Risk Informing Regulations in an Uncertain World

Tim McCartin
Division of Spent Fuel Management, NMSS
301-415-7099
Timothy.McCartin@nrc.gov

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

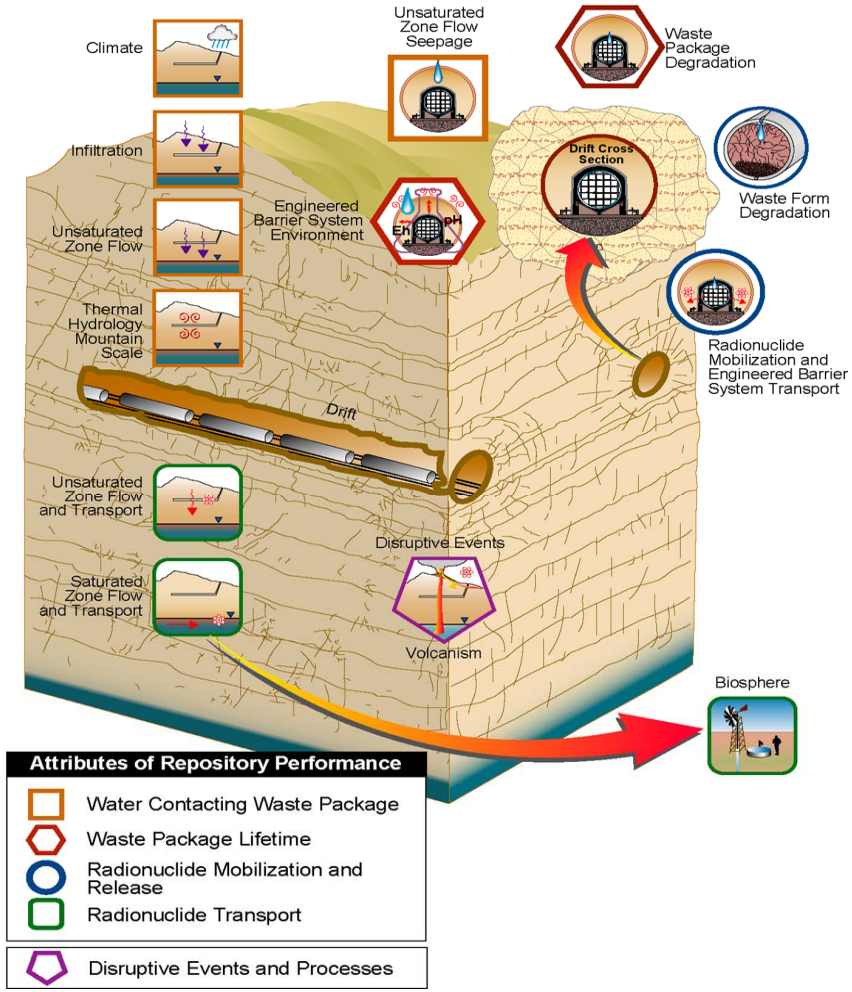
Risk Informing Regulations

- Enabling Legislation
- Development of Regulations
- Implementation and Refinement (hard to get it right the first time)
- Knowledge Evolution (confidence and risk information)
- Public Perception versus Expert Perception

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

What is a Geologic Repository?

- A system for the disposal of radioactive wastes in excavated geologic media.
- No moving parts - but the geologic setting can only be characterized (not designed)



Nuclear Waste Policy Act of 1982

- Assigned responsibilities to DOE, EPA, NRC, the President and to Congress

- NRC issued repository criteria for:
  - Construction authorization
  - Receipt and possession of waste
  - Closure and decommissioning

- NRC criteria for spent fuel and HLW disposal:
  - Provide for a system of multiple barriers
  - Include restrictions on retrievability

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Continual Learning and Use of Information

- Staged licensing (construction authorization, license to receive and possess, closure, and termination)
- Performance Confirmation program till closure decision
- Requirements for retrievability

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Regulatory Concern (70s and 80s)
[limited confidence in performance assessment]

- Compensate for uncertainties in estimating performance (preclude need for bounding and worse case assumptions)
  - quantitative subsystem requirements
  - siting criteria
  - design criteria

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Subsystem Requirement Approach

(NUREG-0804 Staff Analysis of Public Comments on Part 60; Dec. 1983)

Consider Simple Measures to Enhance Confidence

- Protect waste from water when radiation and temperatures are high and release rate predictions are difficult (minimum waste package lifetime of 300 to 1,000 years)
- Gradual release from engineered barrier system (minimum release rate of 1 part in 100,000 per year)
- Small fraction of releases from engineered barrier system will enter the accessible environment far in the future (ground water travel time of at least 1,000 years)

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Analysis Activities (80s)

- **Quantitative subsystem requirements showed limited connection with compliance with overall performance standard**

- **Demonstrating compliance with design requirements proving more difficult than anticipated**

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Performance Assessment Activities

- **ITERATIVE Performance Assessment**
  - methods and techniques development (80s)
  - initial NRC demonstration (early 90s)

- **Performance Assessment continued and integrated into many activities**
  - multiple iterations (e.g., 1992, 1995, 2000, 2004)
  - program planning
  - Review Plan and issue resolution

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Energy Policy Act of 1992

- NAS Report Advised EPA on technical basis for Standards (report issued 1995)
  - limit risk to average member of critical group (starting point for standard of 2 – 20 mrem/yr)
  - avoid quantitative subsystem requirements
  - specify biosphere in regulation
  - evaluate human intrusion separately (not possible to scientifically predict nature and timing of intrusion)
- NRC considered revisions to regulatory approach

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NRC Regulatory Approach

- What information is needed
- How will information be supported
- How should information be collected and used from construction authorization till permanent closure

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

New Regulations

- NRC specified a performance-based, risk-informed approach based on 15 years of performance assessment development

- Recognition that a high-quality performance assessment and its supporting information would provide the information necessary for evaluation of safety of a high level waste repository
  - removed separate quantitative subsystem requirements
  - removed siting and design requirements
  - added requirements for performance assessments

- Continued learning (performance confirmation) provides for updating of performance assessment till closure

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NRC's Requirements for Performance Assessment

- Account for uncertainties
- Consider alternative models consistent with data
- Provide technical basis for inclusion and exclusion of specific features, events, and processes
- Provide technical basis for models used in performance assessment
- Capabilities of barriers, as included in performance assessment, are basis for complying with multiple barrier requirement

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Risk Informing: Early and Often

- **Risk informing is much more than a regulation**
  - experienced staff (continual learning)
  - supporting information
  - updating with new information
- **Willingness to accept change**
  - role for simple and complex models

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Radionuclide Inventory

Nuclide	Half-Life (yrs)	Percent of Inventory at 1,000 yrs (by activity)	Percent of Inventory at 1,000 yrs (by activity - weighted by DCF)
Am 241	427	54%	56%
Pu 240	6,500	25%	25%
Pu 239	24,000	18%	18%
Am 243	7,400	1.2%	1.2%
Tc 99	210,000	0.7%	0.0003%
U 234	240,000	0.1%	0.01%
C 14	5,700	0.07%	0.00005%
Np 237	2,100,000	0.06%	0.08%
Cs 135	2,270,000	0.03%	0.00007%
U 238	4,500,000,000	0.02%	0.001%
I 127	16,000,000	0.002%	0.0002%
Th 227	77,000	0.001%	0.0002%

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Waste Isolation Functions (example)

[D = delay time; L = lowering of release rate; increased letters denotes increased effectiveness]

Safety Functions	Important Features	Radionuclides in the Ground-Water Pathway											
		Am 241	Pu 240	Pu 239	Am 243	Tc 99	U 234	C 14	Np 237	Cs 135	U 238	I 127	Th 227
Onset of Release	Waste Package	DDD	DDD	DDD	DDD	DDD	DDD	DDD	DDD	DDD	DDD	DDD	DDD
Release Rate From Engineered Barriers	Waste Form					LL		LLL		LL	L	L	LL
	Solubility Limits										LLL		L
	Solubility Limits; Limited Water		L	L	L		L		L		LLL		LL
Transport In Geosphere	Transport in Fractures	DDD	DD	DD	DD	D	D	D	D	DDD	D	D	DD
	Transport in Porous Media	DDD	DDD	DDD	DDD	D	DDD	D	DDD	DDD	DDD	D	DDD

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Performance Assessment Iterations

- Improvements/Changes made after each iteration
  - some models simplified
  - complexity added in certain areas
  - data needs identified
  - issues addressed/identified

- Insights documented

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Objectives of a Risk-Informed Approach

- Provides an “informed” and focused approach for NRC’s review
  - identification of important parameters, models, and assumptions
  - identification of important uncertainties
  - focus review on technical support in key areas of performance assessment

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Review Questions Informed by Risk Insights

Is the timing of the dose consistent with the degradation of the engineered barriers?

Is the magnitude of the dose consistent with the number of breached waste packages?

Is the timing of the dose consistent with the retardation processes in the saturated zone?

Is the magnitude of the dose consistent with the inventory and retardation processes?

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Building Confidence is Iterative

- Well-defined decision points based on continual learning (e.g., construction authorization, license to receive and possess, closure)
- Demonstration of safety provided in safety assessments and the supporting technical bases, which will be updated as information is collected
- Forward looking approaches to further ensure safety (performance confirmation program)

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Thank you for your attention.

Questions?

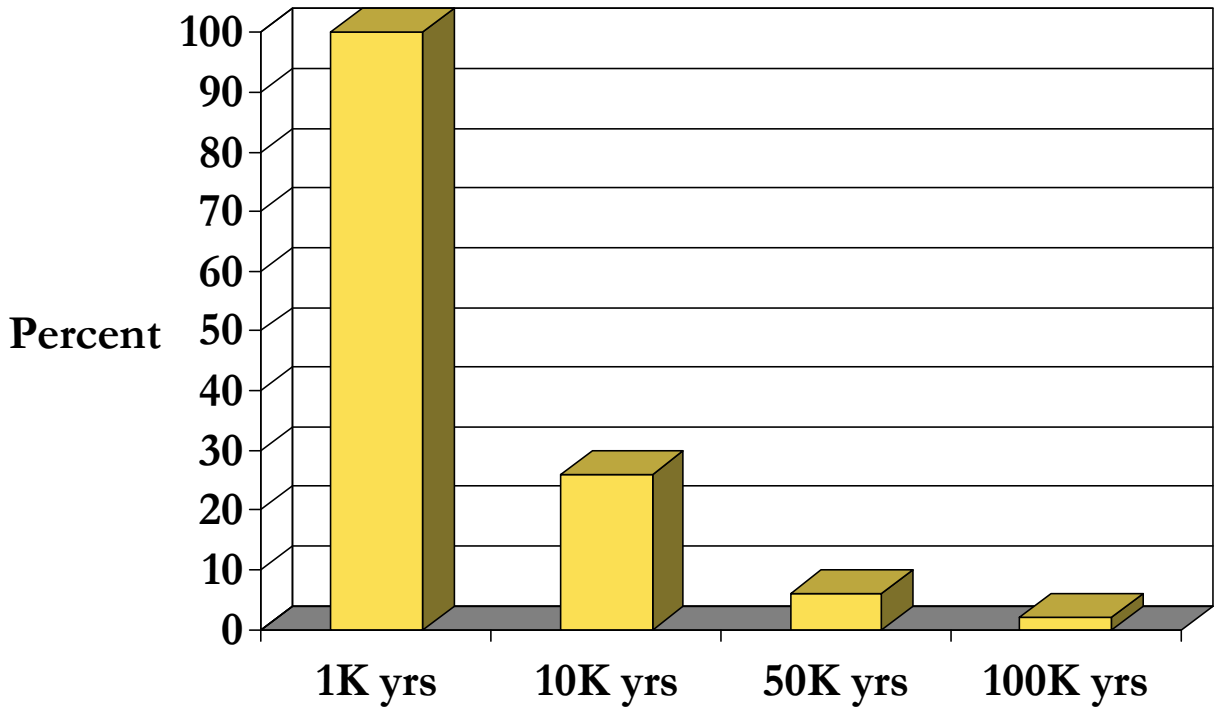
U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

BACKUP SLIDES

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Variation in Inventory over Time

(relative to inventory in curies at 1,000 years)



U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

TSPA Hierarchy (DOE)