40CFR191, NAS, and HR1020 "Standards"

A Preliminary Comparison of Potential Regulatory Standards for Yucca Mountain

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Outline

Electric Power Research Institute (EPRI) involvement with the "Standards"

EPRI's TSPA code, IMARC

Preliminary comparison of the "Standards"

- Basic "Standard" form (release rate; dose rate; health risk)
- 10,000 year versus peak dose or health risk sensitivities
- "Critical groups"
- "Moving the fence post"

Preliminary conclusions

EPRI involvement

EPRI conducts research for US nuclear utilities

US utility view: The "Standard" must

- protect the health of present and future generations
- be licensable (i.e., not ask for more than science can deliver)

EPRI actively participated in the NAS TYMS Committee public meetings

- analysis of 40CFR191
- analysis of alternate Standards
- recommended a Standard

Assessment of NAS recommendations, HR1020 underway

EPRI's primary assessment tool -- TSPA code, IMARC

Developed by Risk Engineering and a small team of experts

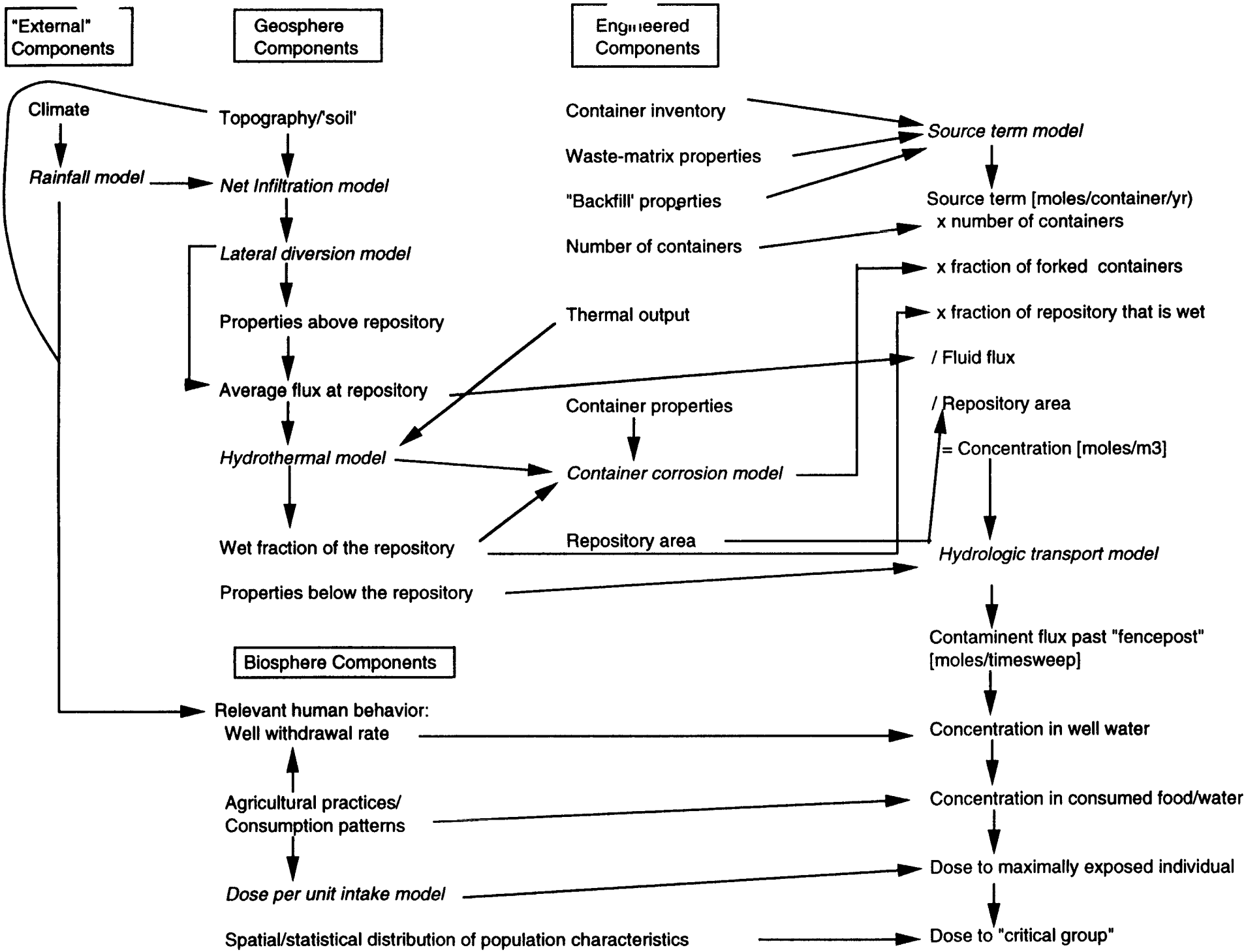
Event tree approach

Recent additions:

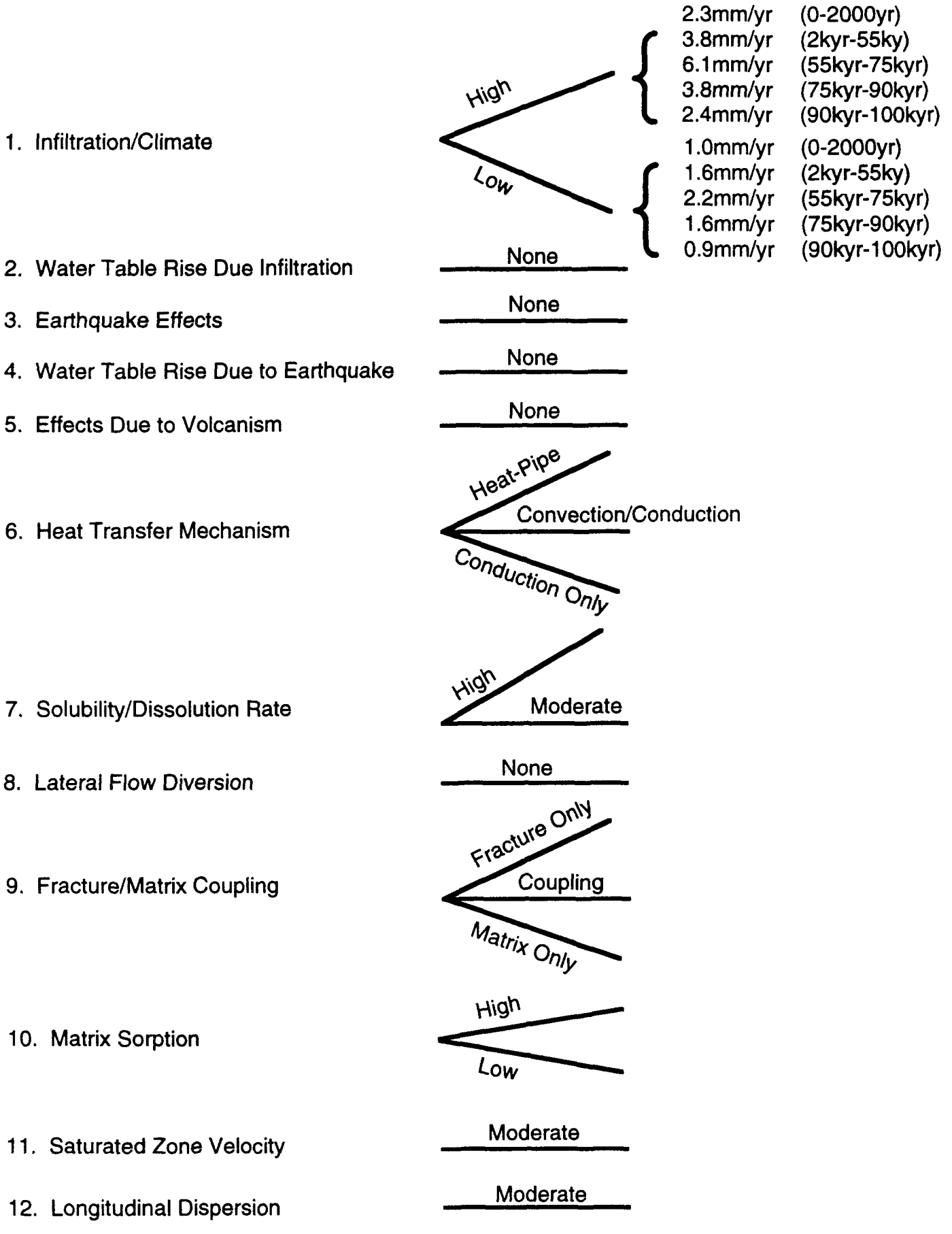
Extend to 1,000,000 years

Time-varying infiltration rate (pluvials)

Hydrology model: 3-D in saturated zone, 1-D in unsaturated zone; fracture/matrix coupling; dispersion; daughter ingrowth


"External" Components
Geosphere Components
Engineered Components
Climate
Topography/'soil'
Container inventory
Source term model
Waste-matrix properties
Rainfall model
Net Infiltration model
"Backfill' properties
Source term [moles/container/yr)
x number of containers
Number of containers
Lateral diversion model
x fraction of forked containers
Thermal output
x fraction of repository that is wet
Properties above repository
/ Fluid flux
Average flux at repository
Container properties
/ Repository area
= Concentration [moles/m3]
Hydrothermal model
Container corrosion model
Wet fraction of the repository
Repository area
Hydrologic transport model
Properties below the repository
Contaminent flux past "fencepost" [moles/timesweep]
Biosphere Components
Relevant human behavior:
Well withdrawal rate
Concentration in well water
Agricultural practices/ Consumption patterns
Concentration in consumed food/water
Dose per unit intake model
Dose to maximally exposed individual
Spatial/statistical distribution of population characteristics
Dose to "critical group"

EVENT TREE BRANCHES USED IN THE PRELIMINARY ANALYSES (IMARC PHASE 3)



Preliminary comparison of the "Standards"

Basic "Standard" form (release rate vs. dose rate or health risk)

10,000 year versus peak dose or health risk

"Critical Groups"

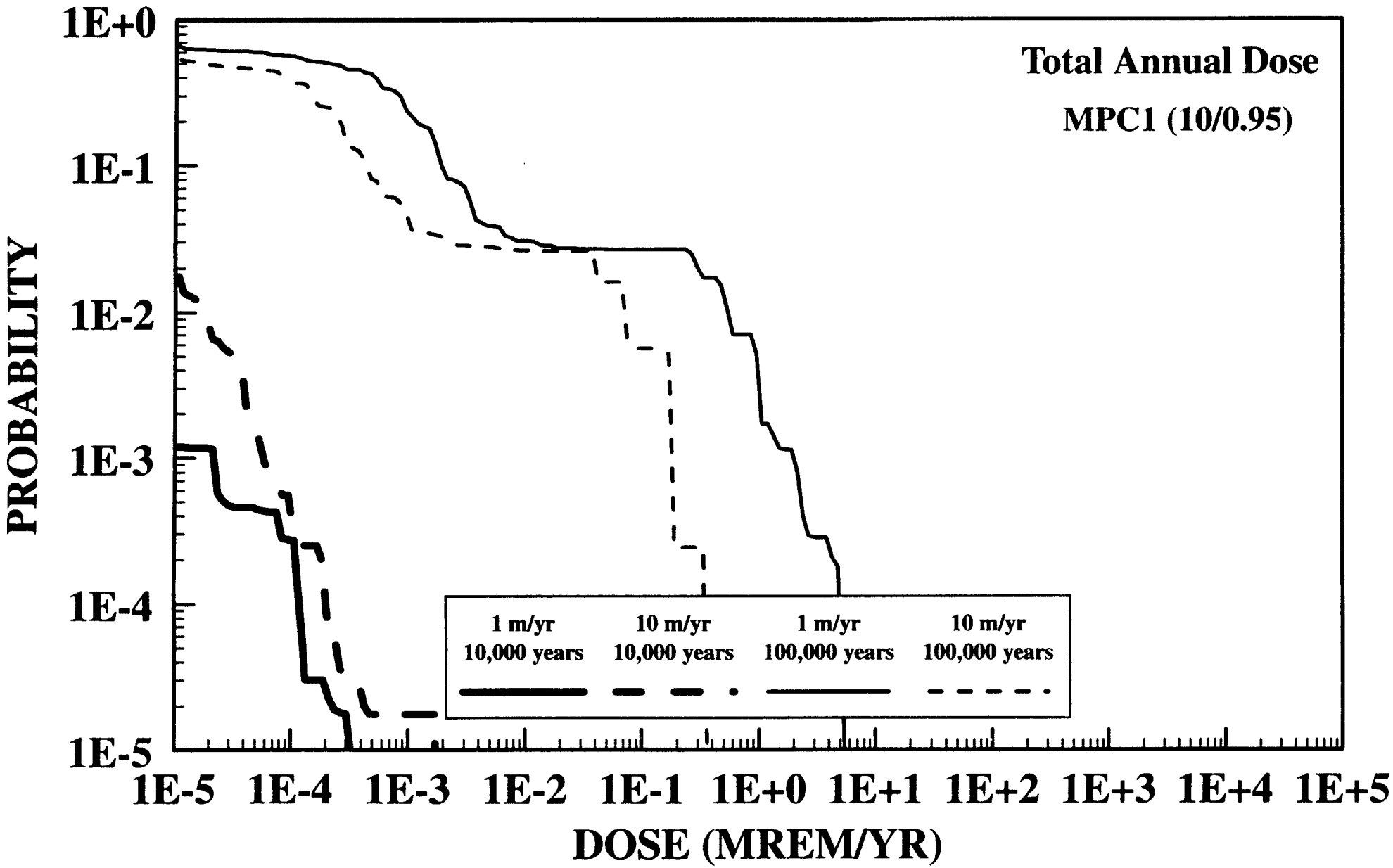
"Moving the fence post"

Parameter sensitivity - release rate vs. dose/health risk criteria

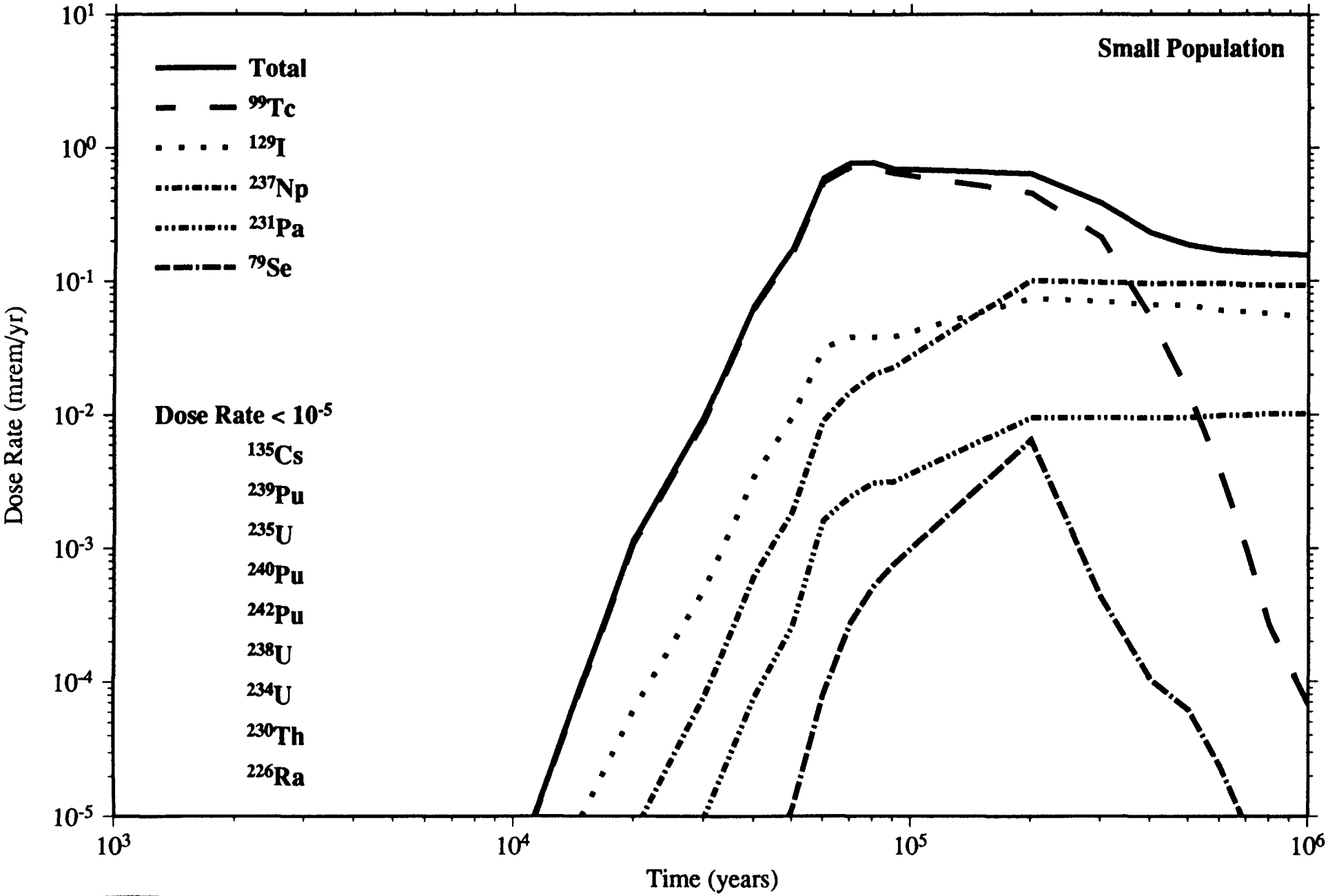
Saturated zone flow velocity

Higher velocity *increases* "release" past boundary

Higher velocity can cause more dilution - so *reduces* dose


Total Annual Dose
MPC1 (10/0.95)
PROBABILITY
1E+0
1E-1
1E-2
1E-3
1E-4
1E-5
1 m/yr 10,000 years
10 m/yr 10,000 years
1 m/yr 100,000 years
10 m/yr 100,000 years
1E-5 1E-4 1E-3 1E-2 1E-1 1E+0 1E+1 1E+2 1E+3 1E+4 1E+5
DOSE (MREM/YR)

EXPECTED ANNUAL DOSE VS. TIME FOR INDIVIDUAL NUCLIDES



Time period of Standard can significantly impact the waste isolation strategy

0-~10^4 years - transient period. Important factors:

Hydrothermal behavior
Container corrosion resistance
Number of leaking containers
Matrix alteration/dissolution rate
Fast flow paths
Longitudinal dispersion
Saturated zone dilution
Biosphere components

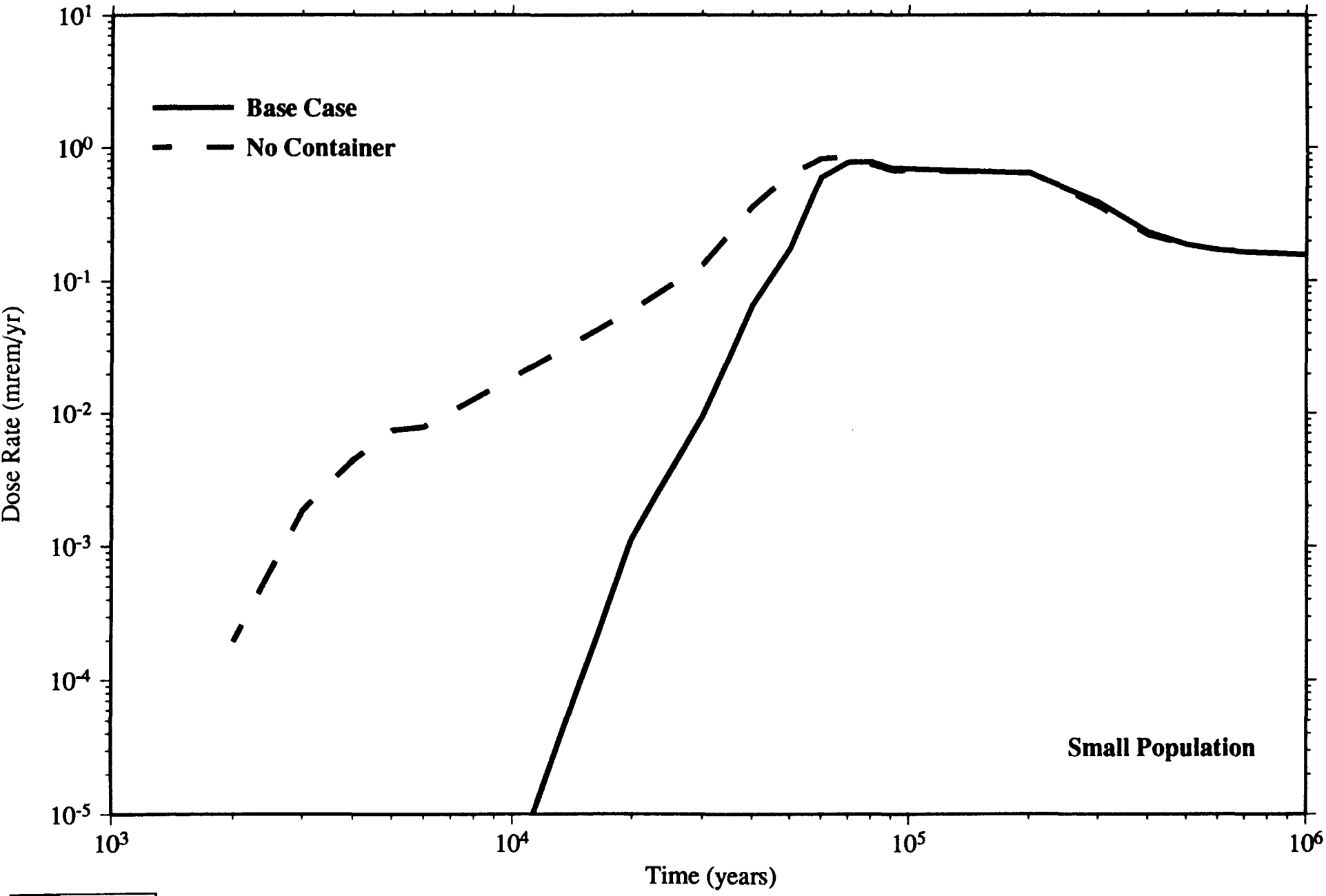
Time period of Standard can significantly impact the waste isolation strategy (continued)

~10^5 years and beyond - peak dose or health risk period. Important factors:

Saturated zone dilution

Biosphere components

TOTAL EXPECTED ANNUAL DOSE VS. TIME



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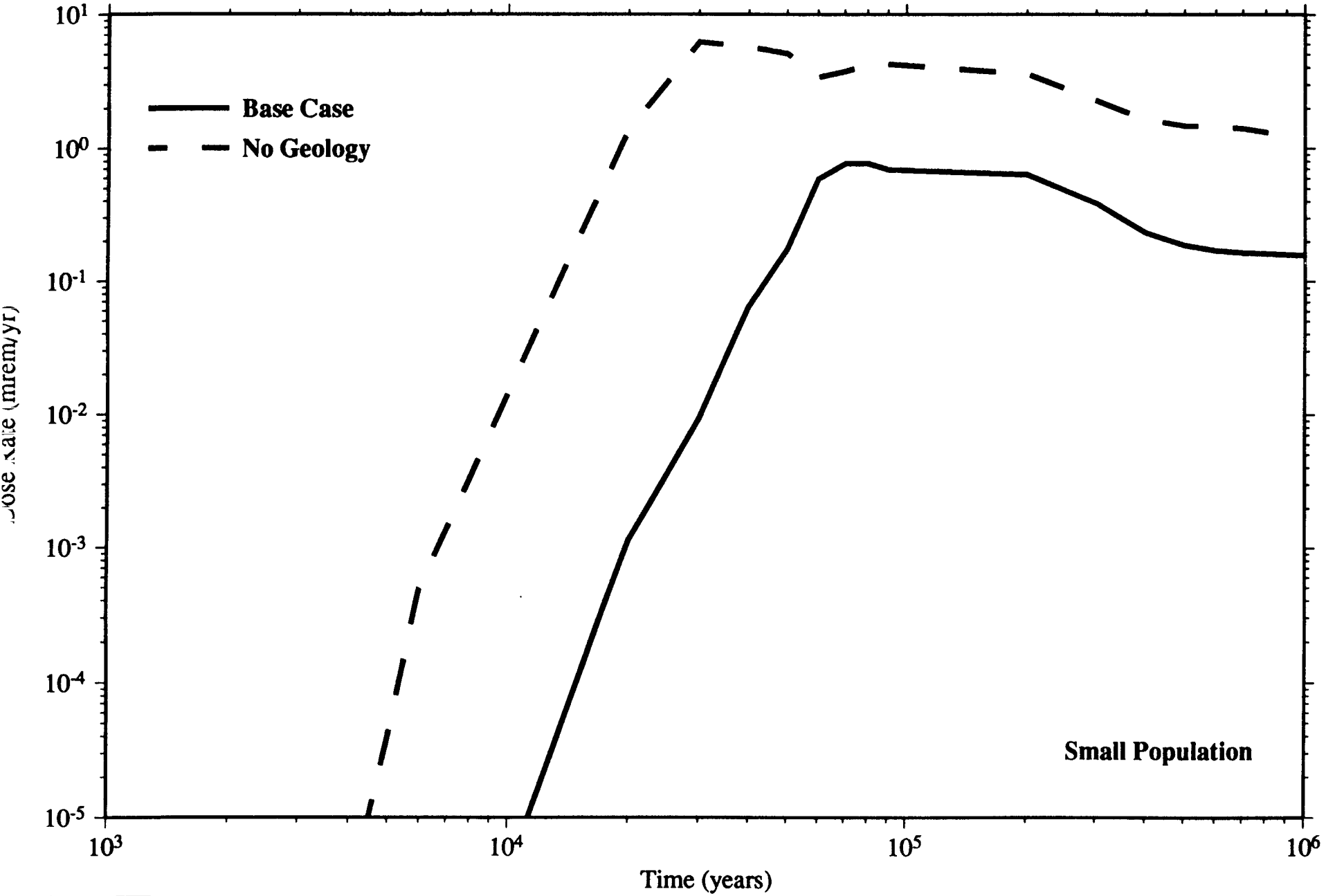
TOTAL EXPECTED ANNUAL DOSE VS. TIME



Comparison of health risk limits

NAS

Suggested annual individual risk limits of 10^{-6} to 10^{-5}

Risk to an average member of a "critical group"

HR1020

100 mrem/yr equals an annual individual risk limit of 5×10^{-5}

Risk to an average individual in the local population

40CFR191 (based on 1,000 deaths in 10,000 years)

Annual, *population-averaged* individual risk limits of:

- $<10^{-10}$ for C-14 (world population of 10 billion assumed)
- $<10^{-5}$ if 10,000 people (drinking water only)
- $<10^{-3}$ If 100 people (agricultural - groundwater source)

Critical Groups - NAS approaches

1. Probabilistic critical group

- a group that is at greatest risk
- should be small in number (less than a few tens)
- homogeneous in risk (within a factor of 10 or less) w.r.t. "diet and other aspects of behavior"
- "Risks can be homogeneous even when outcomes are quite diverse"
- compare Standard to the mean of the critical group

2. Subsistence farmer critical group

- assumed to represent maximally exposed individual
- must assume individual is at the worst place all of the time
- can be adjusted for realistic well locations and water withdrawal rates

Critical Groups (continued)

40CFR191

Population-based approach neglects risk heterogeneity

Therefore, no special protection of those at greatest risk (beyond 1,000 years)

HR1020

Average individual in the local population

- spatially averaged population distribution
- average of distributions in consumption rates

Explore the basis for a limit between 10^{-6} to 10^{-5} per year:

Involuntary risks or risk limits (annual individual average):

Source	Risk
Being struck by a crashing airplane[1]	4×10^{-6}
Extra fatal cancer risk living in Denver[2]	1×10^{-5}
US FDA food additive regulatory risk "floor"[3]	1×10^{-6}
US EPA general risk limit range[4]	10^{-6}-10^{-3}

[1] Harvard Center of Risk Analysis, 1992 Annual Report, pg. 3.
[2] (relative to living in New York) Wilson, R., 1980, Risk/Benefit Analysis for Toxic Chemicals, "Ecotoxicology and Environmental Safety", Vol. 4, pg. 370-383.
[3] Wilson and Crouch, Science, Vol. 236, pg. 293, 1987.
[4] Statement by William K. Reilly, US EPA Administrator on Environmental Tobacco Smoke, Jan. 7, 1992. "Merely for comparison, EPA generally sets it standards or regulations so that risks are below 1-in-1,000 to 1-in-1 million."

Health risk limit - "critical group" link conclusions

- Involuntary health risks of 10^{-6} to 10^{-5} are broadly tolerated by society
- Group sizes are often orders of magnitude larger than a few tens of individuals
- Risk heterogeneity within existing "critical groups" can be large

Implications for "critical groups" at Yucca Mountain:

Applying a 10^{-6}/yr limit to a maximally exposed individual is inconsistent and *very* conservative

A ~10^{-5}/yr limit to an average individual in the local population (HR1020 approach) is still conservative

- present and future local Yucca Mountain populations probably much smaller than Denver (or populations near airports)

US FDA's risk "floor" of 10^{-6}/yr implies

- averaging of food consumption habits over a large population is acceptable

Illustration of the "average individual" concept

EPRI first proposed this approach to the NAS[5]

"Statistical" components (i.e., based on present day behavioral distributions)

Water and food consumption

Agricultural/urban mix

Agricultural practices

Probabilistic components

Water source (local or distant)

Well depth (base on known hydrogeologic properties)

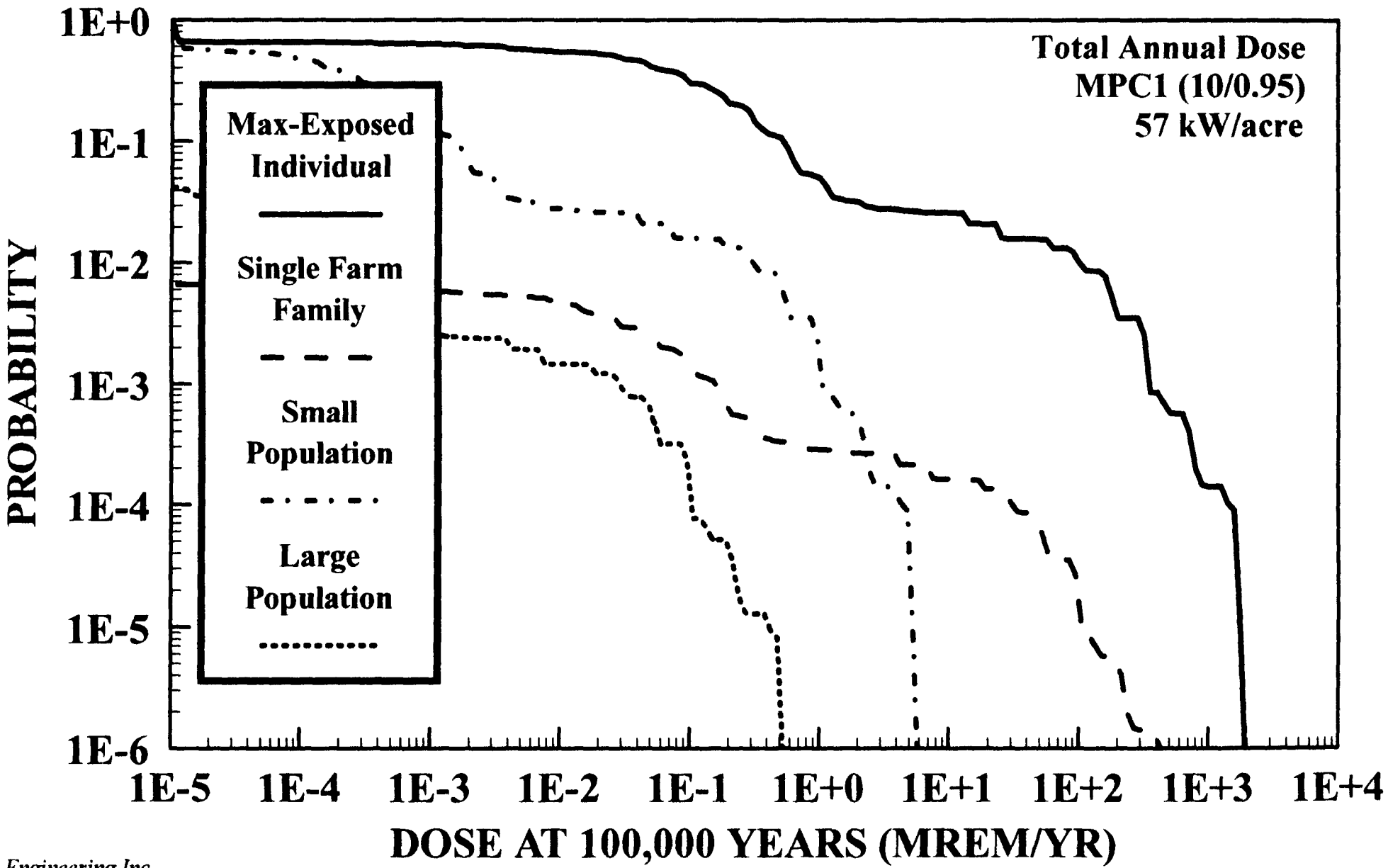
Well location (can assume random placement)

Contamination detection and remediation

[5]EPRI TR-104012, "A Proposed Public Health and Safety Standard for Yucca Mountain", Electric Power Research Institute, Palo Alto CA, December 1994.

SENSITIVITY TO POPULATION

FOR AN AVERAGE PERSON IN THE CRITICAL POPULATION



Risk Engineering Inc.

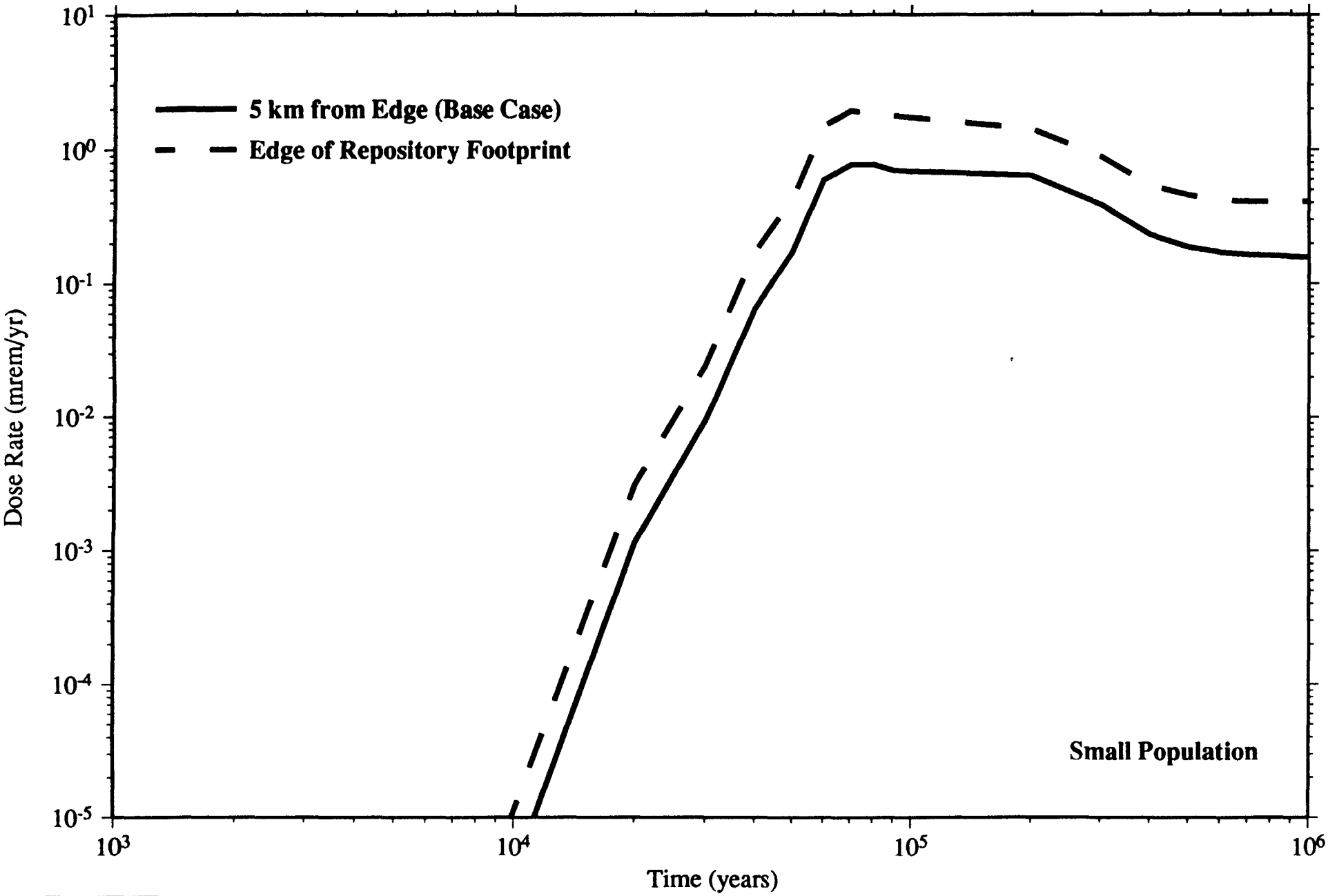
The "fence post": Downstream position assumed for licensing calculations

NAS: Edge of the repository footprint

40CFR191: 5 km from edge of repository

HR1020: edge of the withdrawn land

TOTAL EXPECTED ANNUAL DOSE VS. TIME



Conclusions

Both NAS recommendations and HR1020 are a significant improvement over 40CFR191

- They both directly regulate health effects (i.e., they are dose- or health risk-based)
- Their limits are based on broadly tolerable individual risk values

Individual risk limits and "critical groups" should be consistent

- Annual individual risk range of 10^{-6} to 10^{-5} is broadly tolerable
- Inconsistent approach if applied to a maximally exposed individual
- Most consistent if applied to average individual in the local population

Conclusions (continued)

Time of regulatory cutoff affects the amount of work to be done

- Many parameters/processes are important if regulations set at ~10,000 years only
- Fewer affect peak doses or health risks

Location of "fence post" not very critical