U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

NUCLEAR WASTE TECHNICAL REVIEW BOARD
FULL BOARD MEETING

SUBJECT: WASTE CONTAINMENT AND ISOLATION STRATEGY FOR THE YUCCA MOUNTAIN SITE

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ARLINGTON, VIRGINIA
OCTOBER 17-18, 1995

Background and Perspective

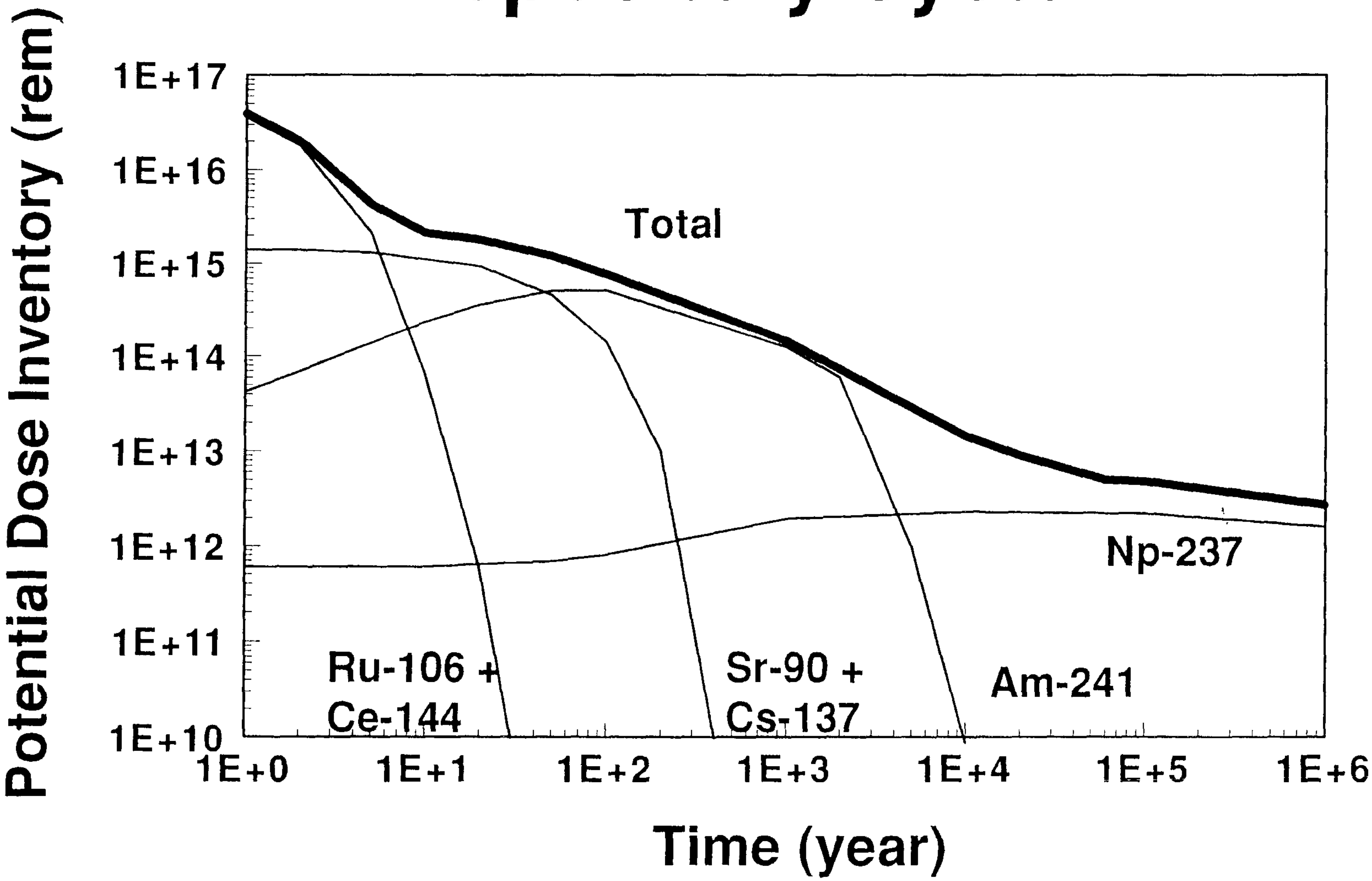
Background

- Times have changed
  - Long-term effects more important--diminishes ability to rely on delay in transport time
  - Evaluation of doses requires information about aquifers
  - Change in approach
- DOE direction for the strategy document
  - Describe elements of the strategy and current understanding
  - Define hypotheses to be evaluated

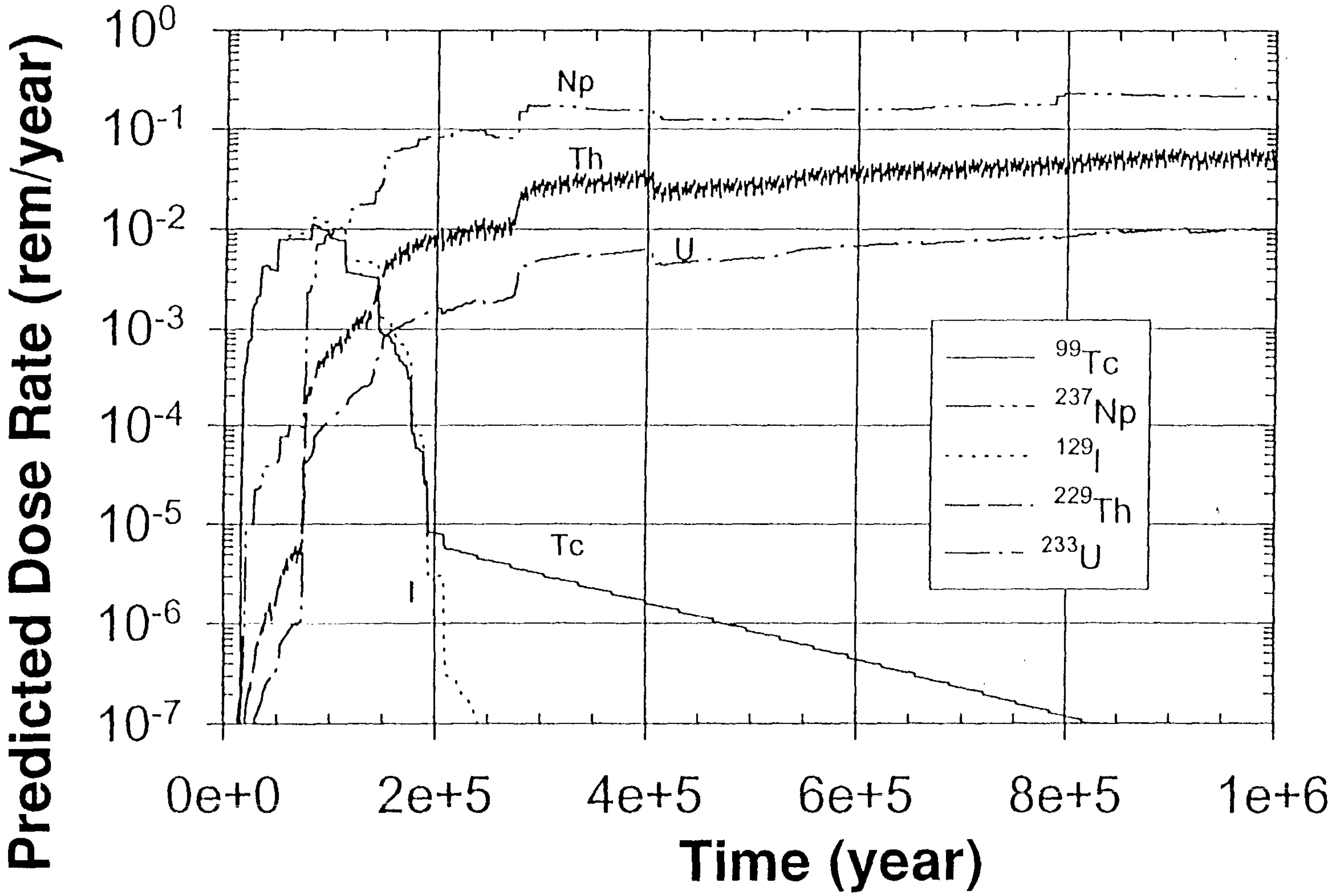
Strategy Focuses on Two Objectives

- **Limit annual dose to member of the general public**
  - Strategy describes how seepage in emplacement drifts, containment time, waste mobilization rates, effectiveness of engineered barriers, and dilution will be tested
- **Containment of waste for thousands of years during high-inventory/high-temperature period**
  - Strategy describes how dry conditions in the repository and low container corrosion rates will be tested

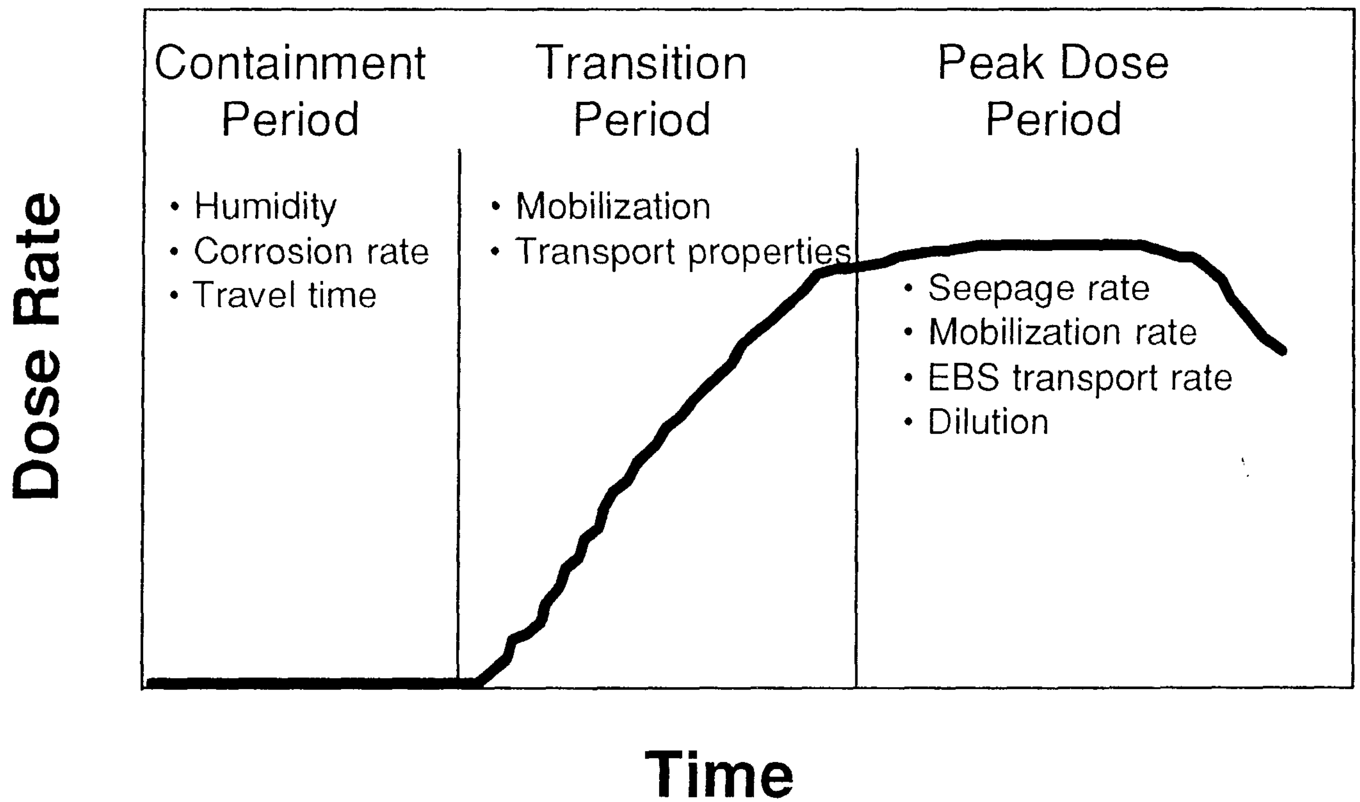
Radionuclide Burden For the Repository System



TSPA 95 -- Dose at Accessible Environment



Key Attributes Affecting Performance



Hypotheses For This Strategy

1 Seepage contacting waste will be low

2 Dry conditions will lead to containment for thousands of years

3 Waste mobilization rates will be low

4 Engineered barriers will limit rate of release to a low value

5 Concentrations will be strongly diluted during transport in natural barriers

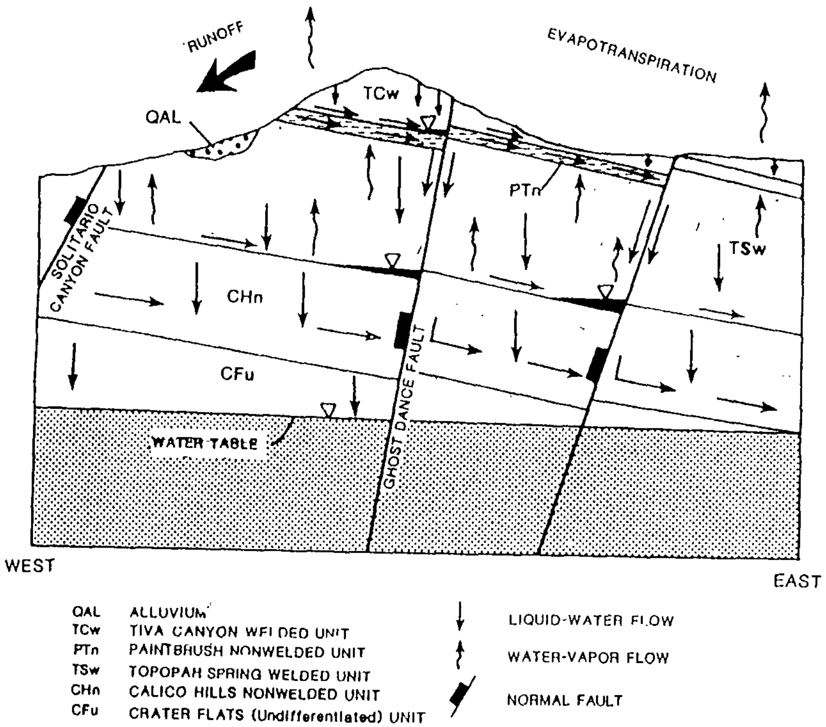
Strategy Also Addresses Cross-Cutting Issues

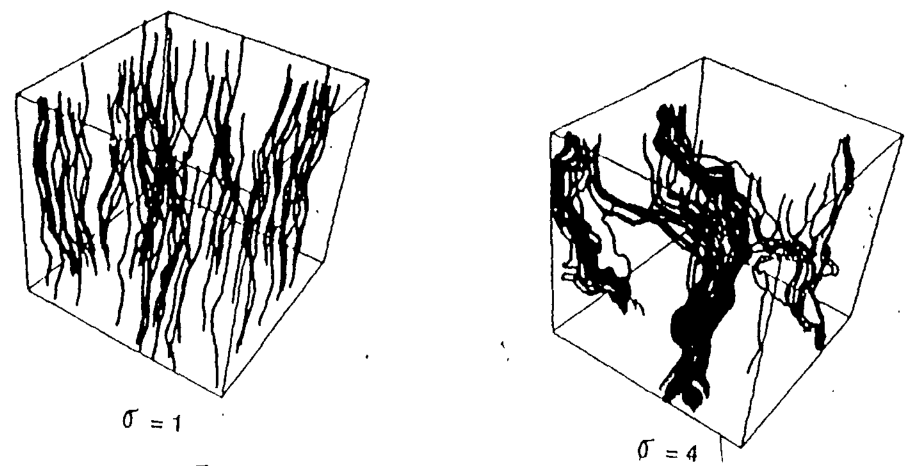
- Impacts of climate change on hydrology are covered in hypotheses and associated testing and modeling
- Effects of heat are addressed by thermal testing and modeling
- Potential effects of disruptive processes and events are also addressed
  - Tectonics and seismicity
  - Volcanism
  - Human interference

Format for Reviewing Hypotheses

- Basis for hypotheses
- Observations/analyses needed to resolve remaining questions

Seepage Into Drifts





σ: standard deviation of the logarithm of permeability

Large-Scale Conceptual Model

Small-Scale Conceptual Model

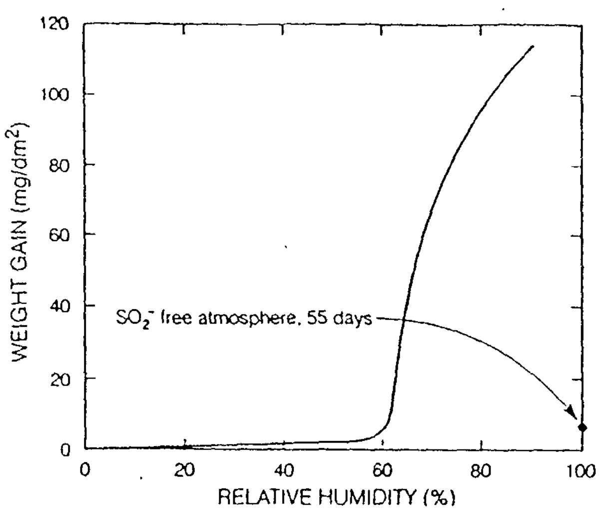
Hypothesis 1--Seepage Into Drifts
What Current Information Tells Us

- Seepage rate affects containment, mobilization, transport in engineered barriers, degree of dilution
- Average flux at repository horizon likely to be low (< 1 mm/yr)
- Localization may occur but may not be disadvantageous (WEEPS model analysis)
- No dripping observed in ramp so far

Hypothesis 1--Seepage Into Drifts
Work Needed To Test Hypothesis

- Synthesis of existing borehole data
- Observations in ESF
  - Inflow rates
  - Moisture content of near-field rock
  - Humidity in drift and host rock
- Large-scale and small-scale flow modeling (e.g., effects of heterogeneity, climate, thermal effects)
- Modeling to determine conditions under which seepage would be too high

Containment



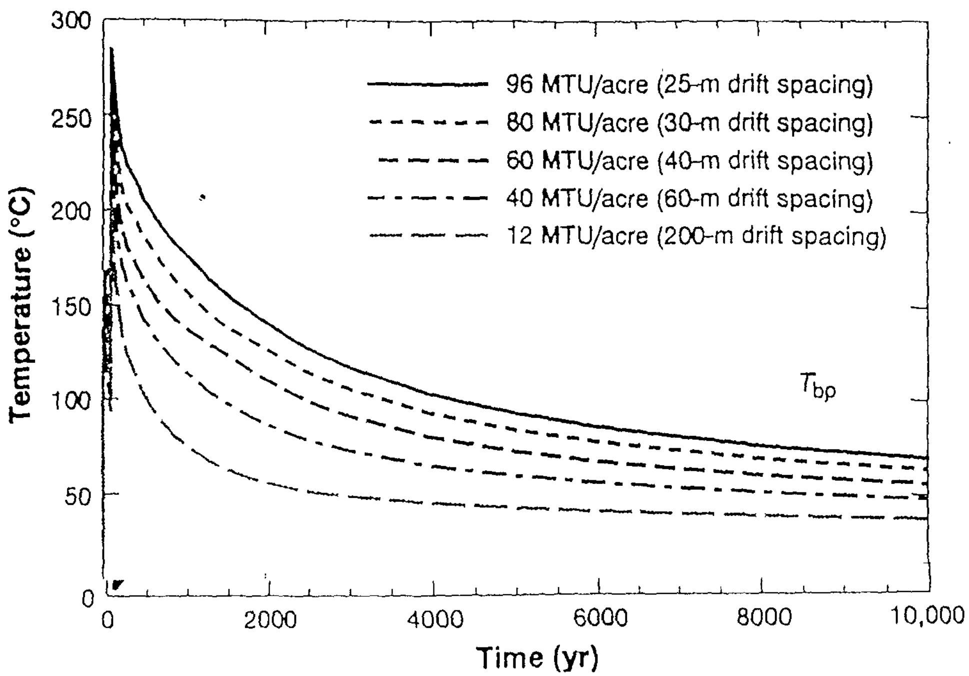
Salt Used	RH_{crit}	Relative Humidity, % 100	90	80	70	60	50
$Na_2SO_4 \cdot 10H_2O$	93	*	∘	∘	∘	∘	∘
KCl	86	*	*	×	∘	∘	∘
NaCl	78	*	*	*	×	∘	∘
$NaNO_3$	77	*	*	*	∘	∘	∘
$NaNO_2$	66	+	+	+	+	∘	∘
$NaBr \cdot 2H_2O$	59	*	*	*	*	*	∘
$NaI \cdot 2H_2O$	43	*	*	*	*	*	*
$LiCl \cdot H_2O$	15	*	*	*	*	*	*

* Salt coating is moist; underlying rust and attack of the steel.
× Salt coating colored brown at edge; underlying attack of the steel.
\+ Salt coating converted to colorless solution; no corrosion.
∘ Salt coating is dry; no corrosion.

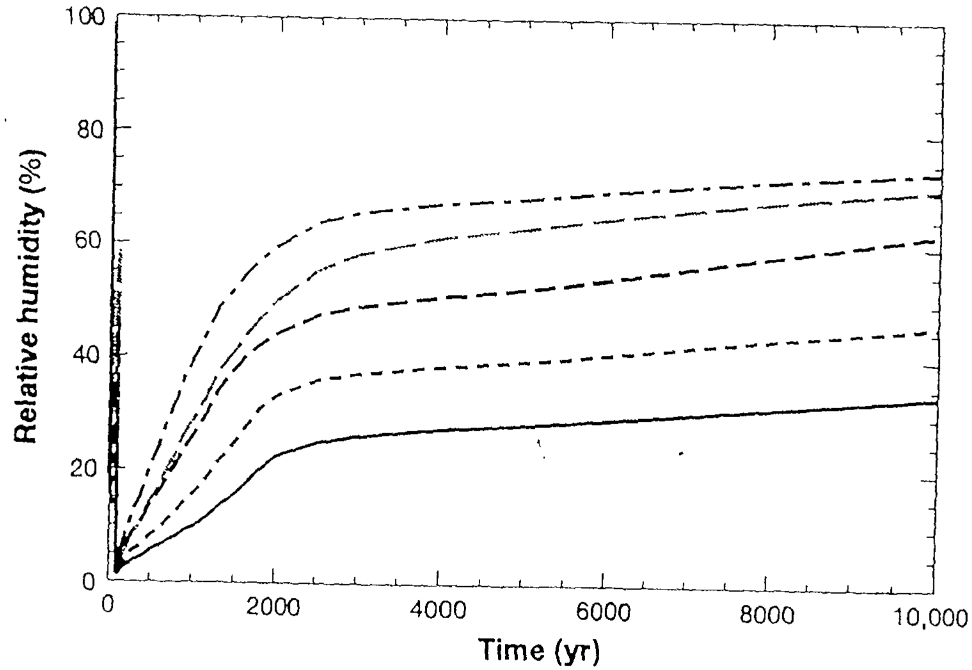
Measured Corrosion Rates (from Brown and Masters, 1982)

Critical Relative Humidities For Salt Contaminants (from Kaesche, 1985)

Waste Package Environments



Calculated Container Temperatures
(from Buscheck et al., 1995)



Calculated Relative Humidities
(from Buscheck et al., 1995)

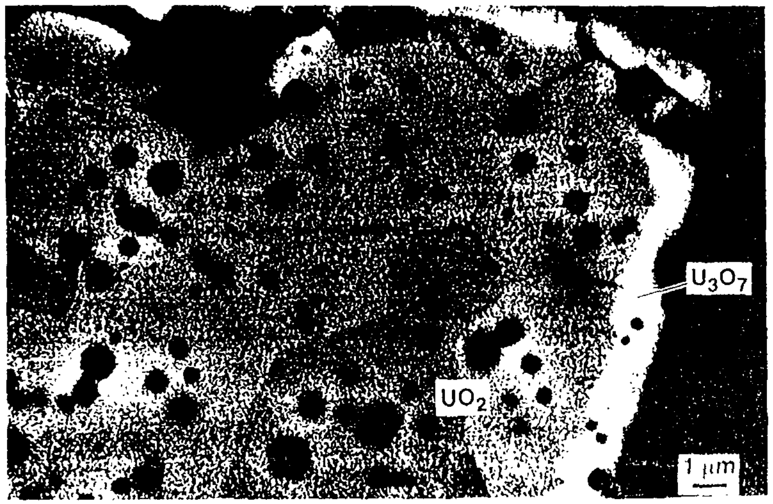
Hypothesis 2--Containment
What Current Information Tells Us

- Limited corrosion at low humidity
- Modeling indicates humidity may be low for thousands of years
- Low humidity conditions may be enhanced by backfill
- Cathodic protection likely

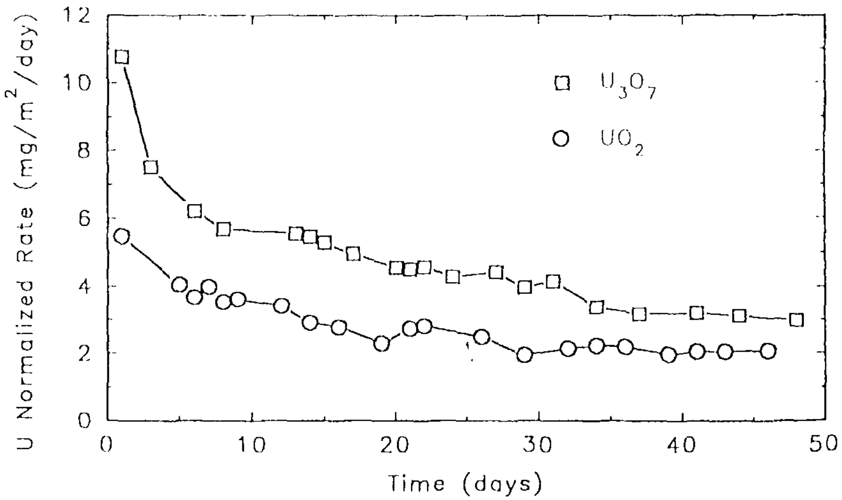
Hypothesis 2--Containment
Work Needed To Test Hypothesis

- Represent environments
  - Observe amount and chemistry of water in ESF
  - Measure possible effect of backfills on humidity
  - Thermohydrologic testing and modeling
- Determine corrosion mechanisms/rates at low humidity
- Establish role of cathodic protection

Waste Mobilization



Scanning Electron Photograph of Bare, Oxidized Spent Fuel (from Gray and Thomas, 1992)



Measured Dissolution Rates For Bare Spent Fuel (from Gray and Thomas, 1992)

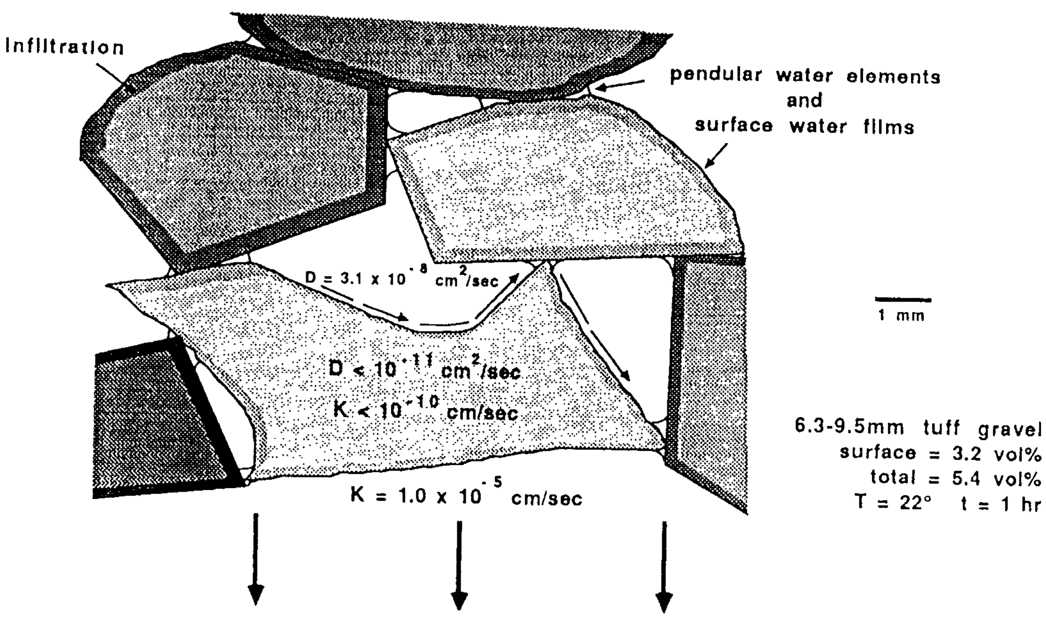
Hypothesis 3--Waste Mobilization
What Current Information Tells Us

- Waste form dissolution rates
  - About 10^{-4}/year for saturated conditions
  - About 10^{-6}/year for unsaturated conditions
- Elemental solubilities give even lower mobilization rates for most radionuclides
- Issues with neptunium solubility, waste form alteration, colloid formation

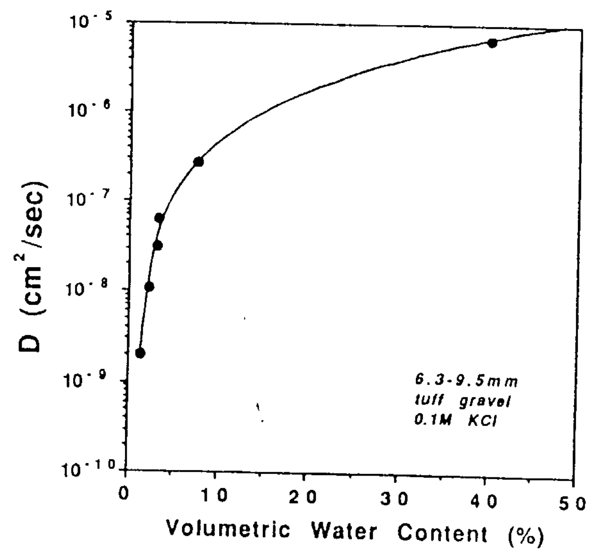
Hypothesis 3--Waste Mobilization
Work Needed To Test Hypothesis

- Refine neptunium solubility data
- Determine effect of radiation and chemistry on waste form dissolution
- Assess effect of containment on waste form alteration (e.g., oxidation of UO_2)
- Determine stability of colloids

Engineered Barriers



Conceptual Model For Unsaturated Backfill (from Conca, 1990)



Measured Diffusion Coefficients For Backfill (from Conca, 1990)

Hypothesis 4--EBS Transport
What Current Information Tells Us

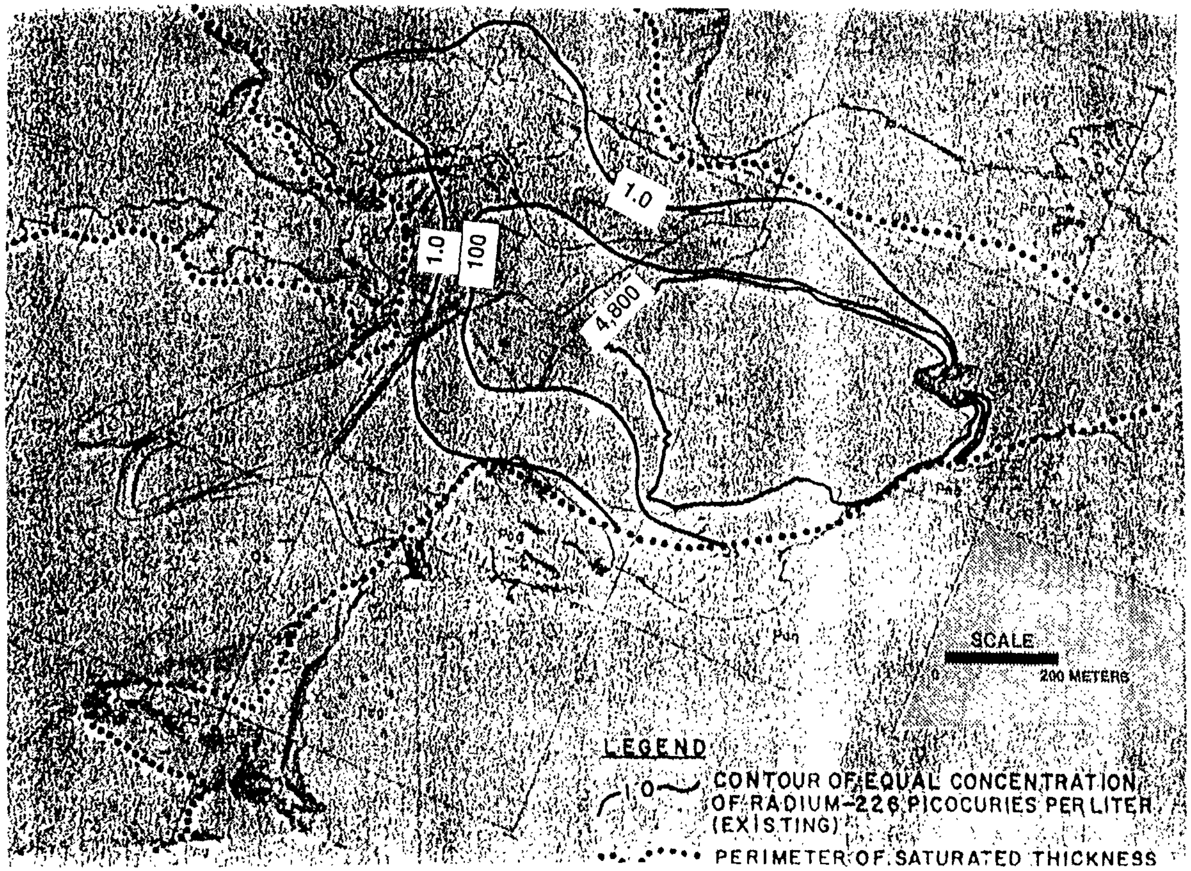
- Very slow transport through waste package
  - Low water content
  - Discontinuous films on waste package components
- Backfill may further limit transport
  - Evaporation effect may limit amount of water contacting waste
  - Thin film effect
  - Films may not exist under repository conditions
  - Transport may result in trapping of radionuclides in pores of backfill

Hypothesis 4--EBS Transport

Work Needed To Test Hypothesis

- Assess transport characteristics of the waste package
- Determine flow and evaporation characteristics of backfill
- Evaluate transport properties of backfill

Dilution During Transport in Natural Barriers



Attenuation of Radium-226 Concentration in Heterogeneous Media at a Uranium Mill Site in South Central Wyoming (Haji-Djafari et al., 1981)

Hypothesis 5--Dilution During Transport in Natural Barriers

What Current Information Tells Us

- Expect dispersion of concentrations in heterogeneous systems
- Textbook solutions indicate large dilution factors
- Mixing during withdrawal
- Uncertainties in transport model at site and in scaling of test results

Hypothesis 5--Dilution During Transport in Natural Barriers

Work Needed To Test Hypothesis

- Determine dispersiveness of local flow system
- Model saturated zone flow system
- Estimate range of scaling effects by analyses using different transport models

Testing the Five Hypotheses Will:

- Provide bounds to seepage into the emplacement drifts
- Estimate bounds to processes that produce low humidity at the waste package
- Determine the upper bounds to waste package breach rates
- Estimate the upper bounds on waste mobilization rates
- Determine the bounds to the flow and transport properties of the EBS
- Estimate lower bounds to dilution factors

Summary

- Strategy is based on the work conducted to date
- We have identified the critical issues and defined how to resolve them
- Strategy calls for significant change in emphasis and provides a basis for estimating the needed work
- Focused efforts could resolve the key issues at a reasonable cost to support near-term milestones