual TL signal at the time of sediment deposition was estimated from ED determinations on modern (surface and near-surface) deposits. By examining the potential of dating water-lain deposits by TL it was possible to obtain ages for a range of deposits that are widespread across northern Australia and are of particular relevance in assessing the long-term geomorphological stability of uranium mining waste sites. Radionuclide concentrations were deduced from high-resolution gamma and alpha spectrometry. which enabled disequilibrium in the uranium decay series to be identified and the time-dependent correction in the dose rate to applied. The latter was preformed using the computer program listed in Appendix A. 66 refs., 3 tab., 3 figs.

1061 Public reactions to nuclear waste: Citizen's views of repository siting. Dunlap, R.E.; Kraft, M.E.; Rosa, E.A. (eds.). 332p. Duke University Press, Durham, NC (United States) (1993).

From review by Domenic Forcella, in Radwaste Magazine, Vol. 1, No. 2 (Apr 1994).

This book, a series of presentations at a 1989 symposium of AAAS, focuses on the social and political factors associated with the disposal of high-level nuclear waste and the development of public opposition. The book is organized into four sections: the first section puts the facility siting issue into a general perspective; another section focuses on public reactions to the Yucca Mountain site. A continuing theme throughout the book is that those involved in the process of siting a nuclear waste repository must step back and examine the roots of public opposition, determine what must be done, and then move forward again.

1062 Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.) (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). 360p. Australian Government Publishing Service, Canberra (Australia) (1992). (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

The objectives of the workshop were to review the current knowledge of land application as a technique for disposal of water from mine sites, to assess the for regulation of use of land application in the Alligator River Region, and to specify future information requirements on land application. The paper sessions were followed by two workshops on land application implications for regulation and future information needs. A summary of these sessions is also included in the proceedings. figs., tabs., refs.

1063 High level radioactive waste management: Proceedings: Volume 2. 748p. American Nuclear Society, La Grange Park, IL (United States) (1990). Sponsored by US-DOE, Washington, DC (United States). (CONF-900406--: 1. international topical meeting on high-level radioactive waste

management, Las Vegas, NV (United States), 8-12 Apr 1990).

The technical program for this meeting is designed to meet two major objectives: provide forums for major technical disciplines to (a) discuss current technical issues related to the full spectrum of international high level radioactive waste management activities, and (b) discuss the general contributions that they make to society and the approaches they use in defining and addressing issues related to high level radioactive waste management. The program includes disciplines related to social, institutional, and regulatory technologies for which data must be collected and evaluated in order to reach conclusions or to make decisions. Full papers are produced here so that appropriate, quality data and results are fully described. Topics covered include: natural systems, exploratory shaft design, intraplate seismotectonics and volcanology, transport processes, regulations, public involvement, intergovernmental issues, transportation operations and routing, total system performance, waste packages, cask system design, social issues, hydrology, site characterization, geochemistry, engineered barriers, systems modeling, system engineering, cask materials, waste producers, Yucca Mountain hydrology, rock mass characterization and testing, vitrification, environmental and health effects, climatology, waste management facilities, and spent fuel materials performance. Individual papers are indexed separately.

1064 Environmental factors in the stress corrosion cracking of type 316L stainless steel and alloy 825 in chloride solutions. Cragnolino, G. (Southwest Research Inst., San Antonio, TX (United States). Center for Nuclear Waste Regulatory Analyses); Dunn, D.; Sridhar, N. pp. 18, Paper 159 of Corrosion/95 conference papers. NACE International, Houston, TX (United States) (1995). pp. 5788 (CONF-950304--: Corrosion '95: National Association of Corrosion Engineers (NACE) international annual conference and corrosion show, Orlando, FL (United States), 26-31 Mar 1995).

This paper describes the experimental studies conducted to date to investigate the stress corrosion cracking of candidate container materials for the proposed high-level nuclear waste repository at Yucca Mountain. The effects of environmental variables, such as chloride concentration, the addition of thiosulfate, and temperature, on the stress corrosion cracking susceptibility of type 316L stainless steel and alloy 825 (Ni29Fe-22Cr-3.0Mo-2.0Cu-1.0Ti) were studied at temperatures ranging from 95 to 120 C. Results of slow strain rate tests (SSRT) at various potentials were compared to those obtained under constant deflection conditions using U-bend specimens to determine the existence of a critical potential for stress corrosion cracking. Results generated thus far, while not conclusive, are consistent with the hypothesis that the repassivation potential for localized corrosion is also the critical potential for stress corrosion cracking in these environments. It was confirmed that alloy 825 is significantly more resistant to stress corrosion cracking than type 316L stainless steel using both constant deflection tests and SSRT, over a wide range of chloride concentrations. In constant deflection tests, type 316L stainless steel exhibited cracks above the vapor/solution interface in solutions containing 1,000 ppm chloride, indicating that the local environment created as a liquid film on the specimen surface could be more detrimental than the bulk environment. Stress corrosion cracking of type 316L SS was observed in SSRT only at chloride concentrations above about 6 molal, whereas U-bend tests indicated cracking in 0.03 molar chloride solutions.

1065 Yucca Mountain: A crisis for policy. Prospects for America's high-level nuclear waste program. Flynn, J. (Decision Research, Eugene, OR (United States)); Slovic, P. pp. 83-118 of Annual review of energy and the environment. Volume 20, 1995. Socolow, R.H. (ed.); Anderson, D. (ed.); Harte, J. (ed.). Annual Reviews, Inc., Palo Alto, CA (United States) (1995). pp. 627

The federal government's attempts to site a permanent high-level radioactive waste repository have been frustrating and so far unsuccessful. Many of the problems were recognized more than a decade ago. In 1982, the US Congress passed the Nuclear Waste Policy Act and established a program to site and develop an underground repository. By 1987, this program was widely considered to be a failure. It was plagued by public opposition, intergovernmental conflict, poor management, scientific questions and concerns, and substantial cost overruns. In December 1987 Congress amended the act and selected Yucca Mountain, Nevada, as the only location to be studied as a potential repository. This halted further work on other potential sites in the western US, the eastern US sites for a second repository, and the monitored retrievable system facility that the US Department of Energy (DOE) wanted to locate in Tennessee. These amendments did not address the basic causes for the failures between 1983 and 1987. As a result, although the program was greatly simplified with only one site, it was beset by the same problems that created the original collapse. Now there are new and widespread calls for a congressional review and restructuring of the program from federal, state, and local officials, government agencies, industry, and public groups. This article examines the lessons from these two failed attempts and makes recommendations for devising a new policy. 85 refs.

1066 Program integration on the Civilian Radioactive Waste Management System. Trebules, V.B. (USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). Program Management Div.); King, M.H. pp. 143-148 of Proceedings of the American Power Conference: Volume 57-I. American Power Conference, Chicago, IL (United States) (1995). pp. 874 (CONF-950414--: 57. annual American power conference, Chicago, IL (United States), 18-20 Apr 1995).

The recent development and implementation of a revised Program Approach for the Civilian Radioactive Waste Management System (CRWMS) was accomplished in response to significant changes in the environment in which the program was being executed. The lack of an interim storage site, growing costs and schedule delays to accomplish the full Yucca Mountain site characterization plan, and the development and incorporation of a multi-purpose (storage, transport, and disposal) canister (MPC) into the CRWMS required a reexamination of Program plans and priorities. Dr. Daniel A. Dreyfus, the Director of the Office of Civilian Radioactive Waste Management (OCRWM), established top-level schedule, targets and cost goals and commissioned a Program-wide task force of DOE and contractor personnel to identify and evaluate alternatives to meet them. The evaluation of the suitability of Yucca Mountain site by 1998 and the repository license application data of 2001 were maintained and a target date of January 1998 for MPC availability was established. An increased multi-year funding profile was baselined and agreed to by Congress. A $1.3 billion reduction in Yucca Mountain site characterization

costs was mandated to hold the cost to $5 billion. The replanning process superseded all previous budget allocations and focused on program requirements and their relative priorities within the cost profiles. This paper discusses the process for defining alternative scenarios to achieve the top-level program goals in an integrated fashion.

1067 Carbonate and hydrolysis complexation studies of actinyl ions towards understanding the environmental behavior of U, Np, and Pu. Clark, D.L. (and others); Ekberg, S.A.; Neu, M.P. pp. 733, Paper GEOC 6 of 209th ACS national meeting. American Chemical Society, Washington, DC (United States) (1995). pp. 2088 (CONF-950402--: 209. American Chemical Society (ACS) national meeting, Anaheim, CA (United States), 2-6 Apr 1995).

A fundamental understanding of the solubility and sorption behaviors of key actinide ions is critical in evaluating the potential migration or retention of radionuclides from a long-term waste repository site. Knowledge of the species likely to form and accurate thermodynamic constants for the formation of these species are required for modeling studies. We are using multinuclear NMR, Raman, Vis/NIR, EXAFS, and x-ray diffraction to study the aqueous behavior of hexavalent and pentavalent U, Np, and Pu ions, and their hydroxo and carbonato complexes.

1068 Reduction of risks to the public from geologic waste repositories by partitioning and transmutation: Rock types. Lee, W.W.L. (Environmental Evaluation Group, Albuquerque, NM (United States)). pp. 887-891 of 9th Pacific Basin Nuclear Conference. Nuclear energy, science and technology - Pacific partnership. Proceedings Volume 2. The Institution of Engineers Australia, Canberra (Australia) (Apr 1994). pp. 572 Sponsored by Australian Nuclear Association, Sutherland, NSW (Australia);Institution of Engineers, Canberra, ACT (Australia). (CONF-940501--: 9. Pacific basin nuclear conference, Sydney (Australia), 1-5 May 1994).

Partitioning light-water-reactor spent fuel (LWR SF) and transmuting the actinides in fast-spectrum liquid-metal reactors (ALMR) has been proposed as a method of reducing the public risks from geologic disposal of nuclear waste. For repositories that contain waste from equal energy generation, maximum radiation dose rates to future individuals were compared with that will result from dissolution and hydrogeologic transport of critical radionuclides for hypothetical repositories in unsaturated, oxidizing rock and water-saturated, reducing rock. In each case the peak radiation dose rate to a maximally exposed individual from a repository containing LWR spent fuel is compared to that from high-level wastes from the reprocessing of LWR and ALMR fuel. It was found that while peak dose rates from a repository in unsaturated rock containing high -level waste is somewhat lower than that from LWR spent fuel, the peak dose rate from a repository in saturated-reducing rock containing high-level waste is actually higher than its counterpart containing spent fuel. 21 refs., 5 tabs., 2 figs.

1069 Alligator Rivers Analogue Project an OECD/NEA international project. Duerden, P. (Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). Environmental Science Program); Airey, P.; Pescatore, C. pp. 893-897 of 9th Pacific Basin Nuclear Conference. Nuclear energy, science and technology - Pacific partnership. Proceedings Volume 2. The Institution of Engineers Australia, Canberra (Australia) (Apr 1994). pp. 572 Sponsored by Australian Nuclear Association, Sutherland, NSW (Australia);Institution of Engineers, Canberra, ACT (Australia). (CONF-940501--: 9. Pacific basin nuclear conference, Sydney (Australia), 1-5 May 1994).

The Koongarra uranium deposit in the Alligator Rivers Region of the Northern Territory of Australia was studied as natural analogue of the far field behaviour of high level waste repository following groundwater ingress. A number of mathematical modelling approaches were developed for processes as divers as groundwater transport, host rock weathering, radionuclide sorption, evolution of the uranium dispersion fan and the distribution of uranium series nuclides between mineral assemblages in weathered host rock. Some of these models are relevant to performance assessment at the level of individual processes and subsystem performance. Through the project, new insights into the application of the natural analogue approach to the assessment of potential waste repository sites were obtained. 6 refs., 1 tab., 1 fig.

1070 Timely topics on spent fuel storage. Selin, I. pp. 10-12 of 35th Annual meeting proceedings. Volume XXIII. Institute of Nuclear Materials Management, Northbrook, IL (United States) ([1994]). pp. 1360 (CONF-940748--: 35. annual meeting of the Institute of Nuclear Materials Management (INMM), Naples, FL (United States), 17-20 Jul 1994).

The history of spent fuel management in this country has taken several turns, with a final resolution still out of reach. Several repository programs started, stalled ans stopped. The latest effort at Yucca Mountain is progressing but, at best, is years from the early phases of licensing, much less the actual underground disposal of spent fuel. A monitored retrieval storage [MRS] facility was expected to start accepting commercial spent fuel beginning in 1998, but no such facility is clearly on the horizon. All of these recent developments changed the circumstances that we face in spent fuel management. The obvious conclusion is that an increasing number of plants, both operating and permanently shutdown reactors, will have to provide for additional spent fuel storage on-site for a longer period than originally planned, and even after plant decommissioning, prudence requires that provision be made for continual, stand-alone, on-site storage. After pool capacity is reached, most utilities opt for some sort of dry storage. But the dry storage option has triggered an unprecedented amount of local opposition at many sites, further taxing NRC and industry resources.

1071 Effects of surface chromium depletion on the localized corrosion of Alloy 825 as a high-level waste container material. Dunn, D.S. (Southwest Research Inst., San Antonio, TX (United States). Center for Nuclear Waste Regulatory Analyses); Sridhar, N.; Cragnolino, G.A. pp. 12, Paper 138 of Corrosion/94 conference papers. NACE International, Houston, TX (United States) (1994). pp. 5005 (CONF-940222--: Corrosion 94: National Association of Corrosion Engineers (NACE) international annual conference, Baltimore, MD (United States), 28 Feb - 4 mar 1994).

The effects of the chromium depleted mill finished surface on the localized corrosion resistance of alloy 825 were investigated. Tests conducted in solutions simulating the groundwater at Yucca Mountain with a higher concentration of chloride indicated that the breakdown and repassivation potentials for the mill finished surfaces were more active than those for polished surfaces. Potentiodynamic polarization tests indicated that pits can be initiated on the chromium depleted surface at potentials of 220 mV_{SCE} in a solution containing 1,000 ppm chloride at 95 C. Potentiostatic tests identified a similar pit initiation potential for the

mill finished surface. However, under longer term potentiostatic tests, a higher potential of 300 mV_{SCE} was needed to sustain stable pit growth beyond the chromium depleted layer. An increase in the surface roughness decreased the localized corrosion resistance of the material.

1072 Domestic and international nuclear waste management. Jones, J. (Dept. of Energy, Washington, DC (United States)). pp. 36-45 of Global strategies for environmental issues. National Association of Environmental Professionals, Washington, DC (United States) (1994). pp. 749 (CONF-940650--: 19. annual conference and exposition of the National Association of Environmental Professionals (NAEP): global strategies for environmental issues, New Orleans, LA (United States), 12-15 Jun 1994).

Passage of the Nuclear Waste Policy Act in 1982, and subsequent 1987 amendments, allowed Congress to establish the plan to manage the nation's spent nuclear fuel and other high-level radioactive waste. The principal elements in the waste management system include waste acceptance, storage, disposal, and transportation. Interim storage of spent fuel is proposed to be in Monitored Retrievable Storage facility. Studies are being implemented for research and design of multipurpose canisters which will be used for the storage, transport, and disposal of spent nuclear fuel. The potential repository site for permanent disposal is located at Yucca Mountain, Nevada. Site characterization activities are currently being conducted. Underground construction has started for the Exploratory Studies Facility; surface based activities are currently under way. Factors considered in this phase include environmental concerns, geologic parameters, public safety, local economic impacts and ease and cost of constructing and operating the facility. The United States is involved in cooperative studies with other countries regarding fundamental aspects of radioactive waste storage and disposal systems for high-level waste. Most emphasize assessment of long-term performance of permanent geologic repositories for spent nuclear fuel and high level waste. By participating in international activities, the United States has been involved in transfer of technological developments and information exchange. Most of the countries which produce electricity with nuclear power plants plan to dispose of the spent fuel within their own countries. The permanent disposal of high level waste for most countries will be in deep geological repositories. This paper will provide the status of the U.S. program in the storage and disposal of its nuclear waste. Strategies for addressing nuclear waste management in the domestic program will be compared to those of foreign countries. 6 refs.

1073 Disposition of actinides released from high-level waste glass. Ebert, W.L. (Argonne National Lab., IL (United States)); Bates, J.K.; Buck, E.C.; Gong, M.; Wolf, S.F. pp. 231-241 of Ceramic transactions: Environmental and waste management issues in the ceramic industry II. Volume 45. Bickford, D.; Bates, S.; Jain, V.; Smith, G. (eds.). American Ceramic Society, Westerville, OH (United States) (1994). pp. 513 DOE Contract W-31109-ENG-38. (CONF-940416--: 96. annual meeting of the American Ceramic Society (ACS), Indianapolis, IN (United States), 25-28 Apr 1994).

The disposition of actinide elements released from high-level waste glasses into a tuff groundwater in laboratory tests at 90°C at various glass surface area/leachant volume ratios (S/V) between dissolved, suspended, and sorbed fractions has been measured. While the maximum release of actinides is controlled by the corrosion rate of the glass matrix, their solubility and sorption behavior affects the amounts present in potentially mobile phases. Actinide solubilities are affected by the solution pH and the presence of complexants released from the glass, such as sulfate, phosphate, and chloride, radiolytic products, such as nitrate and nitrite, and carbonate. Sorption onto inorganic colloids formed during lass corrosion may increase the amounts of actinides in solution, although subsequent sedimentation of these colloids under static conditions leads to a significant reduction in the amount of actinides in solution. The solution chemistry and observed actinide behavior depend on the S/V of the test. Tests at high S/V lead to higher pH values, greater complexant concentrations, and generate colloids more quickly than tests at low S/V. The S/V also affects the rate of glass corrosion.

1074 Process for reduction of volume of contaminated soil by compaction. Johanan, W.L. (EG and G Mound Applied Technologies, Miamisburg, OH (United States)). pp. 920-926 of 1994 Federal environmental restoration III and waste minimization II conference and exhibition: Proceedings. Volume 2. Hazardous Materials Control Resources Inst., Rockville, MD (United States) (1994). pp. 858 (CONF-940499--: Federal environmental restoration and waste minimization conference and exhibition, New Orleans, LA (United States), 25-29 Apr 1994).

Burial costs for low-level radioactive waste are assessed by the volume of the waste. These costs are presently at $10 per cubic foot and will continue to increase with time. A reduction in waste volume can be directly converted to a reduction in burial costs. A large amount of low-level contaminated soil exists throughout the DOE complex. The Nuclear Complex Modernization Task Force has identified over 5 million cubic feet of contaminated soil for eventual clean-up at the Mound site ($50,000,000 to bury at FY 1991 costs). By using a combination of a rock separator (trommel), crusher, clay soil compactor, automatic loading system, specially designed dust enclosures, and specifically designed containers for both on-site haulage and shipment to the Nevada Test Site (NTS), the total waste volume, and burial cost, can be reduced by up to 30% by compacting the soil into high-density bricks (depending upon the compaction quality of the soil). Several tests have been performed on Mound's cold on-site soils, with resulting densities of 131 pounds per cubic foot. When this is compared to normal LSA metal box filling of 80–90 pounds per cubic foot, one can readily see the savings.

1075 The nuclear negociator and public acceptance: the United States experience. Leroy, D.H. pp. 14-21 of Safe Management and disposal of nuclear waste. Volume 1. Societe Francaise d'Energie Nucleaire, Paris (France) (1993). pp. 448 (CONF-930608--: Safewaste '93: the final disposal of nuclear waste, Avignon (France), 13-18 Jun 1993).

In 1987, the United States Congress created the Office of the Nuclear Waste Negotiator. The task of the Office was to seek volunteer host locations for either a temporary storage facility or a permanent repository for spent fuel from the Nation's 110 commercial nuclear reactors. This paper details the organization, operating principles, history and significant findings of the Office since its commencement of activities in September of 1990.

1076 The prospective usage of the multi-purpose canister and impacts on the waste management and

disposal system. McLeod, N.B. (E.R. Johnson Associates, Inc., Fairfax, VA (United States)). pp. 77-82 of Nuclear materials management. 34th Annual meeting proceedings: Volume 22. Institute of Nuclear Materials Management, Northbrook, IL (United States) (1993). pp. 1190 (CONF-930749--: 34. annual meeting of the Institute of Nuclear Materials Management, Scottsdale, AZ (United States), 18-21 Jul 1993).

The Multi-Purpose Canister (MPC) is designed to be loaded with spent fuel and sealed at reactors and then serve the functions of transport, storage and disposal without reopening. It can be either self-shielded or unshielded, thus requiring compatible overpacks for transport, storage and disposal. The MPC is not a new concept but it may now be viable because of the particular characteristics at Yucca Mountain: larger MPCs are possible because of ramp access to the repository horizon, and the less difficult temperature limits because of in-drift emplacement, rather than borehole emplacement. This paper describes the advantages and disadvantages of adopting the MPC as the principal technology to be employed in the US program. Use of the MPC permits integration of the utility and DOE portions of the system as well as among the elements within the DOE portion. Paradoxically, the principal disadvantage of the MPC is a direct consequence of its merit as an integrating technology. Full integration includes disposability without reopening, and requires that disposability design decisions be made and implemented well in advance of when waste package licensing uncertainties are resolved. There is, therefore, a risk that MPCs loaded prior to waste package licensing will have to be opened. This risk is discussed in terms of probability and consequences and various alternatives for mitigating this risk are discussed.

1077 The USA approach to address the issue of the safety of final waste repository. Bernero, R.M. pp. 103-113 of Safe Management and disposal of nuclear waste. Volume 1. Societe Francaise d'Energie Nucleaire, Paris (France) (1993). pp. 448 (CONF-930608--: Safewaste '93: the final disposal of nuclear waste, Avignon (France), 13-18 Jun 1993).

In the United States, the approach to address the issue of safety for high-level nuclear waste repositories is not a simple approach. It involves three agencies of the Federal Government (Department of Energy) (DOE), Nuclear Regulatory Commission (NRC) and Environmental Protection Agency (EPA) which have assumed responsibilities for the safe disposal of high-level radioactive wastes. DOE has received through a number of actions including legislation such Nuclear Waste Policy Act of 1982 and the Low-Level Radioactive Waste Policy Amendments Act of 1985, the responsibility for constructing and operating a high-level radioactive wastes repository. NRC is responsible for licensing and regulating the receipt and possession of high-level radioactive wastes. Its requirements governing the disposal of high-level radioactive wastes in a geologic repository are contained in 10 CFR Part 60 and cover pre-licensing activities, construction authorization, receipt and possession of spent fuel or high-level radioactive wastes. With respect to EPA, its responsibilities are to establish generally applicable standards governing releases of radioactivity. These regulations are found in 40 CFR Part 191 and set the environmental standards for the management and disposal of transuranic and high-level radioactive wastes.

1078 United States high-level radioactive waste repository program. Barrett, L.H. (USDOE, Washington, DC (United States)). pp. 199-207 of Safe Management and disposal of nuclear waste. Volume 1. Societe Francaise d'Energie Nucleaire, Paris (France) (1993). pp. 448 (CONF-930608--: Safewaste '93: the final disposal of nuclear waste, Avignon (France), 13-18 Jun 1993).

Ten years have now passed since the United States established a national policy and process for developing a waste management system for spent nuclear fuel and high-level radioactive waste. Of those ten years, the last two years have marked the greatest progress in studying a site for development of a geologic repository. This paper will discuss the United States program underway for developing the waste management system, with particular emphasis on our recent progress at Yucca Mountain, Nevada – the site designated by the United States Congress for detailed site characterization to determine whether or not it is suitable for development of a repository.

1079 Analysis of waste package environment as related to initiation and propagation of localized corrosion. Walton, J.C. (Southwest Research Inst., San Antonio, TX (United States). Center for Nuclear Waste Regulatory Analyses); Sridhar, N.; Cragnolino, G.; Nair, P. pp. 247-252 of Proceedings of the 1993 international conference on nuclear waste management and environmental remediation. Volume 1: Low and intermediate level radioactive waste management. Alexandre, D.; Baker, R.; Kohout, R.; Marek, J. (eds.). American Society of Mechanical Engineers, New York, NY (United States) (1993). pp. 776 (CONF-930906--: '93 international conference on nuclear waste management and environmental remediation, Prague (Czech Republic), 5-11 Sep 1993).

Models are presented for prediction of waste package lifetime for the proposed high-level nuclear waste repository located at Yucca Mountain, Nevada. The waste package environment is expected to range from saturated, highly-alkaline brine to bicarbonate waters of low ionic strength. Localized corrosion will be predicted by comparing predicted corrosion potentials of the container with critical potentials for pitting and crevice corrosion. The critical potentials will be estimated by a combined program of experiments and mechanistic modeling.

1080 Technical and political aspects for site characterization, evaluation and acceptance. Kuehn, K. (Gesellschaft fuer Strahlen- und Umweltforschung mbH Muenchen, Braunschweig (Germany). Inst. fuer Tieflagerung). pp. 299-311 of Safe Management and disposal of nuclear waste. Volume 1. Societe Francaise d'Energie Nucleaire, Paris (France) (1993). pp. 448 (CONF-930608--: Safewaste '93: the final disposal of nuclear waste, Avignon (France), 13-18 Jun 1993).

All countries which use nuclear energy - have to solve the problem how and where to dispose of the radioactive wastes which are generated by application of nuclear energy. Within these radioactive wastes we can differentiate three categories with regard to their disposal: Irradiated fuel elements if they are declared waste. This is the case in the United States, in Canada, Spain, Sweden, and Finland. Some strong trends into this direction can also be observed in Germany. High-level heat-generating wastes which are generated by vitrification - of liquid wastes produced by reprocessing irradiated fuel. This is true for France, United Kingdom, Japan, Germany, Switzerland, Belgium and the Netherlands. But this is also true for those five countries which possess and/or produce nuclear weapons, namely the United States, the former USSR, China, France, and United

Kingdom. Low- and intermediate-level radioactive wastes which are mainly produced by operating nuclear power and reprocessing plants but also by other nuclear fuel cycle facilities and through application of radionuclides in industry, medicine and research. Most countries have decided to dispose of these wastes by shallow land burial, like the United States, Canada, Japan, France, and United Kingdom. Some other countries, like Germany, Sweden, Finland, and Switzerland, will dispose of these wastes in underground repositories too. Because of the difficult problem of public acceptance, site selection for a radioactive waste repository is not a pure technical and scientific task. On the contrary, it is mainly a political one. Two examples where possible sites were selected more because of political than of technical reasons are Yucca Mountain in the United States and Gorleben in Germany. There do exist, however, also approaches to select a site on technical and scientific grounds like in Canada, France, or Sweden.

1081 Site characterizations and evaluations U.S. policies and approaches for public interactions. Saltzman, J. (USDOE, Washington, DC (United States)). pp. 336-343 of Safe Management and disposal of nuclear waste. Volume 1. Societe Francaise d'Energie Nucleaire, Paris (France) (1993). pp. 448 (CONF-930608--: Safewaste '93: the final disposal of nuclear waste, Avignon (France), 13-18 Jun 1993).

The Nuclear Waste Policy Act of 1982 (NWPA) established the Office of Civilian Radioactive Waste Management within the U.S. DOE to develop a waste disposal system for spent nuclear fuel from civilian nuclear power plants and high-level radioactive waste from the Nation's defense programs. The Act authorizes construction of one geologic repository in which the waste would be permanently isolated and specifies the process for evaluating and siting a repository. In 1987, the Act was amended to instruct DOE to focus all site characterization efforts on Yucca Mountain, Nevada, in order to determine whether or not it is suitable for the development of the Nation's first geologic repository. If site characterization indicates that the Yucca Mountain site is suitable for a repository, DOE will recommend it to the President for construction of a repository. If the President approves, the recommendation will be submitted to Congress. To ensure the complete coverage of all aspects of the program, a set of strategic principles was established to guide through decisions and actions. The first step in developing these principles was the identification of critical issues. Many of the issues identified recognized the importance of full participation in the program by all affected and interested parties. Next meetings were held with external parties to obtain their views on the strategic principles and the future of the program. The input received from the participants of these workshops contributed substantially to the final strategic principles. Some of these relevant strategic principles include: consider public trust and confidence in program decisions; provide for the involvement of affected governments, interested parties, and the public in decision making; work cooperatively with affected governments and interested parties; share information and data; provide for outside review; and evaluate socioeconomic issues in cooperation with affected governments.

1082 Photoacoustic absorption spectroscopy on plutonium(IV) in varying bicarbonate concentrations. Ekberg, S.A. (Los Alamos National Laboratory, NM (United States)); Tait, C.D.; Morris, D.E.; Palmer, P.D. pp. 452, Paper TECH 24 of 205th ACS national meeting. American Chemical Society, Washington, DC (United States) (1993). pp. 1951 (CONF-930304--: 205. American Chemical Society national meeting, Denver, CO (United States), 28 Mar - 2 apr 1993).

This talk will begin with a brief discussion of what photoacoustic Absorption Spectroscopy (PAS) is, and what YMP means. To understand the solubility and speciation studies of potential contaminants must be understood. With this in mind, PAC experiments have been performed on samples with a constant Pu(IV) concentration of 250 nM in varying $NaHCO_3$ concentrations from 1.0M to 0.003M. This work was supported by the Yucca Mountain Site Characterization Project Office as part of the Civilian Radioactive Waste Management Program managed by the U.S. Department of Energy, Yucca Mountain Site Characterization Project Office.

1083 Examination of geological formations and crystalline rock properties on the underground repository site for solidified waste disposal. Leonov, E.A. (VNIPIPROMTECHNOLOGII, Moscow (Russian Federation)); Schishchitz, I.Y. pp. 513-518 of Proceedings of the 1993 international conference on nuclear waste management and environmental remediation. Volume 1: Low and intermediate level radioactive waste management. Alexandre, D.; Baker, R.; Kohout, R.; Marek, J. (eds.). American Society of Mechanical Engineers, New York, NY (United States) (1993). pp. 776 (CONF-930906--: '93 international conference on nuclear waste management and environmental remediation, Prague (Czech Republic), 5-11 Sep 1993).

At the fuel reprocessing plant located on the South Urals the situation arose requiring a solution to the problem of solidified waste disposal. Vitrified wastes are poured into casks which are placed three pieces at a time into steel canisters 3.4 m in height and 0.64 m in diameter. After 6–10 years of storage in a surface facility, the canisters must be disposed of into geological formations. Some variants of possible repository placing were considered in a rock salt deposit located 300–500 km from the plant and in crystalline hard rock. On the basis of the survey results, it was determined that the massif under consideration was located in the center of a geological block in the tectonic zone. Deep faults divided the block into blocks characterized by high uniformity and tectonic stability. The site under consideration was located in the center of a ring structure which came into existence in connection with paleozoic intrusion. Data analysis showed that porphyrite geological area was located in the region of minimum relative geological risk.

1084 State of solutions to high level nuclear waste management. Tang, Y.S. (Tang (Y.S.), Bethel Park, PA (United States)). pp. 2.175-2.179 of Proceedings of the 28th intersociety energy conversion engineering conference. Volume 2–Environmental impact, energy systems, new technology for energy utilization, policy issues, renewable energy sources, stirling cycles. American Chemical Society, Washington, DC (United States) (1993). pp. 1005 (CONF-930804--: 28. intersociety energy conversion engineering conference, Atlanta, GA (United States), 8-13 Aug 1993).

This paper summarizes the current status of the solution to High Level Waste (HLW) management in the US. It addresses all aspects of handling and disposal of HLW from reactor pool storage to final permanent disposal. Each problem area is discussed under the headings of issues, recommended solutions, and current status. Among the issues discussed, the public acceptance and siting obviously are the overriding issues to be solved. After much delay, the

site characterization work at the Yucca Mountain potential site are now in progress.

1085 Alligator Rivers Region. pp. 5-13 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

An introduction to the Alligator Rivers Region is presented. It contains general information regarding the physiography, climate, hydrology and mining of the region. The Alligator Rivers Region is within an ancient basin, the Pine Creek Geosyncline, which has an area of approximately 66000 km^2. The Geosyncline has a history of mineral exploitation dating back to 1865, during which time 16 metals have been extracted (silver, arsenic, gold, bismuth, cadmium, cobalt, copper, iron, manganese, molybdenum, lead, tin, tantalum, uranium, tungsten, zinc). Uranium exploration in the Pine Creek Geosyncline was stimulated by the discovery in 1949 of secondary uranium mineralisation near Rum June, 70 km south-east of Darwin. This was followed by a decade of intense exploration activity resulting in the discoveries of economic uranium ore bodies at Rum Jungle and in the upper reaches of the South Alligator River Valley. All the known major uranium deposits of the East Alligator River uranium field have been discovered since 1969. The present known resources of the Geosyncline are approximately 360 000 tonnes of contained U_3O_8. 2 refs., 2 figs., 1 tab.

1086 Land application for disposal of excess water: an overview. Riley, G.H. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 14-22 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

Water management is an important factor in the operation of uranium mines in the Alligator Rivers Region, located in the Wet-Dry tropics. For many project designs, especially open cut operations, sole reliance on evaporative disposal of waste water is ill-advised in years where the Wet season is above average. Instead, spray irrigation, or the application of excess water to suitable areas of land, has been practised at both Nabarlek and Ranger. The method depends on water losses by evaporation from spray droplets, from vegetation surfaces and from the ground surface; residual water is carried to the groundwater system by percolation. The solutes are largely transferred to the soils where heavy metals and metallic radionuclides attach to particles in the soil profile with varying efficiency depending on soil type. Major solutes that can occur in waste water from uranium mines are less successfully immobilised in soil. Sulphate is essentially conservative and not bound within the soil profile; ammonia is affected by soil reactions leading to its decomposition. The retrospective viewpoint of history indicates the application of a technology inadequately researched for local conditions. The consequences at Nabarlek have been the death of trees on one application area and the creation of contaminated groundwater which has moved into the biosphere down gradient and affected the ecology of a local stream. At Ranger, the outcome of land application has been less severe in the short term but the effective adsorption of radionuclides in surface soils has lead to dose estimates which will necessitate restrictions on future public access unless extensive rehabilitation is carried out. 2 refs., 1 tab.

1087 Soils and hydrology of the Ranger uranium mine land application site. Willett, I.R. (CSIRO, Canberra, ACT (Australia). Div. of Soils); Charters, C.J.; Bond, W.J. pp. 25-42 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

This paper describes the soils and hydrology of an area between Ranger Uranium Mine and Magela Creek, Northern Territory, which is being used for the disposal of retention pond water by irrigation. The soils of an alternative site are also described in less detail. The soil survey of the irrigated area indicated three mapping units differentiated on the basis of texture, colour depth, drainage and the presence of absence of ferricrete. The predominant soils in each unit were yellow earths, red earths and siliceous sands. All the soils had high (20-50%) gravel contents consisting of quartz and ferruginous materials. The gavel is expected to have little ability to retain solutes and therefore reduces the effectiveness of the bulk soil to retain solutes. The soils are generally low in clay (<20%) and organic matter <1%) and are acidic. The clay minerals were of the low activity types, predominantly kaolinite. Consequently the cation exchange capacities of the soils were very low indicating a limited capacity to retain cations. Preliminary calculations showed that the soils would be unable to retain all the cations in the applied water. In order to assess whether redox reactions are likely to be involved in the retention of radionuclides, the responses of the soils to saturation were tested in a laboratory experiment. The implications of these results for the retention of metals and radionuclides were discussed. All soils were found to have high permeabilities. Preliminary calculations showed that transmission of irrigation water to the water table would be rapid (less than 6 weeks). The soils of the alternative site were generally heavier and contained less gravel than those of the current irrigation site. They are likely to retain more solutes than the soils of the current irrigated area and may be better suited to land disposal of retention pond water. 20 refs., 6 tabs., 5 figs.

1088 General monitoring of soils at Nabarlek and Ranger uranium mines. Wigston, S.R. (Conservation Commision of Northern Territory, Winnellie, NT (Australia). Land Conservation Unit). pp. 43-69 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

This paper discusses the principles for soil monitoring in the Uranium province as carried out by the Land Conservation Unit of the Conservation Commission of the Northern Territory. It outlines the past and current practices of soil monitoring and indicates the best future direction which should be taken to ensure optimum environmental safeguards. During the discussion, soils of the areas monitored will be referred to in general terms. 11 refs., 4 figs.

1089 Hydrology of Ranger land application area. McQuade, C.V. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 70-78 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

In 1984 Ranger Uranium Mines (RUM) began assessing the technique of water treatment by land application as a means of reducing the volume of stored water within the Restricted Release Zone. Knowledge of the hydrological characteristics of the treatment site is necessary for optimal day to day and season to season operation of the system and as an input into the assessment of the long-term viability of the site. This paper provides background information on the hydrological requirements for a water treatment site, describes the RUM's water treatment by land application system and summarises the operational statistics and current hydrological knowledge of the site. The general groundwater hydrology of the area comprises a surface soil aquifer overlying a semi-confined aquifer. Drainage of the surface aquifer follows the surface topography along the sandy clays. Vertical permeability ranges between 3 and 12 times greater than horizontal permeability. 7 refs., 2 tabs., 4 figs.

1090 Movement of water and major ions in the Jabiru land application experiment. Bond, W.J. (CSIRO, Canberra, ACT (Australia). Div. of Soils); Willett, I.R. pp. 79-104 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

A field experiment was conducted to simulate the effects of irrigation with water from Ranger Uranium Mine's Retention Pond 2 on the transport of water, solutes and radionuclides in soil near the minesite. The experiment was generally conducted in accordance with the practices of Ranger Uranium Mine. It was aimed to reproduce these practices under more carefully controlled conditions than those of the actual irrigation area. In particular, the application of water in the irrigation area was observed to be very uneven because of the type of impulse sprinklers used, and because of the obstruction of the sprinkler spray patterns by trees and shrubs. An area that had not been irrigated was selected for the experiment so that the effects of applying RP2 type irrigation water without the effects of previous irrigation could be determined. The main differences between the experimental site and the actual irrigation area were that an area with few trees and shrubs was selected, and the herbage was harvested for analyses. This paper describes the effects of irrigation with RP2 water on water and solute movement in the soil. It describes the effect of irrigation on the storage of water in the soil and on the flow of water through the soil, particularly on the amount of water flowing past the 50 cm depth and potentially entering the groundwater. It also describes the fluxes to the groundwater of major ions dissolved in the water. 10 refs., 5 tabs., 13 figs.

1091 Land application at Ranger uranium mine, northern Australia: six years'review. Noller, B.N. (Dept. of Mines and Energy, Darwin, NT (Australia). Mines Environment Directorate); Zhou, J.X. pp. 107-112 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

This report reviews the six years' practice of land application of waste water at the Ranger Uranium Mine, northern Australia. Elements of significance to the chemical impact on the environment by mining and milling at Ranger are analysed taking into consideration ore petrology and mineralogy, chemical compositions of rocks and ore, relative enrichment of different rock- and ore-forming elements, and the chemicals involved in the milling and extraction processes. Biogeochemistry of land application of waste water as an efficient environmental managing technique is discussed by analysing its biogeochemical cycles, variables which affect the biogeochemical processes, and aqueous chemistry. Data from monitoring of the soils, groundwater, biota, and seepage in the land application area at Ranger are collected and re-organised. A new approach to data presentation and interpretation is made based on the analysis of the most important variables which may affect the extent of the chemical impact of land application of waste water. The environmental impact of land application of waste water on soils, ground water, biota, and surface water (through seepage) is assessed accordingly. Uranium is retained in the near-surface soil layer while sulfate is present at lower depths. Manganese shows some mobility, appearing in depressions. Radium 226 shows no clear-cut relationship between location of soil sample and level. It is concluded that land application of waste water at Ranger has resulted in minimal environmental impact. 4 refs.

1092 Adsorption properties of the soils of the Ranger uranium mine land application area for solutes in water from Retention Pond 2. Willett, I.R. (CSIRO, Canberra, ACT (Australia). Div. of Soils); Bond, W.J. pp. 113-138 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

The research reported here aimed to describe the adsorption properties of the soils of Ranger's irrigation area for important constituents of RP2 water. Three kinds of experiments were conducted. For the major ions (Na^+, Mg^{2+}, Ca^{2+}, K^+, SO_4^{2-}, and Cl^-) measurements were made of cation and anion exchange capacities. For the minor solutes (MN^{2+}, U^{238}, and Ra^{226}) which undergo more specific, inner-sphere reactions with soil surfaces, the retention capacities were determined by batch adsorption isotherm methods. Lastly, column experiments were conducted to determine whether the soils could retain U^{238}, Ra^{226} and Pb^{210} when the quantities of each radionuclide were applied in much greater quantities than was possible in the batch adsorption studies, or during the field experiment described earlier at this Workshop (Bond and Willett 1992). It was aimed to obtain information on the retention capacity of the three main soil types of the irrigation area; Unit I, II and III, respectively

red earths, yellow earths and siliceous sands, in relation to soil pH. 7 refs., 4 tabs., 13 figs.

1093 Fate of radionuclides applied to soil in the Ranger uranium mine land application area. Akber, R.A. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)); Marten, R. pp. 139-165 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

This paper describes the behaviour of the radionuclides ^{238}U, ^{226}Ra and ^{210}Pb within the Ranger Uranium Mine Land Application area. The results presented are based mainly upon the radionuclide analysis of sections of soil core samples recovered from various locations in the land application plot and from a separate experimental plot used to study the fate of solutes during the land application of Ranger Retention Pond 2 water. The results demonstrate that a large proportion of the adsorbed radionuclides is small. An autoradiography study of the soil profile showed that some localised downward movement of radioactivity is possible along pores in the soil structure. 5 refs., 4 tabs., 6 figs.

1094 Fate of solutes applied to land application areas. McBride, T.P. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 166-177 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

This paper discusses the fate of major solutes contained in waste waters applied to the Nabarlek and Ranger land application areas. The soils of irrigation plots at Nabarlek and Ranger have limited capacity to retain the major solutes in irradiated waters. At Nabarlek, sulphate (average 5500 mg/L) in irrigated Evaporation Pond 2 (EP2) waters has infiltrated into the soil and is readily transported in groundwater flow. Ammonium (average 1100 mg/L) in irrigated EP2 waters is largely retained by cation adsorption in the soils but is readily oxidised in the aerobic zone to nitrate which can move readily in groundwaters in the same manner as sulphate. Groundwater concentrations of nitrate and sulphate above 500 mg/L and 5000 mg/L respectively have been observed at monitoring bores near the Nabarlek Forest Irrigation Area. At Ranger the sulphate contained in irrigated waters has produced concentrations up to 300 mg/L in groundwaters. Present data suggest that uranium in irrigated waters remains fixed in the top few centimeters of soil in the irrigation area, although the possibility of remobilisation cannot be dismissed because of unexplained high uranium concentrations observed in nearby parts of Magela Creek during the 1991 Wet season. The data presently available do not allow the effects of irrigation-derived solutes on Magela Creek water chemistry to be separated from those of solutes contained in released RP1 and RP4 waters and therefore the amounts of solutes specifically from the irrigation area that have passed down Magela Creek cannot be determined. However, a model developed by OSS for predicting inputs of solutes to Magela Creek from the irrigation area suggests that a significant contribution could be made. Sulphate concentrations in Magela Creek are low and it is uncertain whether most of the major solutes contained in the irrigated waters have moved laterally towards Magela Creek or have continued moving downwards to greater depths. 3 refs., 4 tabs., 9 figs.

1095 Critical groups - basic concepts. Carter, M.W. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 181-186 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

The potential exposure pathways from the land application site to man are presented. It is emphasised that the critical group is not necessary the population group closest to the source. It could be the group impact by the most significant pathways(s). Only by assessing the importance of each of these pathways and then combining them can a proper choice of critical group be made. It would be wrong to select a critical group on the basis that it seems the most probable one, before the pathways have been properly assessed. A calculation in Carter (1983) suggested that for the operating mine site, the annual doses to an Aboriginal person, a service worker and a local housewife, were all about the same and were in the range 0.1 to 0.2 mSv per year. Thus it may be that for the land application area, the critical group turns out to be non-Aboriginal rather than the expected Aboriginal group. 6 refs., 3 figs.

1096 An Aboriginal perspective on future land use of the land application site of Ranger Uranium Mine. Robotham, F.R.J. (Northern Land Council, Casuarina, NT (Australia)); McLaughlin, D. pp. 187-191 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

The Northern Land Council, representing the interests of the traditional owners of the Ranger site, wants the mining site to be restored to its pre-mining condition or as near as possible to it. It is also emphasised that the effective dose equivalent limit to be used for rehabilitation site, including the land application area should be 0.7 mSv per year. Moreover, the land application water should be of such quality that there is no limitation on future land use. 3 refs.

1097 Preliminary assessment of radiological conditions at the Ranger land application area. Kavasnicka, J. (Northern Territory Dept. of Mines and Energy, Darwin, NT (Australia)); Bywater, J. pp. 226-240 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

Some 18 GBq of uranium and 1.5 GBq of ^{226}Ra were disposed of by land application on the designated disposal area by March 1989. This preliminary study, which is part of a longer-term project, outlines the assessment of external

gamma radiation exposures from short-lived gamma-ray emitting decay products of ^{226}Ra and of internal exposures from inhalation of uranium and ^{226}Ra resuspended from the soil surface. The effective dose equivalent from these two exposure pathways for an adult member of the public was calculated to be about 0.05 $mSv.y^{-1}$ (based on a 4 hour per day occupancy of the disposal area). This dose implies a total combined load limit of 490 $kBq.m^{-2}$ of uranium plus 41 $kBq.m^{-2}$ of ^{226}Ra. It is expected that the load limit will be reduced when all pathways and more recent data are taken into the account. 8 refs., 14 tabs., 3 figs.

1098 Radiological impact of radionuclide uptake by plants in the land application area. Akber, R.A. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)); Marten, R. pp. 241-251 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

Radionuclide concentrations in fruits and foliage of plants can increase as the result of irrigation with effluent water from a uranium mine. The significance of this pathway is discussed with respect to radiological impact from consumption of food and from the generation of ash as a result of bush fires. During the irrigation phase, radionuclide uptake by plants is expected to be via roots only. It is important to make a distinction between the contribution of these two systems, because radiological impact on humans via the vegetation pathways is likely to take place after rehabilitation, when the area could be occupied by humans. This distinction has been achieved through comparison of radionuclide concentrations in the vegetation harvested from an experimental plot, before, during and after irrigation with the simulated Retention Pond 2 (RP2) water of the Ranger Uranium Mine. The consumption of terrestrial food by the Aboriginal people is small and annual land application is likely to result in a dose increment of 3 $\mu Sv\ y^{-1}$ during future occupancy of the land application area. Bush fires immediately after irrigation may generate ash material 30-40 times more radioactive than the soil material, but subsequent bush fires will produce less radioactive ash. With the exception of uranium in foliage, the measured concentration factors agree within a factor of two with the default values recommended by IAEA. The uranium concentration factor for foliage material was found to be 2-8 times higher than the IAEA default value. 14 refs., 5 tabs., 3 figs.

1099 External gamma dose rate survey of the Ranger Uranium Mine land application plot. Marten, R. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 252-266 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

Radionuclides, as part of the solutes in retention pond water from a uranium mine, when spray irrigated on land, are adsorbed in the surface 5 to 6 cm layer and impact on the environment in several ways. This survey was conducted to establish the distribution of the external gamma dose rate generated by the applied radionuclide load on the Ranger Uranium Mine land application plot. This paper presents the methodology, the characteristics of the instruments used, and results of investigations of the possible influence of variable background sources, necessary for low level measurements. The final result is compared with results of the analysis of six cores, collected as part of this survey, and with earlier estimates. 2 refs., 3 tabs., 10 figs.

1100 Suspension of dust in the vicinity of Ranger Uranium Mine: an estimate for the land application area. Akber, R.A. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 267-286 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

Suspension of dust in the vicinity of Ranger Uranium Mine is discussed. Estimates of dust loadings are provided through the analysis of two data sets, one covering dust sampling at eight different sites over a six year period and the other an extensive data set for seven different sites sampled for a single Dry season. The Wet season dust loadings average for six years data is $12 \pm 2\ \mu gm^{-3}$ which is only half the average value of $24 \pm 14\ \mu gm^{-3}$ for data in a single Dry season. Occasional high dust loadings were observed in the single Dry season data. About 84% of the total dust loading is due to the $<10\ \mu m$ grain size fraction. No correlation exists between the dust loadings and location of sampling sites with respect to the Ranger Uranium Mine and the townships of Jabiru and Jabiru East. The annual average air-borne long-lived alpha radioactivity concentration is $0.13 \pm 0.02\ mBq^{-3}$. High alpha radioactivity concentrations ($0.55 \pm 0.04\ mBqm^{-3}$) for a sampling site located in the vicinity of an undisturbed uranium orebody were excluded from this average. The seasonal variations of alpha radioactivity concentrations are similar to those of the dust loadings. The corresponding values of the specific radioactivity of dust do not change seasonally which indicates the absence of a strong mine related dust plume associated with the dominant Dry season winds from the mine site to Jabiru East and Jabiru. A resuspension factor 1×10^{-8} is recommended for radionuclide loads arising from land application of water from Retention Pond No. 2 at Ranger Uranium Mine. Uncertainties associated with this estimate are discussed. 25 refs., 9 tabs., 3 figs.

1101 Effects on native plants of the land application of excess mine water. Ashwath, N. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 289-298 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

The effects arising from land application of excess mine water (Retention Pond 2 (RP2)) on soil, water quality and radiation exposure are well documented at Ranger Uranium Mine. However, the effects on local plants have received very little attention. This paper examines the available data on soil and water quality to identify the possible effects of

RP2 water on the health, growth and long-term viability of local native plants. On the basis of these data and on the general responses of crop plants to mineral toxicity, it is speculated that the higher concentrations of Mn and U in RP2 water than in irrigation water may have the potential to affect local plants if the land application of RP2 water is continued until the end of the expected mine life. It is suggested that studies be undertaken on Mn and U uptake of local native plants and on means of reducing litter accumulation on the land application site. In addition, the development of a sound physiologically oriented vegetation monitoring program is proposed to assess the impact of RP2 water on local native plants. 17 refs., 5 tabs., 1 fig.

1102 Ecological effects occurring outside the land application sites. McBride, T.P. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 316-326 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

At Nabarlek the impacts of remobilised salts from the irrigation areas are observable in Gadjerigamundah Creek where the waters contain additional solutes, including ammonium (1991 average 3.6 mg N/L), sulphate (1991 average 73 mg/L and nitrate (1991 average 66 mg N/L) and have low pH (1991 observed minimum 4.4). The existence of biological impacts in Gadjerigamundah Creek is suggested by changes in fish community structure observed in a multi-year study commissioned by Queensland Mines Pty. Ltd. Because of high dilution, mining attributable effects on Cooper Creek water chemistry are scarcely detectable and effects on its biota are not expected to be observable. At Ranger increased concentrations of magnesium (up to 4.3 mg/L), sulphate (up to 17 mg/L) and uranium (up to 1.7 μg/L) have been observed in Magela Creek at site GS8210009 during the 1990-91 Wet season and salts derived from irrigation possibly contributed to these values. However the monitoring data presently available do not allow the effects of irrigation-derived solutes on Magela Creek water chemistry to be separated from those of solutes contained in released Retention Pond 1 (RP1) and Retention Pond 4 (RP4) waters. A model developed by OSS for predicting transport of solutes from the irrigation area to Magela Creek suggests that the irrigation area has the capacity to be significant source of additional solutes. Although no monitoring has taken place in Magela Creek to detect biological impacts in Magela Creek caused specifically by irrigation, sensitive procedures used to monitor waste water releases have not detected any impacts on biota. 3 refs., 4 tabs., 9 figs.

1103 Regulation and monitoring of land application. McGill, R.A. (Northern Territory Dept. of Mines and Energy, Darwin, NT (Australia)). pp. 329-337 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

This paper describes the objectives and regulation of, and the monitoring of the effects of, land application of surplus waters from the uranium mine sites in the Alligator Rivers Region. As a result of past problems, no further permission to use land application has been given at Nabarlek. The land application at Ranger is restricted to those days when runoff is unlikely in the prevailing climatic and soil moisture conditions. The monitoring schedule covers routine analysis of the irrigation water and water from observation bores and seepage sites around the land application area. Soil core samples are also analysed on an annual basis. On areas that are not to be used for mining operations, the most suitable method of land application depends on the chemistry and volume of the water to be irrigated and on the soil types of the irrigation area. However, on stockpiles and areas that are to be mined in the future, such considerations can be ignored. 1 tab., 1 fig.

1104 Environmental monitoring for uranium and neptunium at Yucca Mountain using epithermal neutron activation analysis. Riggle, K.J. Missouri Univ., Columbia, MO (United States). 1992. 109p. Source: University Microfilms, P.O. Box 1764, Ann Arbor, MI 48106 (United States). Order No. 93-07,452.

Epithermal Neutron Activation Analysis (ENAA) is investigated as an analysis method for uranium and neptunium in environmental samples from Yucca Mountain. The design and construction of a facility for this technique are described. Theoretical improvement in sensitivity for ENAA over thermal NAA (TNAA) is discussed and compared to experimental results for different sample types. Uranium is analyzed in eight different sample matrices, including samples from Yucca Mountain. Neptunium has been studied only in AGV-1 Granite. As predicted by theory, uranium shows a high experimental sensitivity improvement factor (average = 7.76), while neptunium has a factor of only 0.49. Detection limits for uranium using ENAA range from 6 to 52 ppb by weight (2.6 to 17 ng in sample) for the different matrices. Neptunium shows a detection limit of 57 ppb by weight (6.2 ng in sample) in AGV-1 Granite using ENAA. Using TNAA, neptunium can be analyzed to 35 ppb by weight (3.4 ng in sample).

1105 Ecology, ethics, and professional environmental practice: The Yucca Mountain, Nevada, project as a case study. Malone, C.R. (Nuclear Waste Project Office, Carson City, NV (United States)). *Environmental Professional;* 17(3): 271-284 (Sep 1995).

The US Department of Energy (DOE) is proposing to develop a geologic repository for disposing of high-level nuclear waste at Yucca Mountain, Nevada. In this commentary, the ecology program for the DOE's Yucca Mountain Project is discussed from the perspective of state-of-the-art ecosystem analysis, environmental ethics, and standards of professional practice. Specifically at issue is the need by the Yucca Mountain ecology program to adopt an ecosystem approach that encompasses the current strategy based on population biology and community ecology alone. The premise here is that an ecosystem approach is essential for assessing the long-term potential environmental impacts at Yucca Mountain in light of the thermal effects expected to be associated with heat from radioactive decay.

1106 Effects of surface chromium depletion on localized corrosion of alloy 825 as a high-level nuclear waste container material. Dunn, D.S. (Southwest Research Institute, San Antonio, TX (United States). Center for Nuclear Waste Regulatory Analyses); Sridhar, N.; Cragnolino, G.A. *Corrosion;* 51(8): 618-624 (Aug 1995).

Effects of the chromium-depleted, mill-finished surface on the localized corrosion resistance of alloy 825 (UNS

N08825) were investigated. Tests were conducted in solutions based on the ground water at Yucca mountain, Nevada, but with a higher concentration of chloride. Results indicated that breakdown (E_p) and repassivation (E_{rp}) potentials for mill-finished surfaces were more active than those for polished surfaces. Potentiodynamic polarization tests indicated pits could be initiated on the chromium-depleted surface at potentials of 220 mV_{SCE} in a solution containing 1,000 ppm Cl^- at 95 C. Potentiostatic tests identified a similar pit initiation potential for the mill-finished surface. However, under longterm potentiostatic tests, a higher potential of 300 mV_{SCE} was needed to sustain stable pit growth beyond the chromium-depleted layer. An increase in surface roughness also was observed to decrease localized corrosion resistance of the material.

1107 DOE not planning to accept spent nuclear fuel. *Electric Light and Power;* 73(5): 29-30 (May 1995).

Samuel K. Skinner, president of Commonwealth Edison Co. (ComEd), said "The federal government has a clear responsibility to begin accepting spent nuclear fuel in 1988," citing the Nuclear Waste Policy Act of 1982 before the Senate Energy and Natural Resources Committee. Based in Chicago, ComEd operates 12 nuclear units, making it the nation's largest nuclear utility. "Since 1983, the consumers who use electricity produced at all nuclear power plants have been paying to fund federal management of spent nuclear fuel. Consumer payments and obligations, with interest, now total more than $10 billion. Electricity consumers have held up their side of the deal. The federal government must do the same," Skinner added. Skinner represented the Nuclear Energy Institute (NEI) before the committee. NEI is the Washington-based trade association of the nuclear energy industries. For more than 12 years, utility customers have been paying one-tenth of a cent per kWhr to fund a federal spent fuel management program under the Nuclear Waste Policy Act of 1982. Under this act, the federal government assumed responsibility for management of spent fuel from the nation's nuclear power plants. The U.S. Department of Energy (DOE) was assigned to manage the storage and disposal program. DOE committed to begin accepting spent fuel from nuclear power plants by January 31, 1988. DOE has spent almost $5 million studying a site in Nevada, but is about 12 years behind schedule and does not plan to accept spent fuel beginning in 1998. DOE has said a permanent storage site will not be ready until 2010. This poses a major problem for many of the nation's nuclear power plants which supply about 20% of the electricity in the US.

1108 Waste Management: Cleanup costs of DOE sites to total at least $230 billion; Dry spent fuel storage planned for North Anna; NRC undertakes changes to HLW,LLW regulations. *Nuclear News;* 38(7): 35 (May 1995).

It will take up to 75 years and between $230 billion and $350 billion to clean up the Department of Energy's former weapons productions facilities, according to the 1995 Baseline Environmental Management Report, issued on April 3, 1995. Thomas Grumbly, assistant secretary for environmental management, said that this is the most reliable estimate to date. Other estimates made in the past for the amount of time the cleanup would take were 30 years (the very rough estimate of former Environmental Restoration and Waste Management head Leo Duffy), and 50 years, an estimate mentioned last November during the American Nuclear Society's Winter Meeting by a DOE representative. Most of the cleanup costs would be expended over a 40-year period, but work at some sites would continue until 2070. Approximately 70 percent of the cleanup costs would go to clean up five sites; Hanford and Savannah River, 21 percent each; Rocky Flats, 10 percent; Oak Ridge National Laboratory, 10 percent; and the Idaho National Engineering Laboratory, 5 percent. The cost estimates are higher than the DOE's proposed budget for cleanup and environmental restoration, which has been around $6 billion a year. Nor do they include remediation of sites for which no viable cleanup technology exists (the Nevada Test Site and the U.S. Navy's nuclear propulsion facilities) or those plants that are still producing or disassembling nuclear weapons parts (such as the Pantex facility, near Amarillo, Tex.). Expenditures already made during the first five years of the cleanup program, estimated at $23 billion, are also not included in the new cost estimates. The DOE estimates that the total amount of radioactive waste that will result from the cleanup and requiring disposal will be around 33 million yd^3.

1109 Cigar lake: A natural example of long-term isolation of uranium. Cramer, J. (Atomic Energy of Canada Limited, Manitoba (Canada)). *Radwaste Magazine;* 2(3): 36-40 (May 1995).

Much research is being conducted to determine the best and safest way to permanently dispose of radioactive wastes. Particularly challenging is waste from the nuclear fuel cycle because of its content of long-lived radionuclides. Long-term predictions on the safe performance of any disposal concept for high-level waste cannot draw on experience with existing manufactured systems on similar timescales. However, there are ways to build confidence in such long-term predictions by looking at evidence from analygous systems and processes in nature. One of these natural analogs for a multibarrier disposal system is the 1.3 billion year old Cigar Lake uranium deposit in northern Saskatchewan, Canada. The Cigar Lake deposit contains a high-grade uranium ore embedded in a thick, clay-rich zone, situated about 430 meters below the surface. This deposit has been well preserved for a long time, but has no known signatures at the surface. This article describes this natural system and how the information can be applied to long term disposal of high-level radioactive wastes.

1110 Mechanisms of lead release from uraninite in the natural fission reactors in Gabon. Janeczek, J. (Silesian Univ., Sosnowiec (Poland)); Ewing, R.C. *Geochimica et Cosmochimica Acta;* 59(10): 1917-1931 (May 1995). Grant 6 P205 130 06.

Twenty-four samples of uranium ore from the natural fission reactors in Gabon were studied by detailed electron microprobe analysis and backscattered electron imaging in order to determine the behavior of radiogenic Pb and fissiongenic nuclides. Lead content in uraninite varies from 19 wt% PbO in relicts of pristine uraninite, which were found only in reactor zone 10, to less than 5 wt% in altered uraninites. Different mechanisms of Pb loss from uraninite prevailed in different reactor zones and included leaching, grain boundary diffusion, exsolution via continuous precipitation, and volume diffusion. As a result of these processes, Pb content in uraninites from all the reactor zones, except for reactor zone 10, are similar and vary around a mean value of 5.2 wt% PbO. All of these processes were thermally activated and episodic. The predominance of any single mechanism in a particular reactor zone was controlled by the accessibility of solutions to the uranium ore. The thermal event which caused Pb mobilization in the deposits resulted from regional igneous activity in the Franceville Basin more than

1100 Ma after the reactors sustained spontaneous fission reactions. Reducing conditions prevented the long distance migration of Pb, as well as of fissiongenic Mo and Ru.

1111 U.S. Department of Energy takes new approaches in waste issues. Dreyfus, D.A. (USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States)). *JNMM;* 23(3): 13-14 (Apr 1995).

Presented at INMM Spent Fuel Management Seminar XII, January 11–13, 1995, Washington, DC (US).

Last year, the author attended this meeting and outlined some of the actions the US DOE would be taking to reblue the Civilian Radioactive Waste Management Program. They took those initiatives. During the past year, US DOE significantly restructured their program. They defined two major "business centers"–the Yucca Mountain Site Characterization Project and the Waste Acceptance, Storage and Transportation Project. They also created a management component for the program that provides integration and support to the director and the projects. They defined their goals and laid a course to meet them. In the past year, the achievement that probably is most important to the future success of their program is the increased level of financial support that has been provided. Congress, acting on its belief that US DOE can and will achieve their objectives, agreed to the administration's proposed 40 percent increase in funding for fiscal year 1995, despite severe government wide budgetary restrictions. Most of the additional funding received for fiscal year 1995 was allocated to Yucca Mountain Site Characterization activity. The new approach is scientifically sound and reasonably achievable given resource limitations. The US DOE set forth explicit tasks and associated the tasks with target dates and costs.

1112 Nuclear waste: How the issue falls out. Garner, W.L. *Fortnightly;* 133(8): 37-39 (15 Apr 1995).

Unless Congress takes some action, utilities will be forced to provide onsite storage of spent fuel from civilian nuclera reactors much longer than they ever imagined. Congress's failure to authorize the Department of Energy (DOE) to begin planning a centralized, interim storage facility and, equally important, to accelerate development of a permanent repository, means that spent nuclear fuel will remain in limbo at 73 reactor sites in 34 states. Today's 30,000 metric tons of spent fuel from civilian nuclear plants will grow to 85,000 metric tons by 2033, according to DOE. The agency also must find a home for a future 70,000 tons of defense waste. There is a growing sense of urgency in Congress this year that something must be done about the nation's nuclear waste problem. By 1998, 26 civilian nuclear units will have exhausted their storage capacity. By 2010 - the earliest DOE says it could open a permanent repository at Yucca Mountain in Nevada, provided the site proves feasible - 80 nuclear units will be out of storage space. At least half a dozen bills have been introduced so far in the 104th Congress, by both propoents and opponents of nuclear power. Recent events in Washington suggest this will be a hard-fought battle.

1113 Late Quaternary geomorphology and soils in Crater Flat, Yucca mountain area, southern Nevada. Peterson, F.F. (Univ. of Nevada, Reno, NV (United States)); Bell, J.W.; Ramelli, A.R.; Dorn, R.I.; Ku, T.L. *Geological Society of America, Bulletin;* 107(4): 379-395 (Apr 1995).

Crater Flat is an alluvium-filled structural basin on the west side of Yucca Mountain, Nevada, which is under consideration for a high-level nuclear waste repository. North-trending, late Quaternary faults offset alluvium in Crater Flat both along the canyons of the western flanks of Yucca Mountain and out on the piedmont slope. We believe the initial lack of young offsets at Yucca Mountain was in part due to unrecognized late Quaternary stratigraphy. We hypothesize that alluviation in the Yucca Mountain region was more active during the late Quaternary than previously thought. Several techniques were tried to test this hypothesis. Results are compared with previous soils and surface-exposure dating studies, and correlated to stratigraphy of other late Quaternary units in the southern Nevada, Death Valley, and Mojave Desert areas, and provide new stratigraphic data relevant to understanding climatic-alluvial processes in the Basin and Range Province during the late Quaternary. 76 refs., 7 figs., 6 tabs.

1114 Fossil spring deposits in the southern Great Basin and their implications for changes in water-table levels near Yucca Mountain, Nevada, during quaternary time. Quade, J. (Univ. of Arizona, Tucson, AZ (United States)); Mifflin, M.D.; Pratt, W.L.; McCoy, W.; Burckle, L. *Geological Society of America, Bulletin;* 107(2): 213-230 (Feb 1995).

The proposed high-level nuclear waste repository at Yucca Mountain will be located nearly 200-400 m above the modern water table. Water tables will rise in response to a future return to glacial climates, but the magnitude of the change - and the consequences for radionuclide travel times and overall repository integrity - are key uncertainties. Increased recharge during past pluvial periods in the Spring Mountains and Sheep Range caused water tables to rise and ground water to discharge over broad expanses of the Las Vegas Valley system, and in nearby Pahrump, Sandy, and Coyote Springs Valleys. The change in water-table levels since the last full glacial period varies between and within valleys, from as little as 10 m in several areas to 95 m in the Coyote Springs Valley. At Yucca Mountain, the water table has probably changed by $\leq$115 m in response to climate change. The spring deposits and the mollusk faunas found with them, often misinterpreted as lacustrine in origin, share many essential features with active spring systems in northeast Nevada. Deposits associated with discharge mainly consist of pale brown silt and sand that is entrapped by dense stands of phreatophytes covering valley bottoms when water tables are high. 81 refs., 13 figs., 6 tabs.

1115 Using science soundly: The Yucca Mountain standard. Fri, R.W. *Resources;* (120): 15-18 (Sum 1995).

Using sound science to shape government regulation is one of the most hotly argued topics in the ongoing debate about regulatory reform. Even though no one advaocates using unsound science, the belief that even the best science will sweep away regulatory controversy is equally foolish. As chair of a National Research Council (NRC) committee that studied the scientific basis for regulating high-level nuclear waste disposal, the author learned that science alone could resolve few of the key regulatory questions. Developing a standard that specifies a socially acceptable limit on the human health effects of nuclear waste releases involves many decisions. As the NRC committee learned in evaluating the scientific basis for the Yucca Mountain standard, a scientifically best decision rarely exists. More often, science can only offer a useful framework and starting point for policy debates. And sometimes, science's most helpful contribution is to admit that it has nothing to say. The Yucca mountain study clearly illustrates that excessive faith in the power of science is more likely to produce messy frustration than crisp decisions. A better goal for regulatory reform is the

sound use of science to clarify and contain the inevitable policy controversy.

1116 Selection of slim hole core rods by vibratory analysis. Eustes, A.W. III (Colorado School of Mines, Golden, CO (United States). Drilling Engineering Research Group); Mitchell, B.J.; Stoner, M.S. *Journal of Energy Resources Technology;* 116(4): 251-257 (Dec 1994).

Presented at the Sixteenth Annual Energy-Sources Technology Conference and Exhibition, Houston, Texas, January 31–February 4, 1993.

The purpose of this research was to determine the nature of the core rod vibrations and characterize their vibratory spectrums in order that an optimal core rod size could be chosen. The research was performed for the Yucca Mountain Site Characterization Project, US Department of Energy, Office of Civilian Radioactive Waste Management, which is directing the coring of boreholes at Yucca Mountain, Nevada. This paper describes the axial, torsional, and transient buckling vibratory models developed for the selection of optimum core rod size. The axial and torsional vibratory core rod simulator (VCRS) models are coupled by way of a transient buckling wave which propagates over the length of the core rod. This paper reports the frequencies and magnitudes of the stresses in the 101 core rod now in use. In addition, four core bit vibratory forcing functions for thrust and torque wee developed. The thrust and torque frequencies and magnitudes for the bit forcing functions were extracted from full-size laboratory core bit tests with fast Fourier transforms. The natural frequencies of the core rod were determined with closed-form solution models and were confirmed with a finite element model. Finally, a selection of core rod sizes were modeled to determine the best size to minimize damaging stress which stems from vibration.

1117 Influence of evaporation on waste package environment and radionuclide release from a tuff repository. Walton, J.C. (Univ. of Texas, El Paso, TX (United States)). *Water Resources Research;* 30(12): 3479-3487 (Dec 1994).

Conceptual and mathematical models are presented for predicting waste package environment and radionuclide release in an unsaturated repository. Presence and ionic strength of water are viewed as a balance between water influx, evaporation, and condensation as modified by salinity-caused vapor pressure lowering. The model is used to examine the influence of thermal loading on waste package environment. Increased thermal gradients near the waste packages are shown to be as important as overall temperature in drying the waste package. The waste package environment is predicted to be highly variable, ranging from a concentrated brine to more dilute solutions. Under certain sets of conditions, water vapor condensation is predicted to occur on the waste package in the absence of liquid water influx.

1118 Socioeconomic studies of high-level nuclear waste disposal. White, G.F. (Univ. of Colorado, Boulder, CO (United States)); Bronzini, M.S.; Colglazier, E.W.; Dohrenwend, B.; Erikson, K.; Hansen, R.; Kneese, A.V. *Proceedings of the National Academy of Sciences of the United States of America;* 91(23): 10786-10789 (8 Nov 1994).

The socioeconomic investigations of possible impacts of the proposed repository for high-level nuclear waste at Yucca Mountain, Nevada, have been unprecedented in several respects. They bear on the public decision that sooner or later will be made as to where and how to dispose permanently of the waste presently at military weapons installations and that continues to accumulate at nuclear power stations. No final decision has yet been made. There is no clear precedent from other countries. The organization of state and federal studies is unique. The state studies involve more disciplines than any previous efforts. They have been carried out in parallel to federal studies and have pioneered in defining some problems and appropriate research methods. A recent annotated bibliography provides interested scientists with a compact guide to the 178 published reports, as well as to relevant journal articles and related documents.

1119 Episodic caldera volcanism in the Miocene southwestern Nevada volcanic field. Revised stratigraphic framework, $^{40}Ar/^{39}Ar$ geochronology, and implications for magmatism and extension. Sawyer, D.A. (Geological Survey, Denver, CO (United States)); Hudson, M.R.; Fleck, R.J.; Lanphere, M.A.; Warren, R.G.; Broxton, D.E. *Geological Society of America, Bulletin;* 106(10): 1304-1318 (Oct 1994). DOE Contract AI08-91NV11040.

The middle Miocene southwestern Nevada volcanic field (SWNVF) is a classic example of a silicic multicaldera volcanic field in the Great Basin. More than six major calderas formed between >15 and 7.5 Ma. We summarize major revisions of the SWNVF stratigraphy that provide for correlation of lava flows and small-volume tuffs with the widespread outflow sheets of the SWNVF. New laser fusion $^{40}Ar/^{39}Ar$ isotopic ages are used to refine and revise the timing of eruptive activity in the SWNVF. The use of high-sensitivity mass spectrometry allowed analysis of submilligram-sized samples with analytical uncertainties of ~0.3% (1 σ), permitting resolution of age differences as small as 0.07 Ma. These results confirm the revised stratigraphic succession and document a pattern of episodic volcanism in the SWNVF. 95 refs., 6 figs., 3 tabs.

1120 Erosional stability of rehabilitated uranium mine structures incorporating natural landform characteristics, northern tropical Australia. East, T.J. (Bureau of Resource Sciences, Canberra (Australia)); Uren, C.J.; Noller, B.N.; Cull, R.F.; Curley, P.M. *Zeitschrift fuer Geomorphologie;* 38(3): 285-298 (Sep 1994). (In German).

Australian Government guidelines specify that tailings containment structures at rehabilitated uranium mines in the Alligator Rivers Region of tropical northern Australia should have an engineered structural life of 1000 years. As part of the containment structure design process, erosion plots incorporating both regional geomorphological characteristics (concave hillslope profiles and a weathering-resistant rock cover of schist) and more conventional engineering design parameters (straight slopes and mine waste rock) were constructed at the Ranger Uranium Mine. The plots were monitored for storm runoff, and concentrations of solutes, suspended solids and selected ions over successive wet seasons. The concave slopes (the hillslope analogues) had lower peak discharges and lower concentrations of suspended solids than the straight slopes. However, solute concentrations in runoff from the schist covered (hillslope) slopes were higher than from the waste rock covered plots. Solute (mainly magnesium sulfate) concentrations for both rock types decreased by about an order of magnitude over the wet season. High sulfate concentrations are also likely to decrease substantially after several wet seasons, due to settlement of the waste rock and a reduction in rates of weathering. Development of a vegetation cover on the rehabilitated landforms will reduce the high suspended sediment

concentrations. These initial results suggest that rehabilitated uranium mine structures which utilise selected features of stable natural landforms in their design may have greater erosional stability than more conventionally engineered structures. (orig.)

1121 But why doesn't anybody know what to do about the waste?. Rossin, A.D. *Bezpecnost Jaderne Energie;* 1(8-9): 294-309 (Aug-Sep 1994). (In Czech). (CONF-930906--: '93 international conference on nuclear waste management and environmental remediation, Prague (Czech Republic), 5-11 Sep 1993).

English translation available from Nuclear Information Center, 156 16 Prague-Zbraslav, Czechoslovakia, at USD 10.- per typewritten page.

A thorough and instructive description is given of the history of nuclear power and nuclear waste issues in the U.S. Special attention is devoted to the impacts of the President Carter's policy, to the Acts of the U.S. Congress, and to the problems connected with the design and construction of the Yucca Mountain repository. Major challenges facing the U.S. nuclear energy policy are recapitulated. 26 refs.

1122 Underground exploration and testing at Yucca Mountain. *Tunnelling and Underground Space Technology;* 9(3): 353-363 (Jul 1994).

Underground exploration and testing are major components of site-characterization efforts, under the direction of the U.S. Department of Energy (DOE), for an underground repository for high-level nuclear waste at Yucca Mountain, in Nevada. The DOE's current program involves extensive tunneling throughout the geologic block at Yucca Mountain, with the goal of gaining visual access to the complex geology at the site. This report reviews the status of the underground exploration and testing program, and reports the Nuclear Waste Technical Review Board's recommendations concerning future strategies for the exploration and testing program. 27 refs., 3 figs.

1123 Impatient states ask court to goad DOE. *ENR;* 232(26): 9 (27 Jun 1994).

On June 20, 27 states asked a federal court in Washington to rule that the U.S. Department of Energy must begin removing spent nuclear fuel from its plants starting in January 1998 despite the current lack of a DOE storage facility for the high-level radioactive wastes. DOE has collected about $10 billion from power customers to cover costs of building storage facilities for waste from U.S. reactors starting in 1998. But it is not expected to open a permanent storage facility at Yucca Mountain, Nevada, until at least 2010, and has not yet sited an interim storage facility.

1124 Potential for Oklo-Mounana type uranium deposit hosted by the Rio Fresco group in Brazil. Kobayashi, Takao (Power Reactor and Nuclear Fuel Development Corp., Toki, Gifu (Japan). Chubu Works). *Donen Giho (PNC Technical Review);* (90): 56-68 (Jun 1994). (In Japanese).

High grade uranium mineralization occurs in the Rio Fresco area, Southern Para, Brazil. The geological characteristics of this mineralization are similar to the Oklo-Mounana type uranium deposit in the Franceville basin, Gabon as; 1. Archean granitic rocks form the basement craton; 2. Lower Proterozoic unmetamorphosed sediments host the uranium mineralization; and 3. Uranium minerals occur in deformed/brecciated sandstone along fine fractures which are closely related to fault structures. Although some geological implications are left to be explained, it is believed that Oklo-Mounana type deposit may exist in the Rio Fresco area. (author).

1125 The first detection of naturally-occurring ^{236}U with accelerator mass spectrometry. Zhao, X.L. (IsoTrace Laboratory, Department of Physics, University of Toronto, 60 St. George St., Toronto, Ontario (Canada)); Nadeau, M.J.; Kilius, L.R. *Nuclear Instruments and Methods in Physics Research, Section B;* 92(1-4): 249-253 (Jun 1994). (CONF-930960--: 6. international conference on accelerator mass spectrometry, Canberra (Australia), 17 Sep - 1 oct 1993).

The IsoTrace heavy element AMS system has been successfully used to detect naturally-occurring ^{236}U ($^{236}U/^{238}U=(5.6\pm1.5)\times10^{-10}$) in samples of uranium ore from Cigar Lake, Saskatchewan, Canada. This level of ^{236}U agrees with that previously claimed for samples of a processed uranium ore (D.J. Rokop, D.N. Metta and C.M. Stevens, Int. J. Mass Spectrom. Ion Phys. 8 (1972) 259 [1]), and is consistent with the amount of ^{239}Pu found in pitchblende (W.A. Myers and M. Lindner, J. Inorg. Nucl. Chem. 33 (1971) 3233 [2]). This experiment illustrates the general capability of a small tandem-based AMS system for analyzing actinides, in particular ^{236}U. It can be shown that the isotope-ratio detection limit of this system, is at present 5×10^{-8} for detecting a less abundant actinide isotope one mass unit above, and 5×10^{-10} one mass unit below, a major isotope. ((orig.))

1126 Yucca Mountain reviews a waste of time. Wamsted, D. *Energy Daily;* 22(25): 3 (8 Feb 1994).

The author of this article contends that two proposed reviews of Yucca Mountain are a waste of time. Further reviews will not eliminate opposition. What is needed is real action on the issue, such as studying the safety and suitability of the proposed waste site.

1127 Board seeks major changes in DOE's Yucca Mountain Program. Wamsted, D. *Energy Daily;* 22(38): 3 (28 Feb 1994).

Seeking to keep the heat on the Department of Energy, the Nuclear Waste Technical Review Board urged the department to make several fundamental changes in its high level radioactive waste program. In particular, the board said DOE currently directs too much funding toward overhead and infrastructure and not enough to on-site characterization activities. In addition to these changes, the board called on O'Leary to convene an independent review of the waste program's management and organizational structure. Such a review, which the board said would complement the secretary's current financial review of the program, is particularly important in light of the department's proposal to boost funding for the program in fiscal 1995.

1128 Gabon's natural reactors: nature shows how to contain radioactive waste. Nagy, B. (Arizona Univ., Tucson, AZ (United States). Lab. of Organic Geochemistry). *Nuclear Engineering International;* 39(475): 30-31 (Feb 1994).

When the Okla "natural" fission reactors were discovered in 1972, investigators were soon surprised at how little several of the fission products or U-235 had moved in the two billion years since they were active. Studies underway in several countries are seeking to determine whether these ancient reactors can serve as time-tested analogs for the modern processes needed for a nuclear waste repository. (author).

1129 Managing nuclear waste from power plants. Keeney, R.L. (Univ. of Southern California, Los Angeles, CA (United States)); Winterfeldt, D. von. *Risk Analysis;* 14(1): 107-130 (Feb 1994). Grant SES-8919502.

National strategies to manage nuclear waste from commercial nuclear power plants are analyzed and compared. The current strategy is to try to operate a repository at Yucca Mountain, Nevada, to dispose storage at a centralized facility or next to nuclear power plants. If either of these is pursued now, the analysis assumes that a repository will be built in 2100 for waste not subsequently put to use. The analysis treats various uncertainties: whether a repository at Yucca Mountain would be licensed, possible theft and misuse of the waste, innovations in repository design and waste management, the potential availability of a cancer cure by 2100, and possible future uses of nuclear waste. The objectives used to compare alternatives include concerns for health and safety, environmental and socioeconomic impacts, and direct economic costs, as well as equity concerns (geographical, intergenerational, and procedural), indirect economic costs, as well as equity concerns (geographical, intergenerational, and procedural), indirect economic costs to electricity ratepayers, federal government responsibility to manage nuclear waste, and implications of theft and misuse of nuclear waste. The analysis shows that currently building an underground repository at Yucca Mountain is inferior to other available strategies by the equivalent of $10,000 million to $50,000 million. This strongly suggests that this policy should be reconsidered. A more detailed analysis using the framework presented would help to define a new national policy to manage nuclear waste. 36 refs., 3 figs., 17 tabs.

1130 Special report: Nuclear waste - under new management. *Nuclear Energy (Washington, D.C.);* : 18-27 (1994).

This article is an overview of the effort to provide a long-term disposal site at Yucca Mountain for high-level wastes. Previous financial and technical problems are discussed, as are current funding initiatives. The final decision on the suitability of the site is scheduled for 1998, and a license application is scheduled for 2001.

1131 Nuclear waste's human dimension. Erikson, K. (Yale Univ., New Haven, CT (United States)); Colglazier, E.W.; White, G.F. *Forum for Applied Research and Public Policy;* 9(3): 91-97 (Fal 1994).

The United States has pinned its hopes for a permanent underground repository for its high-level nuclear wastes on Yucca Mountain, Nevada. Nevertheless, the Department of Energy's (DOE) site research efforts have failed "to adequately consider human behavior and emotions," write Kai Erikson of Yale University, E. William Colglazier of the National Academy of Sciences, and Gilbert F. White of the University of Colorado. The authors maintain that it is impossible to predict changes in geology, seismology, and hydrology that may affect the Yucca Mountain area over the next 1,000 years. Predicting human behavior in that time frame remains even more daunting, they insist. They admit that "DOE...has been given the impossible assignment to take tens of thousands of metric tons of the most hazardous materials ever created and, in the face of growing opposition, entomb them so that they will do little harm for thousands of years." The researchers suggest that the government seek a secure, retrievable storage arrangement while it continues its search for safer long-term options.

1132 Predicted gas-phase movement of carbon-14 from a radioactive waste repository. Ross, B. (Disposal Safety, Inc., Washington, DC (United States)); Amter, S.; Lu, N. *Radioactive Waste Management and Environmental Restoration;* 19(1-3): 97-106 (1994).

Special issue Yucca Mountain.

The migration of radioactive $^{14}CO_2$ gas to the atmosphere is a potentially important mechanism for the release of radioactivity from the potential nuclear waste repository at Yucca Mountain, Nevada. Finite-difference computer simulations of gas circulation within Yucca Mountain suggest that the travel time of ^{14}C gas from a hot repository to the atmosphere may be less than 10,000 yr. (author) 5 figs., 10 refs.

1133 Outlook remains dim for waste solution. Parker, F.L. *Forum for Applied Research and Public Policy;* 9(3): 98-102 (Fal 1994).

When Congress selected Yucca Mountain as the proposed site for storing the nation's high-level nuclear waste, this isolated piece of real estate in Nevada became the focus of national debate about the long-term safety and feasibility of underground storage, writes Frank L. Parker, a professor in environmental engineering at Vanderbilt University. "While scientific knowledge will increase in the future, it is unlikely that we will ever achieve full understanding of the long-term movement of radioactive waste that must remain buried for hundreds of thousands of years," says Parker. Parker maintains that the battle over the future of Yucca Mountain has proved that local communities should have a strong voice in the site-selection process, and, once a site is chosen, people who live nearby should be compensated for the burden they bear.

1134 A cold geologic repository for high-level nuclear wastes. Taylor, E.C. *Transactions of the American Nuclear Society;* 71: 98-99 (1994). (CONF-941102--: Winter meeting of the American Nuclear Society (ANS), Washington, DC (United States), 13-18 Nov 1994).

The idea of a cold repository is discussed, along with the Yucca mountain Project. A cold repository is defined to be one in which the thermal loading is so low that the local hydrology is not significantly affected. The calculations summarized here - and all other calculations relating to the thermal and hydrological behavior of the Yucca Mountain candidate repository site - are necessarily approximations. They must be supported with measurements and appropriately modified. The advantages of low-temperature negligible-seepage repository - if it can exist - are that it would be easier to demonstrate, and it would not require long-term thermal testing. We might be able to demonstrate the safety of a cold repository much earlier than a hot repository - perhaps soon after we get underground. The disadvantage is that it limits area loading and waste-package loading.

1135 High-level waste: View from Nevada. Miller, B. *Forum for Applied Research and Public Policy;* 9(3): 103-105 (Fal 1994).

"Instead of acknowledging the serious shortcomings of the current waste program, the Department of Energy (DOE) has sought to tighten the screws on Nevada," says Nevada Governor Bob Miller. Nevada's opposition to the federal government's proposed high-level radioactive waste repository at Yucca Mountain has grown out of fundamental flaws within the siting process, says Miller. "This process has left the nation with one technically flawed site as its sole prospect for nuclear waste disposal," he says. Miller claims

that DOE has acknowledged that the site is inadequate. Nevertheless, he says, the agency has insisted on pressing ahead with its plans, attempting to "adjust the standards to fit the site." Miller concludes that dry and/or above-ground waste storage at reactor site represents a more sensible - and less costly - disposal method for high-level wastes, at least in the short term.

1136 Oklo: fossil nuclear reactors. Naudet, R. *Memoires de La Societe Geologique de France;* (162): 111-118 (1994). (In French). (CONF-9211338--: Colloquium acts on atom and geology, Paris (France), 25-26 Nov 1992).

Nearly two billions years ago, fission chain reactions set up spontaneously in small portions of a uranium deposit in Gabon, and were sustained for sufficiently long periods for the isotopic compositions of many elements to be deeply modified. These natural reactors were found remarkably preserved. Through neutronic analysis, the operating conditions were reconstituted: during reactions, heat release turned out in convection streams, which dissolved quartz and so eliminated large amounts of silica, densifying uranium and deeply modifying geometry and composition of the rocks; reactors were mainly controlled by temperature which modified water density. 3 figs., 1 tab., 5 refs.

1137 Long-term C-14 source term for a high-level waste repository. Ahn, T.M. (Nuclear Regulatory Commission, Washington, DC (United States)). *Waste Management;* 14(5): 393-408 (1994).

This paper evaluates the possibility of long-term Carbon-14(C-14) releases from spent fuels and containers in the anticipated environments of the proposed Yucca Mountain high-level waste repository. Long-term degradation mechanisms of spent fuel matrices, cladding, and containers are evaluated. Under dry conditions, formation of higher oxides, such as U_3O_8, may lead to significant C-14 releases from the spent fuel matrix. It is unclear whether there will be significant C-14 releases from lower oxidation to $UO_{2.4}$ or from the unoxidized matrix. Under aqueous dissolution conditions, C-14 releases from the spent fuel matrix can be significant. Under aqueous dissolution or dry conditions, it is unlikely that there will be significant C-14 releases from cladding, unless severe localized corrosion takes place. In considering containers and cladding as metallic barriers, the authors discuss qualitatively various factor governing total C-14 containment inside metallic barriers. C-14 releases can be delayed, even by the formation of small through-wall pits in metallic barriers. Although the authors do not have completely definitive information yet, it is clear that the spent fuel matrix, cladding, and containers can serve as important barriers to C-14 releases from waste packages in a repository environment.

1138 Simulation of gas phase transport of carbon-14 at Yucca Mountain, Nevada, USA. Lu, N. (Disposal Safety Inc., Washington, DC (United States)); Ross, B. *Waste Management;* 14(5): 409-420 (1994). DOE Contract AC04-76DP00789.

The authors have simulated gas phase transport of Carbon-14 at Yucca Mountain, Nevada. Three models were established to calculate travel time of Carbon-14 from the potential repository to the mountain surface: a geochemical model for retardation factors, a coupled gas-flow and heat transfer model for temperature and gas flow fields, and a particle tracker for travel time calculation. The simulation used three parallel, east-west cross-sections that were taken from the Sandia National Laboratories Interactive Graphics Information Systems (IGIS). Assuming that the repository is filled with 30-year-old waste at an initial areal power density of 57 kw/acre, the authors found that repository temperatures remain above 60 C for more than 10,000 years. For a tuff permeability of 10^{-7} cm^2, Carbon-14 travel times to the surface are mostly less than 1,000 years, for particles starting at any time within the first 10,000 years. If the tuff permeability is 10^{-8} cm^2, however, Carbon-14 travel times to the surface range from 3,000 to 12,000 years, for particle starting within the 10,000 years.

1139 Petrographic analysis of samples from the uranium deposit at Oklo, Republic of Gabon. Eberly, P. (Dept. of Earth and Planetary Sciences, Univ. of New Mexico, Albuquerque, NM (United States)); Janeczek, J.; Ewing, R.C. *Radiochimica Acta;* 66-67: 455-461 (1994). (CONF-931201--: 4. international conference on chemistry and migration behavior of actinides and fission products in the geosphere, Charleston, SC (United States), 12-17 Dec 1993).

This study is preliminary to detailed X-ray diffraction analysis and additional electron microprobe analyses. Twenty samples were examined; seven from reactor zone 9 (RZ-9), ten from RZ-10, two from RZ-13 and one from RZ-16. This suite of samples includes examples from reactor cores and their associated hydrothermal alteration haloes. The most striking characteristic of the Oklo samples is their heterogeneity. In particular, the samples vary with respect to texture, mineralogy, uranium mineral content, and evidence for deformation. Deformation features provide evidence for both shear and extensional stresses and include brecciation and a variety of mineralized fractures. Opaque phases include orgainc matter, uraninite, coffinite, and sulfides. In many cases, the opaque assemblage is concentrated along fractures. Considerable textural evidence, viz., embayed grain margins and fractures with nonparallel margins, suggests partial dissolution of uraninite in the Oklo ores. Uraninite with embayed margins is commonly accompanied by organic matter. Oklo uraninites are, in many cases, altered to produce coffinite ($USiO_4.nH_2O$) and are associated with varying quantities of galena at grain boundaries, within fractures, and within individual grains at intracrystalline locations. Textural evidence suggests multiple periods of uraninite formation. Electron microprobe data are presented for uraninites from RZ-13. Analytical data are discussed for Oklo reactor zones 2, 9, 10, 13, and 16 and for the reactor at Bangombe. Uraninites are compositionally similar with respect to Pb for RZ-2, RZ-9, RZ-13, RZ-16 and for the Bangombe reactor (average content of PbO is 5.92 weight %). Lead contents for uraninites from RZ-10 are generally higher and more variable than for the other reactor zones (e.g., PbO content for RZ-10 uraninites ranges from approximately 12 to 18 weight %). (orig.)

1140 Migration of fission products into microminerals of the Oklo Natural Reactors. Hidaka, Hiroshi (Dept. of Chemistry, Tokyo Metropolitan Univ. (Japan)); Takahashi, Kazuya; Holliger, P. *Radiochimica Acta;* 66-67: 463-468 (1994). (CONF-931201--: 4. international conference on chemistry and migration behavior of actinides and fission products in the geosphere, Charleston, SC (United States), 12-17 Dec 1993).

Isotopic characterization of two kinds of unique micro inclusions, metallic aggregate and apatite, in reactor core samples at the Oklo uranium ore in Republic of Gabon was studied. In order to investigate the migration and retention mechanism of fission products, in-situ isotopic analyses by

secondary ion mass spectrometry (SIMS), and precise isotopic measurements by thermal ionization mass spectrometry (TIMS) and inductively coupled plasma mass spectrometry (ICP-MS) were carried out. The results of isotopic analyses led to the following observations: (1) fissiogenic Ru, Pd and Te are enriched in the micrometallic inclusions, and (2) micro apatites contain fissiogenic alkaline, alkaline earth, and rare earth elements (REE). Moreover, the geochemical behaviour of long-lived radionuclides ^{99}Tc and ^{137}Cs could be estimated from the precise isotopic determination of fissiogenic Ru and Ba, respectively. Fissiogenic REE have fractionated chemically during the migration processes from the uraninite matrix inot an apatite structure. (orig.)

1141 NWTRB: YM project needs overall strategy. *Nuclear News;* 36(15): 58-59 (Dec 1993).

The eighth report on Underground Exploration and Testing at Yucca Mountain was released by the Nuclear Waste Technical Review Board (NWTRB) on October 15. The report, directed to the US Congress and the Secretary of Energy, says that although the board has seen some improvements over the last four years in the Department of Energy's plans for exploration and testing at the site, it is concerned that important technical decisions about the design and approach to excavating the exploratory facility are being made "without sufficient analysis" in order to comply with overly optimistic schedules. The board fears that this could extend, rather than shorten, program schedules, as well as increase costs.

1142 Oxidation of uraninite: does tetragonal U_3O_7 occur in nature?. Janeczek, J. (Dept. of Earth Sciences, Silesian Univ., Sosnowiec (Poland)); Ewing, R.C.; Thomas, L.E. *Journal of Nuclear Materials;* 207: 177-191 (Dec 1993).

Samples of uraninite and pitchblende annealed at 1200 C in H_2, and untreated pitchblende were sequentially oxidized in air at 180-190 C, 230 C, and 300 C. Uraninite and untreated pitchblende oxidized to the U_4O_9-type oxide, and their X-ray symmetry remained isometric up to 300 C. Reduced pitchblende after oxidation to UO_{2+x} and U_4O_9-type oxides transformed into α-U_3O_8 at 300 C. Two major mechanisms control uraninite and untreated pitchblende stability during oxidation: (1) Th and/or REE maintain charge balance and block oxygen interstitials near impurity cations; (2) the uraninite structure saturates with respect to excess oxygen and radiation-induced oxygen interstitials. Untreated pitchblende during oxidation behaved similarly to irradiated UO_2 in spent nuclear fuel; whereas, reduced pitchblende resembled nonirradiated UO_2. An analysis of the data in the literature, as well as our own efforts to identify U_3O_7 in samples from Cigar Lake, Canada, failed to provide conclusive evidence of the natural occurrence of tetragonal α-U_3O_7. Most probably, reported occurrences of U_3O_7 are mixtures of isometric uraninites of slightly different compositions. (orig.)

1143 Petrography and paragenesis of organic matter associated with the natural fission reactors at Oklo, Republic of Gabon: a preliminary report. Mossman, D.J. (Mount Allison University, Sackville, NB (Canada). Dept. of Physics); Nagy, B.; Rigali, M.J.; Gauthier-Lafaye, F.; Holliger, P. *International Journal of Coal Geology;* 24(1/4): 179-194 (Dec 1993). (CONF-9205398--: Symposium on advances in organic petrology and geochemistry, Wolfville (Canada), 25-27 May 1992).

Sixteen known uranium-rich pockets in the sediment-hosted uranium ore deposits in the Oklo area became nuclear fission reactors 1968±50 Ma ago and operated as such for up to 1 Ma. Nuclear criticality was caused by unique and fortuitous geological environments and events. These included the localized high concentrations of uranium in small pockets in the ore bodies, the fact that the relative abundance of the fissile ^{235}U isotope was five times greater in uranium ~2 Ga ago than present, the presence of water which acted as a moderator in the natural reactors and the absence of neutron poisons, which are elements that can prevent nuclear chain reactions. Organic matter has been studied in natural reactors 7 to 9 and at locations at various distances from these reactors. Bitumen in the Oklo reactors is the predominant organic phase. It is now solid bitumen. Its immediate precursor was liquid bitumen, generated from syngenetic kerogen in organic-rich sedimentary rocks in the Francevillian Basin of Gabon and in the natural reactors themselves by hydrous reaction mechanisms prior to, during, and after nuclear criticality. A preliminary paragenesis of organic matter at Oklo is defined. 36 refs., 3 figs., 1 tab.

1144 Effects of environment on localized corrosion of copper-based, high-level waste container materials. Sridhar, N. (Southwest Research Inst., San Antonio, TX (United States). Center for Nuclear Waste Regulatory Analyses); Cragnolino, G.A. *Corrosion;* 49(12): 967-976 (Dec 1993).

Effects of environmental factors on localized corrosion of copper (Cu)-based materials that are candidates for use in high-level nuclear waste containers were examined. Effects of bicarbonate (HCO_3^-), chloride (Cl^-), and sulfate (SO_4^{2-}), which are present in the ground water near the proposed Yucca Mountain site for a high-level waste repository, were studied. Localized corrosion was observed only at low temperatures in environments involving combinations of high HCO_3^- with high Cl^- or high SO_4^{2-}. Uniform corrosion was observed at low concentrations of HCO^-_3 (< ~2,000 ppm), especially when Cl^- or SO_4^{2-} concentration was high. A passive behavior without localized corrosion was observed at high HCO_3^- concentrations at temperatures > 80 C, irrespective of the Cl^- and SO_4^{2-} concentrations. Localized corrosion observed in the Cu-based alloys was much shallower than in stainless steels and nickel (Ni)-based alloys and tended to broaden with time under potentiostatic conditions. Oxygen-free Cu (CDA-102, UNS C10200) exhibited a greater tendency toward localized corrosion than a 70% Cu-30% Ni alloy (CDA-715, UNS C71500).

1145 Studies of colloids and suspended particles, Cigar Lake uranium deposit, Saskatchewan, Canada. Vilks, P. (Atomic Energy of Canada Ltd., Pinawa, MB (Canada). Whiteshell Labs.); Cramer, J.J.; Bachinski, D.B.; Doern, D.C.; Miller, H.G. *Applied Geochemistry;* 8(6): 605-616 (Nov 1993).

The Cigar Lake U deposit located in the eastern part of the Athabasca Sandstone Basin, consists of a high-grade ore body (up to 55% U) located at a depth of ≈ 430 m. As part of a study to evaluate the analog features of this deposit with respect to a disposal vault for waste nuclear fuel, colloids (1-450 nm) and suspended particles (> 450 nm) in groundwater have been investigated to evaluate their effect on element transport. The results show that particle compositions are similar to the composition of minerals in the sandstones and ore body, suggesting that particles in groundwater are generated by the erosion of fracture-lining minerals and concentrations are affected by the integrity of the host rock. The observed colloid and suspended particle concentrations in the deep groundwaters are too low to have a significant impact on radionuclide migration, provided

that radionuclide sorption is reversible. If radionuclides are irreversibly sorbed to particles they cannot sorb to the host rock and their migration can only be evaluated with an understanding of particle mobility. The data for dissolved and particulate U, Th and Ra were used to calculate field-derived distribution ratios (R_d) between particles and groundwater. The wide range of observed R_d values indicates that these radionuclides in particulate form are not in equilibrium with groundwater. U-series isotope data indicated that most of the U and Ra on particles was derived from groundwater. Some particles could have retained their U for as long as 8000 a. The U and Ra contents of particles in the ore and surrounding clay zones are significantly higher than in particles from sandstone, suggesting that the clay has been an effective barrier to particle migration. (author).

1146 Okulo natural reactors: Recent findings and their significance on geologic disposal of high level radioactive waste. Yamakawa, Minoru (Power Reactor and Nuclear Fuel Development Corp., Tokyo (Japan)). *Nippon Genshiryoku Gakkai-Shi (Journal of the Atomic Energy Society of Japan);* 35(11): 978-984 (Nov 1993). (In Japanese).

French CEA has reported in 1972 that natural nuclear reactors existed in Okulo uranium deposit in Gabon in Africa, that caused nuclear fission chain reaction (Okulo phenomena) spontaneously two billion years ago. The fission products and transuranic elements produced by the natural reactors have been preserved in strata without movement while subjected to geological phenomena for such very long years. 16 zones of the natural reactors have been discovered so far. The geological features of the Okulo uranium deposit are explained. The total amount of ^{235}U lost by the chain reaction was estimated to be about 6t, and the fission products were about 6t. The Okulo phenomena offered the valuable results of the synthetic formation disposal test that the nature has carried out for such long years. The significance of the study on natural analog is discussed. Organic substances and the mechanism of holding and movement of uranium and fission nuclides, the stability of uraninite and the age measurement of the deposit by Nd-Sm process are reported as the main results. (K.I.).

1147 The Nevada initiative: A risk communication Fiasco. Flynn, J. (Decision Research, Eugene, OR (United States)); Solvic, P.; Mertz, C.K. *Risk Analysis;* 13(5): 497-502 (Oct 1993).

The U.S. Congress has designated Yucca Mountain, Nevada as the only potential site to be studied for the nation's first high-level nuclear waste repository. People in Nevada strongly oppose the program, managed by the U.S. Department of Energy. Survey research shows that the public believes there are great risks from a repository program, in contrast to a majority of scientists who feel the risks are acceptably small. Delays in the repository program resulting in part from public opposition in Nevada have concerned the nuclear power industry, which collects the fees for the federal repository program and believes it needs the repository as a final disposal facility for its high-level nuclear wastes. To assist the repository program, the American Nuclear Energy Council (ANEC), an industry group, sponsored a massive advertising campaign in Nevada. The campaign attempted to assure people that the risks of a repository were small and that the repository studies should proceed. The campaign failed because its managers misunderstood the issues underlying the controversy, attempted a covert manipulation of public opinion that was revealed, and most importantly, lacked the public trust that was necessary to communicate credibly about the risks of a nuclear waste facility. This article describes the advertising campaign and its effects. The manner in which the ANEC campaign itself became a controversial public issue is reviewed. The advertising campaign is discussed as it relates to risk assessment and communication. 29 refs., 2 tabs.

1148 GAO report recommends review of goals, objectives. *Nuclear News;* 36(9): 50-51 (Jul 1993).

This article highlights a recent GAO study titled Nuclear Waste: Yucca Mountain Project Behind Schedule and Facing Major Scientific Uncertainties. The study was undertaken at the request of the former chairman of the Subcommittee on Nuclear Regulation, the predecessor of the current Subcommittee on Clean Air and Nuclear Regulation of the Senate Committee on Environment and Public Works. The report concludes that the level of funding DOE is requesting is not adequate to complete the goals of the project within the established timeline, and questions whether the changes being recommended by DOE to streamline the project will save money at the cost of safety. The GAO report recommends that the Secretary of Energy "...review the program's goals and objectives in the context of the program's priority for funding." It also recommends that Congress not consider any funding changes until the Secretary's report is in and an independent review by the Nuclear Waste Technical Review Board is also available.

1149 Permeability of Apache Leap Tuff: Borehole and core measurements using water and air. Rasmussen, T.C. (Univ. of Arizona, Tucson, AZ (United States)); Evans, D.D.; Sheets, P.J.; Blanford, J.H. *Water Resources Research;* 29(7): 1997-2006 (Jul 1993). Contract NRC-04-86-114.

Characterization data for water and air properties of variably saturated rocks are required for evaluation of the candidate high-level nuclear waste disposal site at Yucca Mountain, Nevada, as well as for municipal, toxic, and hazardous waste sites situated in variably saturated fractured rock elsewhere. Field and laboratory methods for estimating and interpreting parameters obtained from field borehole and laboratory core experiments are examined using permeability data interpreted from air and water injection tests in variably saturated fractured tuff at the Apache Leap Tuff Site in central Arizona. The tuff at the field site has a matrix porosity of approximately 17.5% and contains numerous near-vertical fractures at an average spacing of 1.3 m. More than 270 m of 6.4-cm-diameter oriented core were collected from boreholes. Laboratory estimates of absolute permeabilities using air and water as the test fluids were acquired at a range of matric potentials for 105, 5-cm-long core segments extracted at approximately 3-m intervals containing no obvious fractures. Field scale estimates of fractured rock permeabilities using air and water as test fluids were obtained at ambient matric suctions and water saturated conditions, respectively. The field tests were conducted along 3-m intervals within boreholes with the intervals centered on core sampling positions. Permeabilities measured in boreholes using air are shown to provide good estimates of permeabilities measured using water into initially unsaturated, fractured rock at the Apache Leap Tuff Site.

1150 Magnetic grain-size variations through an ash flow sheet: Influence on magnetic properties and implications for cooling history. Rosenbaum, J.G. (Geological

Survey, Denver, CO (United States)). *Journal of Geophysical Research;* 98(B7): 11715-11727 (10 Jul 1993). DOE Contract AI08-86NV10583.

Rock magnetic studies of tuffs are essential to the interpretation of paleomagnetic data derived from such rocks, provide a basis for interpretation of aeromagnetic data over volcanic terranes, and yield insights into the depositional and cooling histories of ash flow sheets. A rhyolitic ash flow sheet, the Miocene-aged Tiva Canyon Member of the Paintbrush Tuff, contains both titanomagnetite phenocrysts, present in the magma prior to eruption, and cubic Fe-oxide microcrystals that grew after emplacement. Systematic variations in the quantity and magnetic grain size of the microcrystals produce large variations in magnetic properties through a section of the ash flow sheet penetrated in a borehole on the Nevada Test Site. Natural remanent magnetization varies from less than 1×10^{-4} to more than 8×10^{-4} A m^3 kg^{-1}, and in-phase magnetic susceptibility varies from less than 1×10^{-6} to more than 10×10^{-6} m^3 kg^{-1}. The microcrystals, which include both magnetite and maghemite, have Curie points and maximum unblocking temperatures between 580°C and 640°C. Rock magnetic data, including in-phase and quadrature magnetic susceptibilities as well as hysteresis parameters, demonstrate that these microcrystals are of superparamagnetic and single-domain sizes. Titanomagnetite phenocrysts are the dominant remanence carriers in the central 50 m of the section, whereas microcrystals are important contributors to remanent magnetization and magnetic susceptibility in two 15-m-thick zones at the top and bottom. Within these zones the size of microcrystals decreases both toward the quenched margins and toward the interior of the sheet. The decrease in microcrystal size toward the interior of the sheet is interpreted to indicate the presence of a cooling break; possibly represented by a concentration of pumice. 32 refs., 11 figs.

1151 The Cigar Lake uranium deposit, Saskatchewan (Canada). Pagel, Maurice (Centre de Recherches sur la Geologie de l'Uranium (CREGU), 54 - Vandoeuvre-les-Nancy (France)); Ruhlmann, Francois; Bruneton, Patrice. *Canadian Journal of Earth Sciences;* 30(4): 651-652 (Apr 1993). (In English, French).

This brief preface introduces a special section devoted to Cigar Lake. Discovered by Cogema, the deposit has estimated reserves of 154 600 tonnes of uranium with an average grade of 7.9%. The other eight articles in this section have been abstracted separately.

1152 Geological environment of the Cigar Lake uranium deposit. Bruneton, P. (Cogema/ branche Uranium, Departement des recherches minieres, Velizy-Villacoublay (France)). *Canadian Journal of Earth Sciences;* 30(4): 653-673 (Apr 1993).

The Cigar Lake uranium deposit occurs within the Athabasca Basin of northern Saskatchewan, Canada. Like other major uranium deposits of the basin, it is located at the unconformity separating Helikian sandstones of the Athabasca Group from Aphebian metasediments and plutonic rocks of the Wollaston Group. The Athabasca Group was deposited in an intra-continental sedimentary basin that was filled by fluviatile terrestrial quartz sandstones and conglomerates. The group appears undeformed, and its actual maximum thickness is about 1500 m. On the eastern side of the basin, the detrital units correspond to the Manitou Falls Formations where most of the uranium deposits are located. The lower Pelitic unit of the Wollaston Group, which lies directly on the Archaean basement, is considered to be the most favourable horizon for uranium mineralization. On the Waterbury Lake property, the Manitou Falls formation is 250-500 m thick and corresponds to units MFd, MFc, and MFb. The conglomeratic MFb unit hosts the Cigar Lake deposit. However, the basal conglomerate is absent at the deposit, wedging out against an east-west, 20 m high, pre-Athabasca basement ridge, on top of which is located the orebody. Despite the presence of the orebody, large areas of the Waterbury lake property remain totally unexplored and open for new discoveries. 45 refs., 23 figs., 4 tabs.

1153 Petrography and mineralogy of alteration halos around the Cigar Lake deposit and their relation to the mineralization. Pacquet, A. (Cogema. Groupe des sciences de la Terre, Razes (France)); Weber, F. *Canadian Journal of Earth Sciences;* 30(4): 674-688 (Apr 1993). (In French).

Around the Cigar Lake orebody, the present zoneography of alteration halos reflects several alteration episodes, some of which are anterior to and others coeval with the mineralizing events and have a regional extension. In the main pod, the uraninite mineralization was dated 1341 ± 12 Ma. In the sandstones, it is surrounded by ferromagnesian chlorites with a variable sudoitic character. This proximal alteration halo grades into a more distal envelope, visible in the sandstone and in the basement, that is composed of magnesium sudoite and 3T hydromuscovite. During this mineralizing event, dravite crystallized in the form of urchin-like clusters in the basement and xenotime overgrowth, around altered zircon, and apatite formed in the sandstones. Around the main pod and in some perched orebodies, an alteration zone of vanadium-bearing ferrikaolinite and iron-bearing 3T hydromuscovite, crosscut by a later siderite, surrounds the pitchblende dated 323 ± 4 Ma. Coffinite and an aluminous hydromuscovite crystallized during a later fracture event. The aluminous hydromuscovite also appears, with a silica-carbon-uranium complex, in perched mineralizations. Kaolinization and iron-sulfide oxidation into iron hydroxides occurred in perched orebodies that were more exposed to meteoric alteration. 19 refs., 12 figs., 11 tabs.

1154 Clay mineralogy and isotope geochemistry of the alteration halo at the Cigar Lake uranium deposit. Percival, J.B. (Geological Survey of Canada, Ottawa, ON (Canada). Mineral Resources Division); Bell, K.; Torrance, J.K. *Canadian Journal of Earth Sciences;* 30(4): 689-704 (Apr 1993).

Geological Survey of Canada Contribution 48590.

The clay-size fraction of the alteration halo associated with the Cigar Lake uranium deposit consists of illite with subordinate kaolinite, sudoite (Al-chlorite), Fe-chlorite, hematite, and traces of an illite-chlorite mixed-layer mineral. The Kuebler Index of illite crystallinity ranges from 2.0 to 6.7; the most-altered samples average 4.0. These data indicate that high-grade diagenetic to anchizonal conditions have been reached within the alteration halo. Intensity ratios of the 002 and 001 illite reflections (I(002)/I(001)) are generally greater than 0.4, the phengite-muscovite boundary, reflecting aluminum-rich illites; illite composition approaches hydromuscovite. K-Ar dates for illite-rich samples, from 1255 to 1148 Ma, could reflect variable resetting of the K-Ar system during hydrothermal fluid circulation after or during main-stage ore formation. The sudoite-illite assemblage from an altered basement sample yield a date of 815 Ma, unlike the clay-rich ore sample which contains no radiogenic argon. The younger date of the basement sample and the lack of radiogenic ^{40}Ar in the ore sample may result from alteration. Average δD and $\delta^{18}O$ values for illite-rich samples

are -82 and +10, respectively. Samples that contain sudoite are enriched in D, but the ore sample containing Fe-chlorite is depleted in D and ^{18}O relative to the illite-rich samples. 72 refs., 12 figs., 6 tabs.

1155 Metallographic study of the different mineral associations and chemical characterization of the uraniferous minerals of Cigar Lake deposit (Saskatchewan, Canada). Reyx, Jean (Cogema/ branche Mine, Departement des recherches minieres, Velizy (France)); Ruhlmann, Francois. *Canadian Journal of Earth Sciences;* 30(4): 705-719 (Apr 1993). (In French).

The Cigar Lake deposit, discovered in 1981, represents one of the richest uranium occurrences known in the province of Saskatchewan. Being located at the unconformity between the Aphebian metasediments and the Helikian sandstone cover, this deposit is classified in the group of deposits spatially related to the Proterozoic unconformity. The metallographic study of the mineralizations in the main ore body, hosted in the basement, and the so-called 'perched' mineralization in the cover rocks, led to the definition of three major mineralizing stages, which contributed in varying degrees to ore deposition. A major stage is characterized by the association of U-Ni-Co-As-S ± Mo-Bi-Cu-Zn-Pb and reflects the polyphased nature of this hydrothermal stage. This early deposition of the uraniferous phase (massive, botryoidal and euhedral uraninite) was followed, on one hand, by a phase precipitating nickel-cobalt and iron arsenides and sulfoarsenides, and on the other hand, by a phase exclusively of sulfides. The age of emplacement of this stage is 1341 Ma. The second stage appears only in the metamorphic units of the Aphebian basement. It is represented by a uraninite-sulfide paragenesis, the uraninite being characterized principally by the presence of thorium and, as well, a lead content lower than that in the uranous oxide stage. The third mineralizing stage affects the basement rocks, the main orebody, and the cover rocks with their perched mineralization. It is a simple pitchblende - iron or iron-nickel sulfide and (or) hematite paragenesis with an age of emplacement of 323 Ma. 23 refs., 19 figs., 3 tabs.

1156 Formation and evolution of the Cigar Lake uranium deposit based on U-Pb and K-Ar isotope systematics. Philippe, S. (Montpellier-2 Univ., 34 (France)); Lancelot, J.R.; Clauer, N.; Pacquet, A. *Canadian Journal of Earth Sciences;* 30(4): 720-730 (Apr 1993).

A systematic geochronological study was conducted on the Cigar Lake uranium deposit. U-Pb and Pb-Pb systematics were applied to different types of uranium ore, and various associated sheet silicates were dated by the K-Ar method. These two approaches define a widespread retrograde metamorphic event in the basement, which occurred at about 1780 Ma during the Hudsonian orogeny, and a four-stage evolutionary model for the ore deposit. This model is compatible with the history of other unconformity-type uranium deposits in the Athabasca Basin. The first stage in the evolution of the Cigar Lake uranium deposit is marked by uraninite crystallization at 1341 ± 17 Ma, which, in association with arsenides and sulfarsenides, constitutes the mineralization of economic interest (main orebody). The second stage, characterized by a Fe-kaolinite and Fe-illite paragenesis, occurred locally at about 900 Ma. The third stage involved uranium mobilization at about 325 Ma and is characterized by (i) preferential loss of radiogenic lead from primary uraninite and crystallization of pitchblende at the rims of uraninite grains and (ii) formation of pitchblende associated with Fe sulfides or hematite in the main and perched orebodies. The last stage is characterized by recent alteration and coffinitization which have affected all ore types. 40 refs., 8 figs., 3 tabs.

1157 Sm-Nd, Pb-Pb, and Rb-Sr systematics of the basement in the Cigar Lake area, Saskatchewan, Canada. Pagel, Maurice (Centre de Recherches sur la Geologie de l'Uranium (CREGU), 54 - Vandoeuvre-les-Nancy (France)); Juteau, Martine; Michard, Annie; Turpin, Laurent. *Canadian Journal of Earth Sciences;* 30(4): 731-742 (Apr 1993).

The Sm-Nd, Pb-Pb, and Rb-Sr isotope geochemistry of graphitic metapelitic gneisses and their altered equivalents from the Cigar Lake area (Saskatchewan, Canada) has been investigated. Some granitic gneisses were also analyzed for Pb-Pb and Rb-Sr. Sm-Nd data show that the metapelitic gneisses are composed of detritus from heterogeneous, mainly mantle-derived Archean rocks (2.5-2.6 Ga) and that the Sm-Nd system has not been significantly perturbed during subsequent alteration and metamorphic events. The Pb-Pb age for samples of the less altered graphitic metapelitic gneisses is 1.77 ± 0.03 Ga. The crustal common Pb is located on the Pb-Pb isochron, but there are different zones with high and variable U/Pb ratios (μ 15-280). The Pb-Pb age for the granitic gneisses is 1.79 ± 0.11 Ga. The Pb isotope data show that there has been no major uranium redistribution in the basement after the Hudsonian orogeny. However, there has been a strong perturbation of the U-Pb system in the regolithic zone beneath the Athabasca cover. In some samples, uranium was added during the mineralizing event. The Rb-Sr system in the graphitic metapelitic gneisses was also affected. The $^{87}Sr/^{86}Sr$ ratio in pitchblende is 0.709. At 1.3 Ga, there is a strong contrast between the $^{87}Sr/^{86}Sr$ ratio in the Athabasca sandstones (0.706-0.710) and the $^{87}Sr/^{86}Sr$ ratio in the metapelitic gneisses from the basement (0.725-0.775). The upper zone of the regolith is characterized by a low $^{87}Sr/^{86}Sr$ ratio (0.705-0.707). The Pb-Pb and Pb-Sr data are consistent with the circulation of a fluid with a low $^{87}Sr/^{86}Sr$ ratio, derived from sedimentary cover; this fluid passed through the most permeable zones of the basement rocks, especially the regolith. The mineralizing fluid had a $^{87}Sr/^{86}Sr$ value typical of a fluid in equilibrium with the Athabasca sandstones. 36 refs., 9 figs., 6 tabs.

1158 Characterization of graphite alteration and bitumen genesis in the Cigar Lake deposit (Saskatchewan, Canada). Landais, Patrick (Centre de Recherches sur la Geologie de l'Uranium (CREGU), 54 - Vandoeuvre-les-Nancy (France)); Dubessy, Jean; Dereppe, Jean-Marie; Philp, R.P. *Canadian Journal of Earth Sciences;* 30(4): 743-753 (Apr 1993).

Bitumens collected in the east zone of the Cigar Lake deposit have been analyzed by ^{13}C nuclear magnetic resonance, pyrolysis - gas chromatography, Rock-Eval, and elementary analysis. Carbon and hydrogen isotopic compositions and uranium contents have been determined. Results indicate that the bitumens consist mainly of aromatic structure, and have undergone a late oxidation process. Similarities in carbon isotopic composition between barren bitumens and graphite collected in the basement gneisses, as well as evidence for progressive disorganization of graphite along a basement profile, suggest a genetic relationship between graphite and bitumens from the mineralized areas. The presence of amorphous carbon in pit structures inside graphite flakes close to the unconformity

supports this assessment. Significant differences in geochemical and isotopic characteristics of Cigar lake barren bitumens and the Cluff Lake mineralized bitumens suggest that there are two possible mechanisms for their formation. Barren ^{13}C-enriched bitumens could have formed directly by hydrogenation of amorphous carbon, whereas mineralized, isotopically light bitumens from Cluff Lake may result from the polymerization of light hydrocarbons around uraninite grains. 41 refs., 9 figs., 5 tabs.

1159 Geochemistry of the waters associated with the Cigar lake uranium deposit (Saskatchewan, (CA)) and their uranium and lead isotope contents as guides for prospecting. Toulhoat, Pierre (CEA Centre d'Etudes de Fontenay-aux-Roses. Dept. Stockage Dechets, Fontenay-aux-Roses CEDEX (France)); Beaucaire, Catherine. *Canadian Journal of Earth Sciences;* 30(4): 754-763 (Apr 1993). (In French).

The primary objective of this study is to understand the chemical evolution of the waters crossing the Cigar Lake (Saskatchewan, Canada) uranium ore deposit, then to investigate the behavior of the lead and uranium isotopes, and to test their use as guides in exploration. The underground waters around the Cigar Lake ore deposit were sampled by pumping boreholes or by air lifting. Isotopic analyses of U and Pb and chemical analyses of the major elements and of some trace elements (Ba, Ra, U) were completed. Based on these results, a model is proposed to explain the genesis and evolution of the waters, and also to account for the water-minerals equilibria. 37 refs., 8 figs., 4 tabs.

1160 Draft report uges DOE to consider second waste repository. Lane, E. *Energy Daily;* 21(33): 4 (19 Feb 1993).

The permanent nuclear waste repository planned for Yucca Mountain, Nevada, cannot hold the projected spent fuel that will be generated by future nuclear plants and defense facilities so the Energy Department should consider a second repository now, according to an annotated outline of a draft report to Congress from the Office of Civilian Radioactive Waste Management discussed at a public meeting Wednesday. The report, required under Section 803 of the Energy Policy Act of 1992, is supposed to determine the adequacy of spent nuclear fuel and high-level radioactive waste management plans for future waste generation. The report is scheduled for completion Oct. 24.

1161 Technetium in nature and age of the solar system. Kuroda, P.K. *Radiochimica Acta;* 63: 9-18 (1993). (CONF-9303140--: Topical symposium on the behavior and utilization of technetium '93, Sendai (Japan), 18-20 Mar 1993).

The age of discovering new elements by artificial means began in 1937 when element 43, technetium, was discovered. It so happened, however, that technetium was found to occur in certain stars in 1952 and ^{99}Tc produced by the spontaneous fission of ^{238}U was found to occur in uranium-bearing minerals and ores such as pitchblende, in 1961. When the Oklo phenomenon was discovered in 1972, it became also apparent that a large quantity of ^{99}Tc existed in nature approximately 1,700 million years ago, when the pre-Fermi reactors were operating on the earth. Results from recent studies on the occurrences of technetium and another man-made element, plutonium, in nature indicate that the solar system began to form about 5,000 million years ago. (orig.)

1162 Geochemical behaviour of ^{99}Tc in the Oklo natural fission reactors. Hidaka, Hiroshi (Dept. of Chemistry, Faculty of Science, Tokyo Metropolitan Univ. (Japan)); Shinotsuka, Kazunori; Holliger, P. *Radiochimica Acta;* 63: 19-22 (1993). (CONF-9303140--: Topical symposium on the behavior and utilization of technetium '93, Sendai (Japan), 18-20 Mar 1993).

Ru isotopic ratios of five Oklo uranium ore samples were determined by inductively coupled plasma mass spectrometry (ICP-MS). We found fissiogenic Ru enriched metallic micro-inclusions in the samples, so in-situ isotopic measurements were performed by secondary ion mass spectrometry (SIMS). From the isotopic abundances of fissiogenic ^{99}Ru, the geochemical behaviour of ^{99}Tc in the Oklo natural reactors could be inferred. More ^{99}Ru has been enriched in metallic inclusions of the samples than in matrix uraninite grains. (orig.)

1163 Relationship of Superfund risk assessments to repository performance assessments. Avci, H.I. (Argonne National Lab., IL (United States)). *Transactions of the American Nuclear Society;* 69: 43-44 (1993). (CONF-931160--: American Nuclear Society (ANS) winter meeting, San Francisco, CA (United States), 14-18 Nov 1993).

There has been little or no interaction among the scientists performing risk assessments for Superfund sites and those conducting performance assessments for geologic repositories; however, there are enough similarities between the two types of assessments that it is worthwhile to examine how the repository performance assessments can benefit from the Superfund risk assessments. The evolving regulations for the repositories to be built and operated in the United States make the cross-over between the two assessments particularly apparent. In this paper, similarities and differences between the two types of assessments are examined, and suggestions are provided to improve communication among the analysts performing them.

1164 The Department of Energy's approach to high-level waste standards. Brocoum, S. (DOE, Washington, DC (United States)); Dyer, J.R. *Transactions of the American Nuclear Society;* 69: 86-87 (1993). (CONF-931160--: American Nuclear Society (ANS) winter meeting, San Francisco, CA (United States), 14-18 Nov 1993).

The U.S. Department of Energy (DOE) has the legal responsibility to (a) characterize the Yucca Mountain site to evaluate its suitability for a high-level radioactive waste repository and (b) develop and operate a repository if the site is suitable, if the recommendation of the site is approved by the President, and if the U.S. Nuclear Regulatory Commission (NRC) issues a construction authorization and a license to operate the repository and permanently dispose of waste. The DOE, as implementing agency, will bear the burden of proof in demonstrating compliance with the standards established by the US Environmental Protection Agency (EPA) and incorporated in the NRC's implementing rules and the DOE's siting guidelines.

1165 Effects of evaporation and solute concentration on presence and composition of water in and around the waste package at Yucca Mountain. Walton, J.C. (Southwest Research Inst., San Antonio, TX (United States). Center for Nuclear Waste Regulatory Analyses). *Waste Management;* 13(4): 293-301 (1993).

For the proposed repository at Yucca Mountain, the amount, timing, and expected composition of water contacting the waste package are major concerns. In the presence

of thermal loading from radioactive decay, a flow system is set up with water leaving as vapor and returning as liquid flowing through the matrix and fractures. A hypothesis is developed suggesting that most water in the vicinity of the waste package evaporates, leaving behind a scale deposit and concentrated solution. The vapor pressure lowering caused by the brine solution maintains a water film on the rock and waste package materials even in the presence of a dry environment with thermal gradients. The chemical environment within which container corrosion and spent fuel alteration occur is anticipated to be an initial period of concentrated brine, followed by solutions of lower ionic strength as the repository cools. The specific environment and timing could vary widely between different waste packages and within individual waste packages subsequent to container failure.

1166 Alternate conceptual model of ground water flow at Yucca Mountain. *Transactions of the American Nuclear Society;* 67(Suppl.1): 344-346 (1993). (CONF-920957--: 3. annual Nuclear Society International (NSI) meeting: nuclear technology tomorrow, St. Petersburg (Russian Federation), 14-18 Sep 1992).

Attempts to predict the performance of a high-level nuclear waste repository in the United States have lead to the development of alternative conceptual models of the ground watre flow field in which the repository will be located. This step has come about because of the lage uncertainties involved in predicting the movement of water and radionuclides through an unsaturated fractured rock. Further, one of the standards to which we are comparing performance is probabilistic, so we are forced to try to conceive of all credible scenarios by which ground water may intersect the repository horizon and perhaps transport radionuclides to a given compliance boundary. To simplify this task, the DOE set about identifying alternative conceptual models of ground water flow which are consistent with existing data. Modeling these concepts necessitates the use of simplifying assumptions. Among the modeling assumptions commonly utilized by analysts of the Yucca Mountain site are those of uniformly distributed, small volumes of recharge and matrix or porous media flow. Most scientists would agree that recharge at Yucca Mountain does not occur in this ideal and simplified fashion, yet modeling endeavors continue to commonly utilize this approach. In this paper, we examine the potential effects of focused recharge on the flow field at Yucca Mountain in concert with a fractured matrix and non-equilibrium view of ground water flow.

1167 Can you say 'N'? NIMBY, NWPA and nuclear Preemption. *Natural Resources Journal;* 33(2): 493-506 (Spr 1993).

In Nevada v. Watkins, the Ninth Circuit Court of Appeals upheld the constitutionality of the 1987 NWPA amendments, which enabled the continued site characterization of Yucca Mountain and thwarted Nevada's attempt to ban nuclear waste within its borders. The Watkins court ruled that Nevada's statute, which banned nuclear waste, was preempted by NWPA. Nevada, like many states has passed laws that limit the storage, transportation or disposal of nuclear waste within its state boundaries. These statutes will meet the same fate as the one struck down in the Watkins decision - that is, until states rights in the area of nuclear energy are clarified. This note examines Watkins' application of the preemption doctrine, as well as general preemption principles, to determine what avenues may still be open to states seeking to regulate the disposal of nuclear waste. The Watkins decision neither discussed the fully authority of NWPA nor defined the extent of the federal government's preemption of state regulation of nuclear waste disposal. However, Watkins seems to solidify the rationale of other recent court decisions holdings that Congress has occupied the nuclear-energy field. This interpretation could effectively eliminate any state regulatory power over the nuclear-energy field, including nuclear-waste disposal.

1168 Micromechanical modeling of tuffaceous rock for application in nuclear waste storage. Wang, R. (Arizona Univ., Tucson, AZ (United States). Dept. of Mining and Geological Engineering); Kemeny, J.M. *International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts;* 30(7): 1351-1357 (1993). Grant NSFSGP MSS9022381. (CONF-930644--: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993).

This paper describes the development of micromechanical models for tuffaceous rock. In particular, laboratory tests have been conducted on Topopah Spring tuff from Yucca Mountain, Nevada and Apache Leap tuff from Superior, Arizona. Topopah Spring tuff is the host rock for the proposed underground nuclear waste repository at Yucca Mountain, and Apache Leap tuff is an analog for the host rock. Based on SEM microscopy of the damaged rock specimens, the specific micro-mechanisms for deformation in tuffs have been determined. Micromechanical models based on fracture mechanics theory are then developed for these specific mechanisms. The micromechanical models are able to predict the nonlinear stress-strain behaviour of tuff, including strain-hardening, strain-softening, triaxial strength, and dilatation. (Author).

1169 In situ flow testing of a cement borehole seal in welded tuff. Crouthamel, D.R. (Stone and Webster Engineering Corp., Boston, MA (United States)); Fuenkajorn, K.; Daemen, J.J.K. *International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts;* 30(7): 1503-1506 (1993). (CONF-930644--: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993).

The experimental determination of the hydraulic conductivities of cement borehole plugs in welded tuffs and the effects of field installation and in-situ environment is described. The field results are compared with those from related laboratory experiments which give hydraulic conductivity values nearly two orders of magnitude lower. This improved performance in sealing characteristics is brought about by the controlled installation procedures and conditions in the laboratory. Seal performance can be improved in the field by developing controlled emplacement techniques and careful evaluation of site conditions preparation prior to installing the plug. (4 figures, 1 table, 14 references) (UK).

1170 Canada remains Western World's leading uranium supplier. *Canadian Energy News;* 7(23): 182-183 (1 Dec 1992).

Canada is the leading producer-exporter of uranium in the Western World, and hosts a significant portion of the global uranium exploration. Estimates of known uranium resources were 459,000 tU at the start of 1992, down over 20% from 1991. The decrease is mainly due to mine closures at Elliot Lake. Total shipments in 1991 approached 8,200 tU, valued at over $500 million. Actual exports were 7,810 tU. A major part of the $ 44 million spent on exploration in 1991 is accounted for by underground geotechnical testing at Cigar Lake.

1171 Trust as a determinant of opposition to a high-level radioactive waste repository: Analysis of a structural model. Flynn, J.; Burns, W.; Mertz, C.K.; Slovic, P. *Risk Analysis;* 12(3): 417-429 (Sep 1992).

Residents in the State of Nevada hold strong opinions about the federal government's proposal to site the nation's first high-level radioactive waste repository at Yucca Mountain. The model developed in this study is designed to examine the relationship between public perceptions of risk, trust in risk management, and potential economic impacts of the current repository program using a confirmatory multivariate method known as covariance structure analysis. The data used to test the model was collected in a 1989 statewide survey of Nevada residents. The results indicate that, for a statewide sample, perceptions of potential economic benefits do not have a significant role in predicting support or opposition to the repository program. On the other hand, risk perceptions and the level of trust in repository management are closely related to each other and to positions on Yucca Mountain. Trust directly influences risk perceptions which, in turn, have a direct effect on the attitude toward the repository, and an indirect effect through perceived stigma effects. 45 refs., 2 figs., 5 tabs.

1172 Fluid density and gravitational variations in deep boreholes and their effect on fluid potential. Oberlander, P.L. (Pacific Northwest Lab., Richland, WA (United States)). *Ground Water;* 27(3): 341-350 (May-Jun 1989).

As depth below the water table increases, there can be significant spatial variations in fluid density. Fluid density is a function of fluid temperature, total dissolved solids and gases content, fluid compressibility, and the force of gravity. Variations in fluid density can affect the applicability of measured water levels to represent fluid pressure at depth and the existence of a scalar fluid potential. Where ground water is sufficiently heterogeneous, fluid pressure and fluid density must be known spatially to properly determine the three-dimensional impelling force per unit mass $E = -[g_k + (1/\rho) \nabla P]$. Assuming that the water-level elevation in deep boreholes represents a fluid potential may result in significant errors in determining flow direction and quantities under conditions of a variable density fluid and low hydraulic gradients. Boreholes constructed to investigate the feasibility of deep geologic disposal of nuclear waste have penetrated to depths greater than 1,500 m below the Earth's surface. In these deep boreholes, fluid density variations may need to be considered as a part of the hydrologic analysis. Fluid density variations with depth, predicted as general cases based on simple models, indicate the relative importance of temperature, compressibility, and gravity variations at three potential high-level nuclear waste repository locations. Fluid density generally decreases with depth for sites where geothermal gradients are greater than 20° C/km, and thermal expansion can offset the effects of fluid compressibility.

1173 USA: Changes in DOE's High-Level Waste Program. *NUEXCO. Monthly Report to the Nuclear Industry;* (234): 26-27 (Feb 1988).

The search for an acceptable repository for high-level nuclear wastes in the USA may be nearing resolution, with the US Congress deciding on Yucca Mountain, Nevada as the probable site. In December 1987, members of key committees of the US House of Representatives and Senate agreed on a compromise package of amendments to the Nuclear Waste Policy Act (NWPA) that creates major changes in the US high-level waste disposal program, managed by DOE. President Reagan signed the bill on December 22, 1987. The recent amendments to the NWPA appear, at least for now, to have resolved the impasse in the attempt to find a solution to the nation's high-level nuclear waste accumulation, expected to exceed 40,000 tonnes of spent fuel by the year 2000. Whether the Nevada site will prove suitable, and whether legal challenges to the program can stall its progress and final implementation, will take considerable time to resolve. Although uncertainties remain, Congress has taken a significant step forward in nuclear waste policy.

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Vol.294	94:803	Materials Research Society, 9800 McKnight Road, Pittsburgh, PA 15237			ND-2070; ND-2030
CONF-9211338–		(Colloquium acts on atom and geology; Paris (France); 25-26 Nov 1992)			
	94:1136				
CONF-930205–		(Waste management '93; Tucson, AZ (United States); 28 Feb - 4 mar 1993)			
82	94:24	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94000976	MF-802
CONF-9303140–		(Topical symposium on the behavior and utilization of technetium '93; Sendai (Japan); 18-20 Mar 1993)			
	94:1161				
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CONF-9303214–		(National Social Science Association meeting; San Francisco, CA (United States); 31 Mar - 3 apr 1993)			
1	94:25	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE93018976	MF-814
CONF-930408–		(10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993)			
Vol.1	94:811	American Society of Civil Engineers, 345 East 47th Street, New York, NY 10017-2398.			
CONF-930644–		(34. US symposium on rock mechanics; Madison, WI (United States); 27-30 Jun 1993)			
	94:575				
	94:1168				
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Vol.2	94:927	*See* DOE/ER/14352–1			
CONF-930906–		('93 international conference on nuclear waste management and environmental remediation; Prague (Czech Republic); 5-11 Sep 1993)			
	94:1121				
CONF-9309146–		(5. annual American Chemical Society (ACS) Industrial and Engineering Chemistry (I&EC) Division special symposium on emerging technologies for hazardous waste management; Atlanta, GA (United States); 27-29 Sep 1993)			
7	94:528	*See* SAND–93-7116C			
CONF-9309228–		(Focus 93: site characterization and model validation; Las Vegas, NV (United States); 26-29 Sep 1993)			
5	94:292	*See* LA-UR–93-3691			
7	94:395	*See* UCRL-JC–114791			
8	94:514	*See* SAND–93-2507C			
10	94:659	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94014223	MF-814

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11	94:660	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94014850	MF-814
13	94:526	*See* SAND–93-7106C			
CONF-9309295–		(Nuclear as a large-scale global option conference; Oak Ridge, TN (United States); 28-30 Sep 1993)			
3	94:1049	*See* UCRL-JC–114686			
3-Rev.1	94:390	*See* UCRL-JC–114686-Rev.1			
CONF-930960–		(6. international conference on accelerator mass spectrometry; Canberra (Australia); 17 Sep - 1 oct 1993)			
	94:1125				
CONF-9310102–		(4. energy natural phenomena hazards mitigation conference; Atlanta, GA (United States); 19-22 Oct 1993)			
42	94:1050	*See* UCRL-JC–115255			
CONF-9310222–		(Seminar on physics of vapor explosion; Tomakomai (Japan); 25-29 Oct 1993)			
1	94:293	*See* LA-UR–93-3699			
CONF-9310276–		(8. wildland shrub and arid land restoration symposium; Las Vegas, NV (United States); 19-21 Oct 1993)			
1	94:157	*See* EGG–11265-2030			
2	94:158	*See* EGG–11265-2031			
3	94:156	*See* EGG–11265-2029			
5	94:152	*See* EGG–11265-1066			
7	94:160	*See* EGG–11265-2036			
12	94:159	*See* EGG–11265-2035			
CONF-9310364–		(Oklo meeting; Brussels (Belgium); 11-12 Oct 1993)			
	94:777	*See* CEA-CONF–11823			
CONF-9310378–		(Oklo Working Group Meeting; Bruxelles (Belgium); 11-12 Oct 1993)			
	94:776	*See* CEA-CONF–11814			
CONF-931108–		(Fall meeting of the Materials Research Society (MRS); Boston, MA (United States); 29 Nov - 3 dec 1993)			
94	94:401	*See* UCRL-JC–115734			
Vol.333	94:839	Materials Research Society, 9800 McKnight Road, Pittsburgh, PA 15237			ND-2070; ND-2030
CONF-931160–		(American Nuclear Society (ANS) winter meeting; San Francisco, CA (United States); 14-18 Nov 1993)			
	94:171				
	94:574				
	94:1163				
	94:1164				
CONF-931201–		(4. international conference on chemistry and migration behavior of actinides and fission products in the geosphere; Charleston, SC (United States); 12-17 Dec 1993)			
	94:312				
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3	94:294	*See* LA-UR–93-3992			
6	94:988	*See* LA-UR–93-4253			
CONF-9402115–		(2. international workshop on design and construction on final repositories; Winnepeg (Canada); 15-17 Feb 1994)			
1	94:58	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95003024	MF-814
CONF-940225–		(Waste management '94: working towards a cleaner environment; Tucson, AZ (United States); 27 Feb - 3 mar 1994)			
112	94:151	*See* EGG–11265-1058			
Vol.1	94:845	Laser Options, Inc., 245 S. Plumer, Suite 19, Tucson, AZ 85719 (United States)			ND-940
CONF-940416–		(96. annual meeting of the American Ceramic Society (ACS); Indianapolis, IN (United States); 25-28 Apr 1994)			
7	94:318	*See* ANL/CMT/CP–81047			

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CONF-940506–		(8. international conference on computer methods and advances in geomechanics; Morgantown, WV (United States); 22-28 May 1994)			
3	94:507	*See* SAND–93-0817C			
CONF-9405191–		(Scanning microscopy conference; Toronto (Canada); 7-19 May 1994)			
1	94:300	*See* LA-UR–94-1613			
CONF-940538–		(48. annual quality congress; Las Vegas, NV (United States); 24-26 May 1994)			
3	94:296	*See* LA-UR–94-921			
CONF-940553–		(International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994)			
5	94:523	*See* SAND–93-4097C			
8	94:1039	*See* SAND–93-2240C			
9	94:402	*See* UCRL-JC–115798			
100	94:676	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001466	MF-814
101	94:677	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001467	MF-814
13	94:295	*See* LA-UR–94-640			
15	94:394	*See* UCRL-JC–114790			
18	94:531	*See* SAND–94-0185			
20	94:533	*See* SAND–94-0207C			
22	94:391	*See* UCRL-JC–114776			
23	94:1051	*See* UCRL-JC–116349			
26	94:518	*See* SAND–93-3903C			
27	94:299	*See* LA-UR–94-1071			
28	94:535	*See* SAND–94-0261C			
30	94:520	*See* SAND–93-4002C			
31	94:297	*See* LA-UR–94-925			
33	94:319	*See* ANL/CMT/CP–81910			
35	94:396	*See* UCRL-JC–115230			
39	94:404	*See* UCRL-JC–116315			
41	94:541	*See* SAND–94-0343C			
42	94:542	*See* SAND–94-0348C			
44	94:522	*See* SAND–93-4045C			
45	94:543	*See* SAND–94-0351C			
46	94:547	*See* SAND–94-0443C			
47	94:365	*See* LBL–35186			
48	94:406	*See* UCRL-JC–116357			
52	94:59	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94012149	MF-814
53	94:60	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94012152	MF-814
57	94:61	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94012156	MF-814
62	94:602	*See* LBL–35560			
63	94:600	*See* LBL–35388			
64	94:529	*See* SAND–94-0087C			
65	94:540	*See* SAND–94-0326C			
66	94:530	*See* SAND–94-0155C			
67	94:661	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94013978	MF-814
68	94:545	*See* SAND–94-0414C			
71	94:371	*See* PNL-SA–23748			
73	94:393	*See* UCRL-JC–114786			
74	94:405	*See* UCRL-JC–116350			
76	94:392	*See* UCRL-JC–114784			
77	94:403	*See* UCRL-JC–116147			
78	94:537	*See* SAND–94-0305C			
81	94:398	*See* UCRL-JC–115351			
82	94:399	*See* UCRL-JC–115352			
83	94:372	*See* PNL-SA–23965			
84	94:539	*See* SAND–94-0323C			
85	94:662	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001451	MF-814
86	94:663	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001452	MF-814
87	94:664	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001453	MF-814
88	94:665	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001454	MF-814
89	94:666	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001455	MF-800
90	94:667	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001456	MF-814
91	94:668	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001457	MF-814
92	94:669	OSTI; NTIS; GPO Dep.	E 1.99:	DE96001458	MF-800
93	94:670	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001459	MF-814
95	94:671	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001461	MF-814
96	94:672	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001462	MF-814

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97	94:673	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001463	MF-814
98	94:674	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001464	MF-814
99	94:675	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001465	MF-814
CONF-9406262–		(North American tunneling conference and exhibition; Denver, CO (United States); 6-9 Jun 1994)			
1	94:549	*See* SAND–94-0712C			
CONF-9406334–		(Conference on plutonium in nature; Pierrelatte (France); 24 Jun 1994)			
	94:778	*See* CEA-CONF–11972			
CONF-940642–		(1. North American rock mechanics symposium; Austin, TX (United States); 1-3 Jun 1994)			
6	94:538	*See* SAND–94-0306C			
CONF-9407103–		(International conference on accelerator-driven transmutation technologies and applications; Las Vegas, NV (United States); 25 Jul - 1 aug 1994)			
	94:990	*See* LA-UR–95-1792			
CONF-940815–		(SPECTRUM '94: international nuclear and hazardous waste management conference; Atlanta, GA (United States); 14-18 Aug 1994)			
71	94:550	*See* SAND–94-1370C			
75	94:400	*See* UCRL-JC–115613			
93	94:891	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94018138	MF-814
CONF-9409231–		(NEA workshop on binding models concerning natural organic substances in performance assessment; Bad Zurach (Switzerland); 14-16 Sep 1994)			
1	94:302	*See* LA-UR–94-3303			
CONF-9409238–		(Workshop on rock mechanics; Rockville, MD (United States); 19-20 Sep 1994)			
1	94:556	*See* SAND–94-2243C			
2	94:559	*See* SAND–94-2339C			
CONF-940985–		(American Society for Quality Control Energy and Environmental Quality Division conference; Tucson, AZ (United States); 18-21 Sep 1994)			
1	94:298	*See* LA-UR–94-1038			
4	94:548	*See* SAND–94-0668C			
CONF-941075–		(18. international symposium on the scientific basis for nuclear waste management; Kyoto (Japan); 23-27 Oct 1994)			
1	94:301	*See* LA-UR–94-2891			
3	94:409	*See* UCRL-JC–116431			
4	94:411	*See* UCRL-JC–116436			
5	94:410	*See* UCRL-JC–116435			
7	94:408	*See* UCRL-JC–116429			
CONF-941088–		(Annual meeting of the Geological Society of America; Seattle, WA (United States); 24-27 Oct 1994)			
2	94:1017	*See* LA-UR–95-2086			
CONF-941102–		(Winter meeting of the American Nuclear Society (ANS); Washington, DC (United States); 13-18 Nov 1994)			
	94:234				
	94:424				
	94:1134				
CONF-941207–		(Spent nuclear fuel meeting: challenges and initiatives; Salt Lake City, UT (United States); 14-16 Dec 1994)			
33	94:320	*See* ANL/CMT/CP–83895			
CONF-950216–		(Waste management '95; Tucson, AZ (United States); 26 Feb - 2 mar 1995)			
59	94:1040	*See* SAND–94-2348C			
76	94:1042	*See* SAND–95-0271C			
CONF-9503110–		(TOUGH 95: transport of unsaturated ground water and heat workshop; Berkeley, CA (United States); 20-22 Mar 1995)			
	94:611	*See* LBL–37200			
CONF-9503116–		(1995 TOUGH workshop; Berkeley, CA (United States); 20-22 Mar 1995)			
7	94:609	*See* LBL–36872			

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CONF-950401–		(97. annual meeting of the American Ceramic Society; Cincinnati, OH (United States); 30 Apr - 1 may 1995)			
13	94:321	*See* ANL/CMT/CP–84524			
20	94:322	*See* ANL/CMT/CP–84591			
CONF-9504148–		(Institute of shaft drilling technology annual technical conference; Las Vegas, NV (United States); 24-27 Apr 1995)			
1	94:306	*See* LA-UR–95-1286			
CONF-9504179–		(6. annual international conference on high level radioactive waste management; Las Vegas, NV (United States); 30 Apr - 5 may 1995)			
2	94:373	*See* PNL-SA–26209			
4	94:606	*See* LBL–36527			
CONF-950435–		(2. international conference on mechanics of jointed and faulted rock; Vienna (Austria); 10-14 Apr 1995)			
1	94:397	*See* UCRL-JC–115341			
2	94:407	*See* UCRL-JC–116418			
CONF-9505188–		(1995 American Institute of Hydrology annual meeting; Denver, CO (United States); 14-18 May 1995)			
1	94:304	*See* LA-UR–95-572			
CONF-950570–		(International high-level radioactive waste management conference: progress toward understanding; Las Vegas, NV (United States); 1-5 May 1995)			
1	94:303	*See* LA-UR–94-3820			
2	94:417	*See* UCRL-JC–119131			
3	94:412	*See* UCRL-JC–118689			
9	94:415	*See* UCRL-JC–119119			
16	94:414	*See* UCRL-JC–119116			
18	94:416	*See* UCRL-JC–119121			
20	94:413	*See* UCRL-JC–119106			
21	94:99	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95012123	MF-814
23	94:100	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95012996	MF-802
24	94:101	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95013014	MF-814
25	94:220	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95012255	MF-814
28	94:323	*See* ANL/CMT/CP–84720			
30	94:327	*See* ANL/RA/SUMM–85653			
CONF-9506204–		(1995 rapid excavation and tunneling conference; San Francisco, CA (United States); 18-21 Jun 1995)			
1	94:102	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95014249	MF-814
CONF-950655–		(35. US symposium on rock mechanics; South Lake Tahoe, NV (United States); 4-7 Jun 1995)			
1	94:561	*See* SAND–94-2384C			
7	94:565	*See* SAND–94-2970C			
CONF-950868–		(ER '95: environmental remediation conference: committed to results; Denver, CO (United States); 13-18 Aug 1995)			
3	94:1052	*See* UCRL-JC–120389			
CONF-950888–		(International symposium on water-rock interaction; Vladivostok (Russian Federation); 13-28 Aug 1995)			
1	94:305	*See* LA-UR–95-871			
CONF-9509100–		(5. international conference on nuclear criticality safety; Albuquerque, NM (United States); 17-22 Sep 1995)			
4	94:1043	*See* SAND–95-1270C			
CONF-9509121–		(Characterizations of long term geological changes being considered for disposal sites; Paris (France); 19-21 Sep 1995)			
1	94:717	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95009558	MF-814
CONF-9509200–		(International congress on rock mechanics; Tokyo (Japan); 25-30 Sep 1995)			
1	94:418	*See* UCRL-JC–119574			

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CONF-9510171–		(PMI '95: Project Management Institute conference; New Orleans, LA (United States); 13-19 Oct 1995)			
1	94:566	*See* SAND–94-3249C			
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95007796	94:922	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95007796	MF-810
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94.031	94:934	Available from the British Library Document Supply Centre, Boston Spa, Wetherby, West Yorks. LS23 7BQ			
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0203-D-Vol.1-App.F	94:924	OSTI; NTIS; INIS; GPO; GPO Dep.	E 1.99:	DE94014155	MF-630
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1	94:927	OSTI; NTIS; GPO Dep.	E 1.99:	DE94014602	MF-403
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94002466	94:932	OSTI; NTIS (US Sales Only); GPO Dep.	E 1.99:	DE94002466	MF-814
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28-Add.2	94:938	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94005932	MF-702
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49	94:939	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95006253	MF-703
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1	94:940	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94004562	MF-814
2	94:941	OSTI; NTIS; GPO Dep.	E 1.99:	DE94004563	MF-814
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4	94:132	OSTI; NTIS; GPO Dep.	E 1.99:	DE94014166	MF-814
5	94:133	OSTI; NTIS; GPO Dep.	E 1.99:	DE95001321	MF-814

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6	94:134	OSTI; NTIS; GPO Dep.	E 1.99:	DE95005122	MF-814
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T4	94:135	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95008139	MF-814
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3406(Suppl.4)	94:137	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94005360	PC-814
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3406-(Suppl.3)(Add.3)	94:136	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE93015389	PC-814
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0434	94:143	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94008654	MF-800
0441	94:945	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94015371	MF-810
0448	94:946	OSTI; INIS; OSTI (Free of Charge)		TI95001363	MF-800
0449	94:947	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95003292	
0450	94:144	OSTI (Free of Charge); INIS		TI95001712	MF-814
0460	94:948	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95008452	MF-800
0463	94:145	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95010517	MF-814
0464	94:949	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95013657	MF-800
0476	94:950	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95017244	MF-800
0477	94:146	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96000156	MF-814
0478	94:951	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95017242	MF-810
0481	94:952	OSTI; NTIS; GPO Dep.	E 1.99:	DE96002257	MF-800
95014715	94:147	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95014715	MF-814
DOE/RW/00134–					
T10	94:224	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94015897	MF-814
T11	94:225	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94015954	MF-814
T12	94:226	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94015955	MF-814
T14	94:227	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95002190	MF-814
T15-Vol.1-Rev.1	94:228	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95006912	MF-814
T15-Vol.2-Rev.1	94:229	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95006913	MF-814
T16	94:230	OSTI; NTIS; GPO Dep.	E 1.99:	DE95007580	MF-814
T17	94:231	OSTI; NTIS; GPO Dep.	E 1.99:	DE95013073	MF-814
T18	94:232	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95013302	MF-820
T19	94:142	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95015529	MF-814
T5	94:221	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94004175	MF-814
T6	94:222	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94004174	MF-814
T7	94:140	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94005462	MF-814
T8	94:223	OSTI; NTIS; GPO Dep.	E 1.99:	DE94008425	MF-800
T9	94:141	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94010427	MF-814
DOE/RW/00286–					
3	94:944	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94011159	MF-820
DOE/YMPO–					
001	94:148	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94014099	MF-814
DOE/YMSCO–					
002	94:149	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95009812	MF-814
003	94:150	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001065	MF-814
EGG–					
11265-1058	94:151	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94012670	MF-802
11265-1066	94:152	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94012666	MF-802
11265-1073	94:153	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94016797	MF-708
11265-1118	94:154	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96000185	MF-702
11265-1136	94:155	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96000155	MF-814
11265-2029	94:156	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94006476	MF-702
11265-2030	94:157	OSTI; NTIS; GPO Dep.	E 1.99:	DE94006475	MF-702
11265-2031	94:158	OSTI; NTIS; GPO Dep.	E 1.99:	DE94006482	MF-702
11265-2035	94:159	OSTI; NTIS; GPO Dep.	E 1.99:	DE95004166	MF-702
11265-2036	94:160	OSTI; NTIS; GPO Dep.	E 1.99:	DE94013571	MF-702
EPRI-TR–					
104012	94:953	EPRI Distribution Center, 207 Coggins Drive, PO Box 23205, Pleasant Hill, CA 94523 (United States)			
ESTSC–					
000324SUN0003	94:364	ESTSC; Lawrence Livermore National Lab			
EUR–					
14877	94:954	OSTI; NTIS (US Sales Only); INIS		TI94612684	
FRCEA-TH–					
486	94:972	OSTI; NTIS; INIS		DE95631542	
INIS-XN–					
505	94:984	OSTI; NTIS (US Sales Only); INIS		DE94629680	
INIS-mf–					
14377	94:976	OSTI; NTIS (US Sales Only); INIS		DE95606001	

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14378	94:977	OSTI; NTIS (US Sales Only); INIS		DE95606009	
14379	94:978	OSTI; NTIS (US Sales Only); INIS		DE95606010	
14380	94:979	OSTI; NTIS (US Sales Only); INIS		DE95605960	
14381	94:980	OSTI; NTIS (US Sales Only); INIS		DE95605961	
14382	94:981	OSTI; NTIS (US Sales Only); INIS		DE95605962	
14383	94:982	OSTI; NTIS (US Sales Only); INIS		DE95605963	
14384	94:983	OSTI; NTIS (US Sales Only); INIS		DE95605964	
JAB–					
10733-TM12	94:985	OSTI; NTIS; GPO Dep.	E 1.99:	DE94001371	MF-703
JAERI-M–					
94-061	94:986	OSTI; NTIS; INIS		DE94785243	
LA–					
11844-MS	94:261	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95005745	MF-814
12411-SR	94:262	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94008703	MF-802; MF-814
12563-MS	94:263	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94008790	MF-802
12573-MS	94:264	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95011012	MF-814
12596-MS	94:265	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94004880	MF-814
12652-MS	94:266	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94005018	MF-814
12703-SR	94:267	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94007726	MF-810
12707-MS	94:268	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95016381	MF-802
12720-MS	94:269	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94008780	MF-814
12779-MS	94:270	OSTI; NTIS; GPO Dep.	E 1.99:	DE95010558	MF-802
12780-MS	94:271	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94012370	MF-802
12803-MS	94:272	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95010669	MF-802
12810-MS	94:273	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95008371	MF-802
12820-MS	94:274	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94016957	MF-802
12824-MS	94:275	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95015063	MF-802
12886-MS	94:276	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95012118	MF-814; MF-802
12894-MS	94:277	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95007726	MF-802
12897-MS	94:278	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95008109	MF-801; MF-802
12905-SR	94:279	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95015021	MF-814
12908-MS	94:280	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95009090	MF-802
12917-PR	94:281	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95007675	MF-702; MF-721
12968-MS	94:987	OSTI; NTIS; GPO Dep.	E 1.99:	DE96000894	MF-2070
13004-T	94:282	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95016706	MF-802
13036-MS	94:283	OSTI; NTIS; GPO Dep.	E 1.99:	DE96000885	MF-903
LA-SUB–					
94-109	94:286	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94017065	MF-802
94-111	94:287	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94016570	MF-814
94-159	94:288	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95001752	MF-801
94-34	94:284	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94017049	MF-801
94-92	94:285	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94017052	MF-814
95-36-Vol.2	94:289	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95013477	MF-814
95-41	94:290	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95012085	MF-814
95-73	94:291	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95014568	MF-814
LA-UR–					
93-3691	94:292	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94002699	MF-814
93-3699	94:293	OSTI; NTIS; GPO Dep.	E 1.99:	DE94002698	MF-703
93-3992	94:294	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94003956	MF-721
93-4253	94:988	OSTI; INIS; NTIS; GPO Dep.	E 1.99:	DE94004989	MF-802; MF-402
94-1038	94:298	OSTI; NTIS; GPO Dep.	E 1.99:	DE94009337	MF-800
94-1071	94:299	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94009332	MF-814
94-1613	94:300	OSTI; NTIS; GPO Dep.	E 1.99:	DE94014807	MF-802
94-2245	94:989	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94016080	MF-814
94-2891	94:301	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94018318	MF-814; MF-802; MF-810
94-3303	94:302	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95000843	MF-814
94-3820	94:303	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95003692	MF-814
94-640	94:295	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94007559	MF-810
94-921	94:296	OSTI; NTIS; GPO Dep.	E 1.99:	DE94009358	MF-800
94-925	94:297	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94009360	MF-814
95-1286	94:306	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95010890	MF-802; MF-814
95-1792	94:990	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95014018	MF-414

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95-2086	94:1017	OSTI; NTIS; GPO Dep.	E 1.99:	DE95015300	MF-403
95-572	94:304	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95007886	MF-802
95-871	94:305	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95009430	MF-814
LBL–					
35186	94:365	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94011350	MF-810
35381	94:162	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94011016	MF-814
35388	94:600	OSTI; NTIS; GPO Dep.	E 1.99:	DE94013097	MF-900
35518	94:601	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94015159	MF-1240; MF-814
35560	94:602	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94013105	MF-800
35976	94:603	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95004815	MF-800
36235	94:604	OSTI; NTIS (documentation only); ESTSC (complete software package), P.O. Box 1020, Oak Ridge, TN 37831-1020 (United States); GPO Dep.	E 1.99:	DE96000874	MF-814; MF-1240
36467	94:605	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95006724	MF-814
36527	94:606	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95016455	MF-814
36614	94:607	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95006723	MF-814
36807	94:608	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95012438	MF-814
36872	94:609	OSTI; NTIS; GPO Dep.	E 1.99:	DE95012392	MF-814
37018	94:610	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95016523	MF-814
37200	94:611	OSTI; NTIS; GPO Dep.	E 1.99:	DE95014788	MF-1240
37332	94:616	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95015139	MF-814
37356	94:617	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96000149	MF-814
37492	94:618	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96001002	MF-814
LLNL–					
95012992	94:366	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95012992	MF-814
MIC–					
94-04011/XAB	94:1021	NTIS Prices: PC E07/MF E02			
95-00953/XAB	94:1022	NTIS Prices: PC E19/MF E01			
NAGRA-NTB–					
93-03.	94:1059				
NUREG–					
1464	94:1023	OSTI; NTIS; INIS; GPO		TI96001786	
NUREG/CR–					
6203	94:1024	OSTI; NTIS; INIS; GPO		TI94017979	
6221	94:1025	OSTI; NTIS; GPO; INIS		TI95004333	
6288	94:1026	OSTI; NTIS; GPO; INIS		TI95004715	
6308	94:1027	OSTI; NTIS; GPO		TI95014938	MF-900
6347	94:1028	OSTI; NTIS; INIS; GPO		TI95016096	
6356	94:1029	OSTI; NTIS; INIS; GPO		TI95017371	
PB–					
94-113636/XAB	94:1030	NTIS Prices: PC A03/MF A01; INIS			
94-116886/XAB	94:1031	NTIS Prices: PC A03/MF A01; INIS			
94-174133/XAB	94:1032	NTIS Prices: PC A09/MF A02; INIS			
PNL–					
8659	94:1033	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94004566	MF-810
8853	94:1034	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94004586	MF-810
9414	94:367	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94013744	MF-814
9415	94:1035	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94013957	MF-802
9416	94:368	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94013863	MF-802
9418	94:369	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94013956	MF-814
9788	94:370	OSTI; NTIS; GPO Dep.	E 1.99:	DE94014218	MF-814
PNL-SA–					
23748	94:371	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94014413	MF-812
23965	94:372	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95007260	MF-820
26209	94:373	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95014620	MF-814
RIVM–					
715206005	94:1036	Available from RIVM, P.O. Box 1, 3720 BA Bilthoven (Netherlands)			
725206010	94:1037	Available from RIVM, P.O. Box 1, 3720 BA Bilthoven (Netherlands)			
SAIC–					
94-001	94:164	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95012990	MF-810
94-002	94:165	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95012991	MF-810
SAND–					
91-1653	94:499	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94001779	MF-814
92-0119	94:500	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94011000	MF-814
92-0449	94:501	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94008700	MF-814

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92-0847	94:502	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94017498	MF-814
92-0984	94:1038	OSTI; NTIS; GPO Dep.	E 1.99:	DE94003312	MF-703
92-2186	94:503	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95009315	MF-814
92-2248	94:504	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94006117	MF-814
92-2333	94:505	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94009248	MF-814
92-2625	94:506	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94007582	MF-814
93-0817C	94:507	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94005270	MF-802
93-0852	94:508	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94003314	MF-814
93-1157	94:509	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95001114	MF-814
93-1182	94:510	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94005956	MF-814
93-1184	94:511	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94015043	MF-814
93-1891	94:512	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94014302	MF-814
93-2240C	94:1039	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94006583	MF-702; MF-721
93-2365	94:513	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95000709	MF-814
93-2507C	94:514	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94005249	MF-802
93-2675	94:515	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94012995	MF-814
93-2675-Vol.1	94:516	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94013818	MF-814
93-2675-Vol.2	94:517	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94013819	MF-814
93-3903C	94:518	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94008953	MF-814
93-3997	94:519	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95008439	MF-814
93-4002C	94:520	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94009287	MF-814
93-4020	94:521	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95004385	MF-814
93-4045C	94:522	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94010395	MF-814
93-4097C	94:523	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94005588	MF-814
93-7079	94:524	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94013363	MF-814
93-7081	94:525	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95010513	MF-814
93-7106C	94:526	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95003351	MF-814
93-7109	94:527	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95004269	MF-814
93-7116C	94:528	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94004694	MF-814
94-0087C	94:529	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94014184	MF-814
94-0155C	94:530	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94014177	MF-814
94-0185	94:531	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94008612	MF-814
94-0189	94:532	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95017630	MF-814
94-0207C	94:533	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94008956	MF-814
94-0244	94:534	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96000699	MF-814
94-0261C	94:535	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94009282	MF-814
94-0278	94:536	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95001856	MF-814
94-0305C	94:537	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94015280	MF-814
94-0306C	94:538	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94014176	MF-814
94-0323C	94:539	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95014216	MF-802; MF-814
94-0326C	94:540	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94014178	MF-814
94-0343C	94:541	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94010389	MF-814
94-0348C	94:542	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94010386	MF-814
94-0351C	94:543	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94010380	MF-814
94-0379	94:544	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95013836	MF-814
94-0414C	94:545	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94014179	MF-814
94-0437	94:546	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE96000207	MF-814
94-0443C	94:547	OSTI; NTIS; GPO Dep.	E 1.99:	DE94010754	MF-814
94-0650	94:1025	*See* NUREG/CR–6221			
94-0668C	94:548	OSTI; NTIS; GPO Dep.	E 1.99:	DE94015738	MF-800
94-0712C	94:549	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94019183	MF-814
94-1370C	94:550	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE94015750	MF-814
94-1941	94:551	OSTI; NTIS; INIS; GPO Dep.	E 1.99:	DE95016953	MF-814
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