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Overview of NRC Approach to Performance Assessment for LLW Shallow Land Disposal & The IAEA Safety Case

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Office of Federal and State Materials and Environmental Management Programs

Workshop on Performance Assessment of Near-Surface Disposal Facilities
U.S. NRC Auditorium, Rockville, MD
August 29-30, 2012

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Topics

- 10 CFR Part 61: disposal concepts & performance objectives
- Performance assessment (PA) overview
- PA LLW approach & methodology –
  NUREG-1573 & NUREG-1854
- The IAEA Safety Case Approach
- Key PA issues
- Concluding remarks and path forward

10 CFR Part 61 LLW Disposal Concept

Near-surface (<30 m depth) land disposal with specific technical requirements, performance objectives, and procedural requirements

Cornerstone of safe disposal is stability:

- Stable wastes, design
- Reliance on natural system isolation
- Reduced exposure to intruders
- Stability of waste form & packaging

Graded stability requirements using waste classes A, B, and C

10 CFR Part 61 LLW Disposal Concept (Cont'd)

Inadvertent intruder dose limit not to exceed 5 mSv/yr

Greater than class C waste unsuitable for near- surface disposal

Site closure and stabilization (a 5-year post-closure period for observation, monitoring, and maintenance)

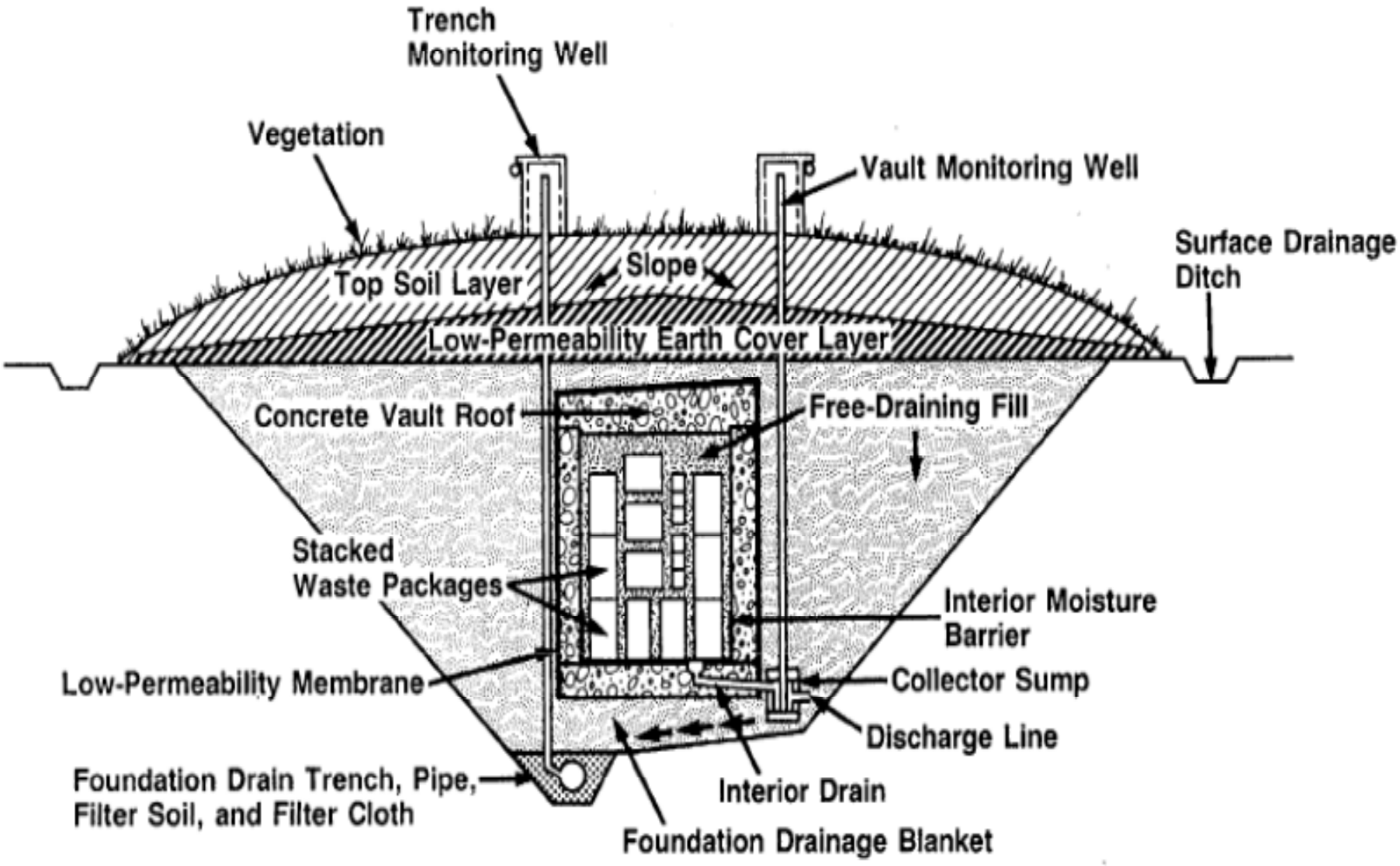
Monitoring, access restrictions, and custodial activities after license transferred to the State or Federal agency for 100 year of institutional control period

State or federal government ownership of land assuring custodial care during institutional control period

10 CFR Part 61 Subpart C Performance Objectives

- §61.41 Protection of the general public *(annual doses not to exceed 0.25 mSv/yr to the whole body, 0.75 mSv/yr to the thyroid, and 0.25 mSv/yr to any other organ and maintain effluent releases ALARA)*
- §61.42 Protection of individuals from inadvertent intrusion *(< 5 mSv/yr)*
- §61.43 Protection of individuals during operation based on §61.41 (public) & §20.1201 (occupational).
- §61.44 Stability of disposal site after closure (the LLW facility must be sited, designed, operated, and closed to achieve long-term stability) so that following closure, only surveillance, monitoring, or minor custodial care are required

A LLW Disposal Design Concept



NUREG-1573

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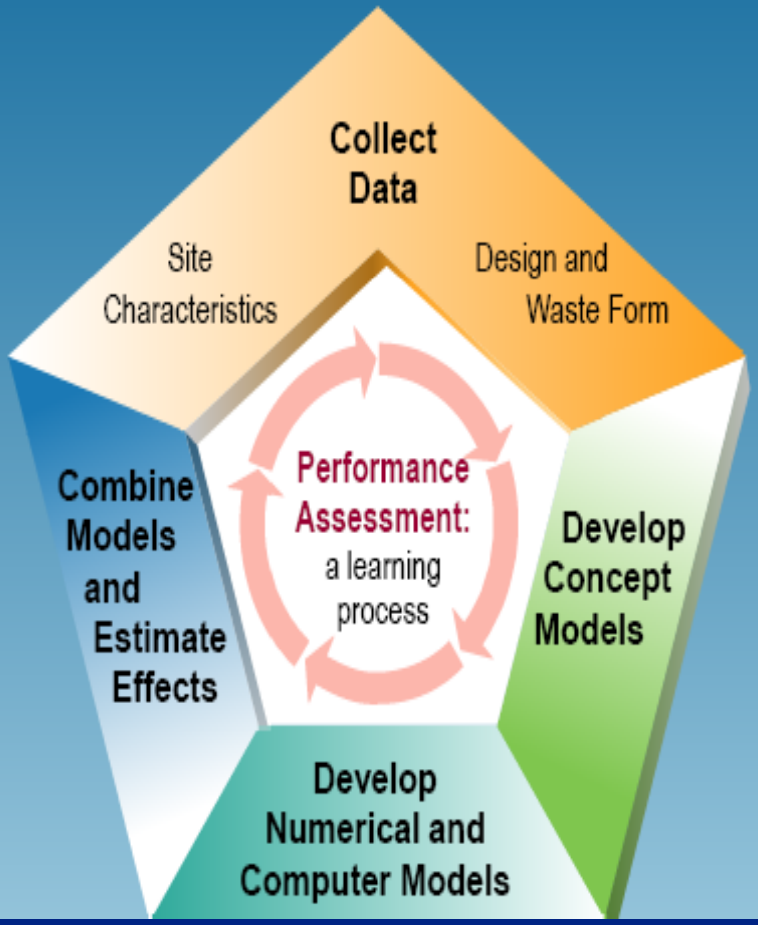
Overview of Performance Assessment

What is Performance Assessment?

- Systematic analysis of what could happen at a site



What is assessed?

- What can happen?
- How likely is it?
- What can result?

Why use it?

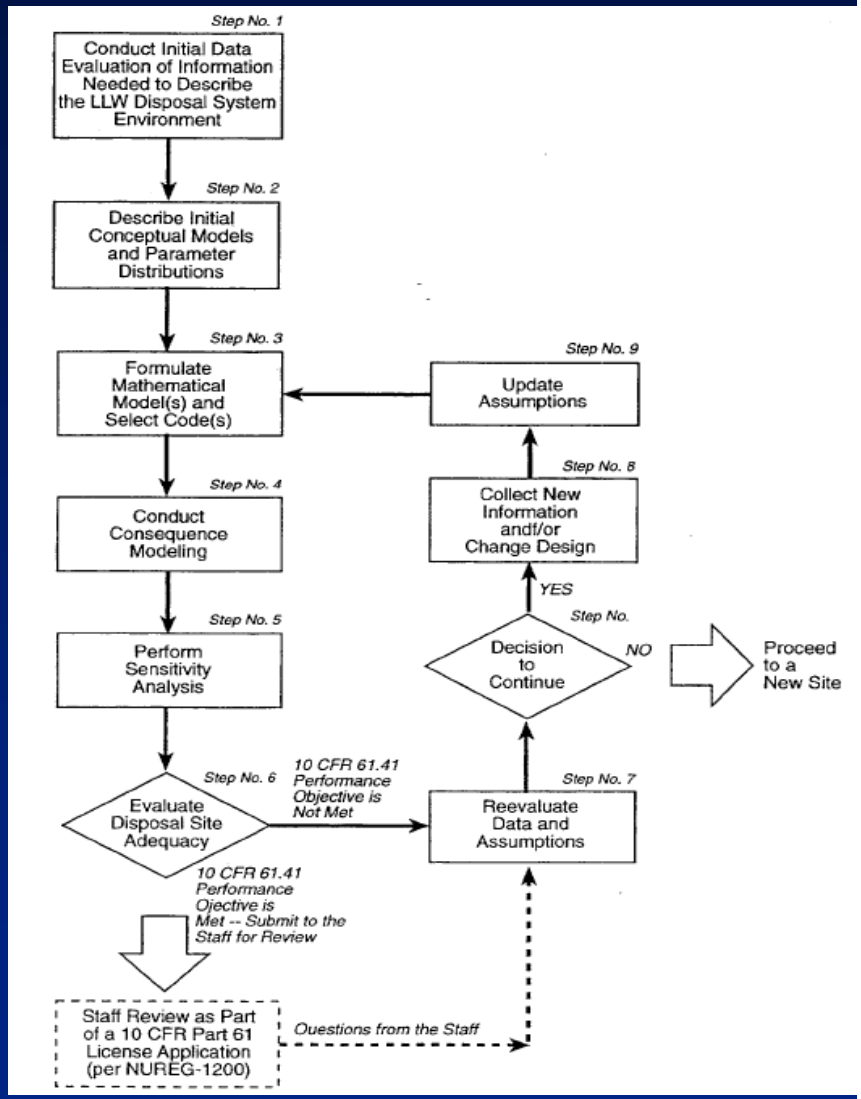
- Complex system
- Systematic way to evaluate data
- Internationally accepted approach

How is it conducted?

- Collect data
- Develop scientific models
- Develop computer code
- Analyze results

Steps in NRC NUREG-1573 PA Methodology Reviews

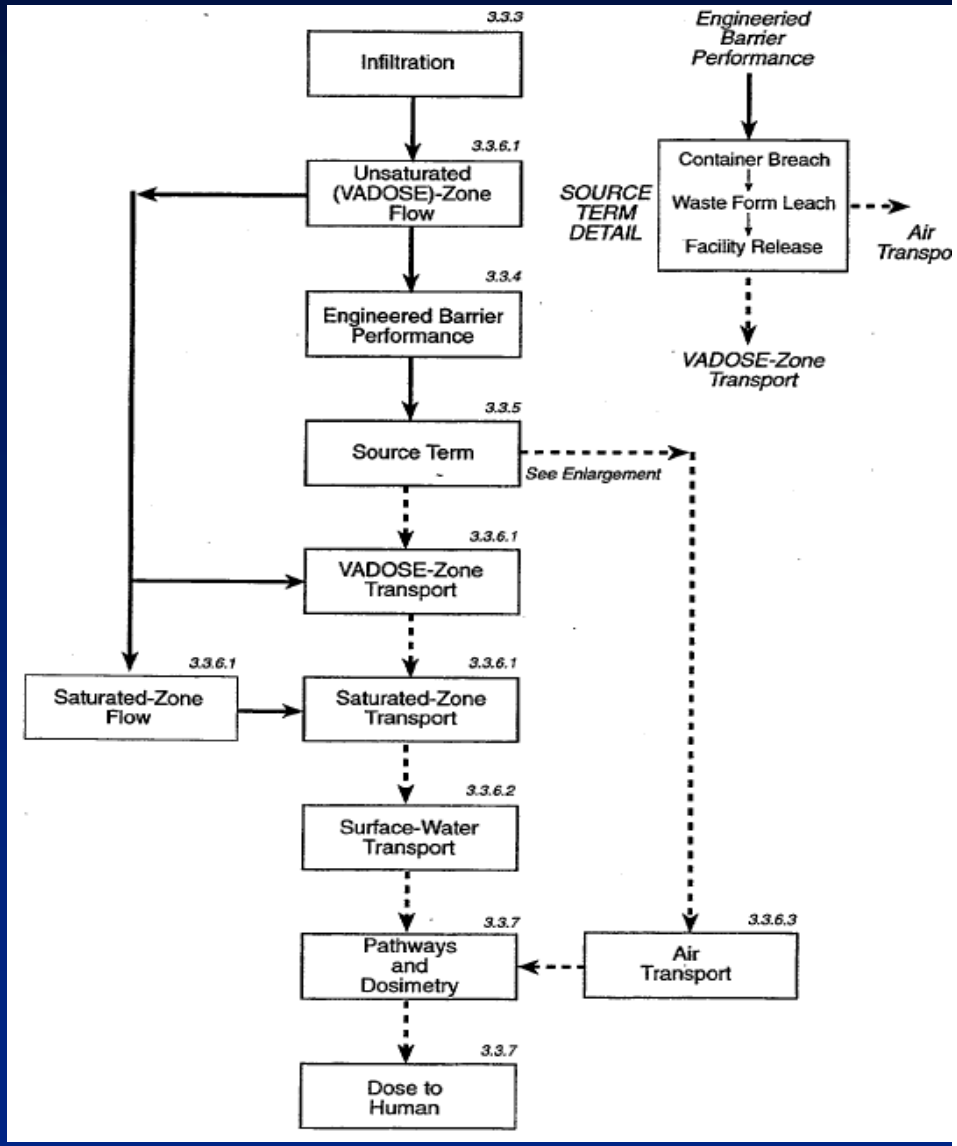
- Data evaluation
- Conceptual models & scenarios
- Parameter distributions
- Mathematical models & codes
- Consequence modeling & analysis
- Sensitivity & uncertainty analysis
- Initial evaluation of site performance
- R-evaluation of data & assumptions
- Assessment of compliance with 10 CFR 61.41 & §61.42



Specific Processes Considered in NRC LLW PA

- Infiltration
- UZ Flow
- Eng. Barrier Performance
  - Container Breach
  - Waste Form Leach
  - Source term releases
- VZ Transport
- SZ flow & Transport
- Surface water transport
- Exposure scenarios & pathways transport
- Dose to human

NUREG-1573



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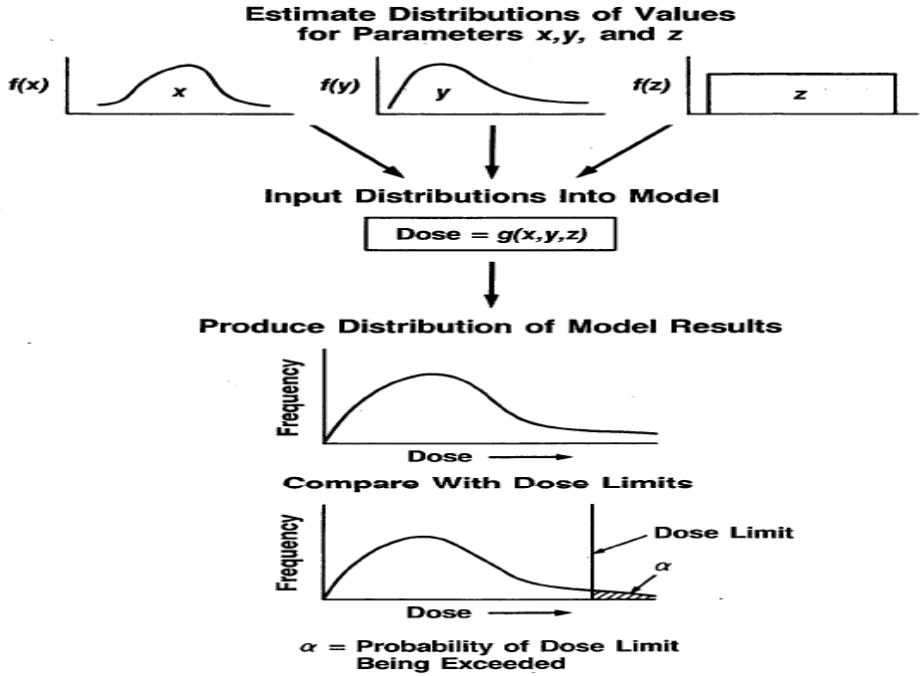
An Approach to Uncertainty Analysis



$$\text{Max}[\text{Mean}(t)] \leq \textit{Regulatory Limit}$$

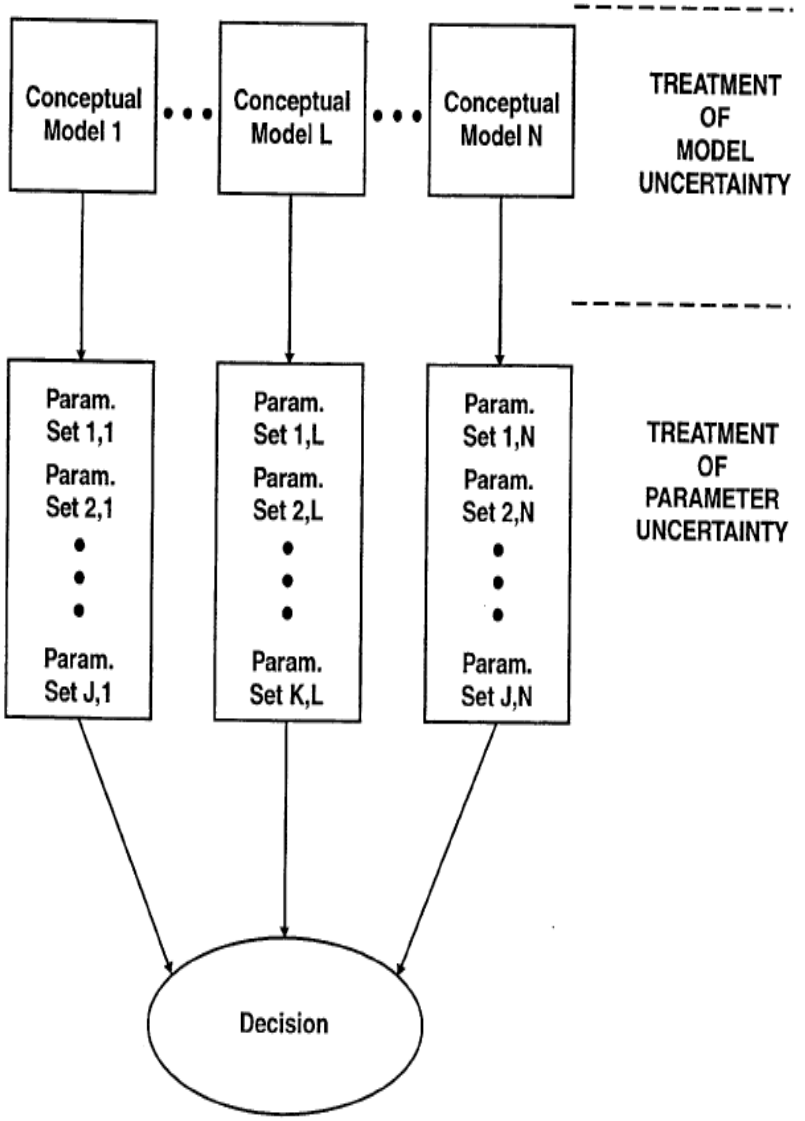
where:

$$\text{Mean}(t) = \frac{\sum_{k=1}^{N} \text{Dose}_k(t)}{N}$$

$\text{Dose}_k(t)$ = doses *at time t, for run k*

N = *number of Monte Carlo runs*

t = *time*



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NUREG-1854 - *PA Guidance for Activities Related to U.S. DOE Waste Determinations*

- **Discusses the main areas that should be addressed during a WIR *(e.g.; Waste Incidental to Reprocessing*) review**
- **Applies to all four WIR sites (SRS, INL, Hanford, West Valley)**
- **Is risk-informed and performance-based**
- **Is based on existing NRC guidance (e.g., NUREG-1573, NUREG-1757) as well as staff experience**

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NUREG-1854 Areas of PA Review Guidance

PA Review areas include:

- Scenario Selection and Receptors
- General Technical Review Procedures
- Specific Technical Review Procedures
  - Climate and Infiltration
  - Engineered Barriers
  - Source Term/Near Field Release
  - Radionuclide Transport
  - Biosphere Characteristics and Dose Assessment
- Models and Codes
- Uncertainty/Sensitivity Analyses
- Evaluating Model Results
- ALARA Analysis

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NUREG-1854 PA Reviews Generic Approaches

- The guidance emphasizes the need for adequate model to support its stability
- The amount of model support is to be commensurate with the risk significance of the model
- Model support may entail multiple lines of evidence
- The guidance recognizes that traditional validation may not be possible for some PA models
- Technical basis is needed for the performance of intruder protection systems
- Types of scenarios envisioned: residential, agricultural, recreational, hunting & fishing, well-driller, construction, or others
- Site stability PA includes:
  - Natural stability of the site (e.g., effects of floods, erosion)
  - Stability of the waste (e.g., potential for differential settling)
  - Stability of the engineered facility (e.g., vault degradation)

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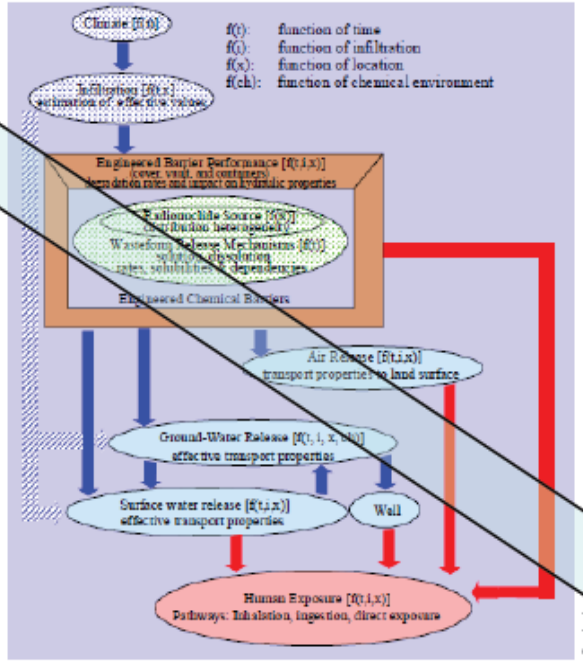
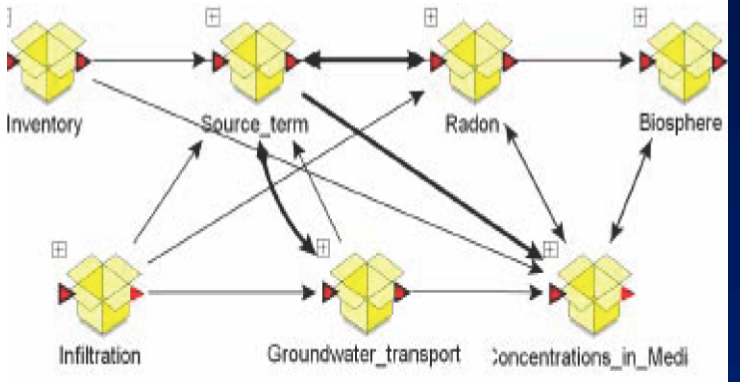
PA Approach: Representation of LLW System, Conceptual & Mathematical Models, and Estimated Performance

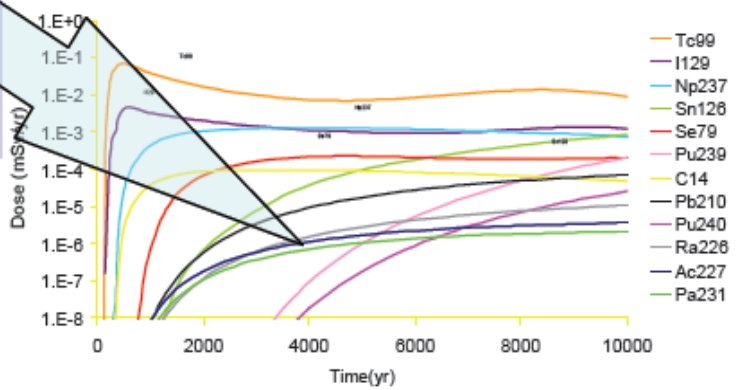
Real system



Mathematical model



Estimated future performance



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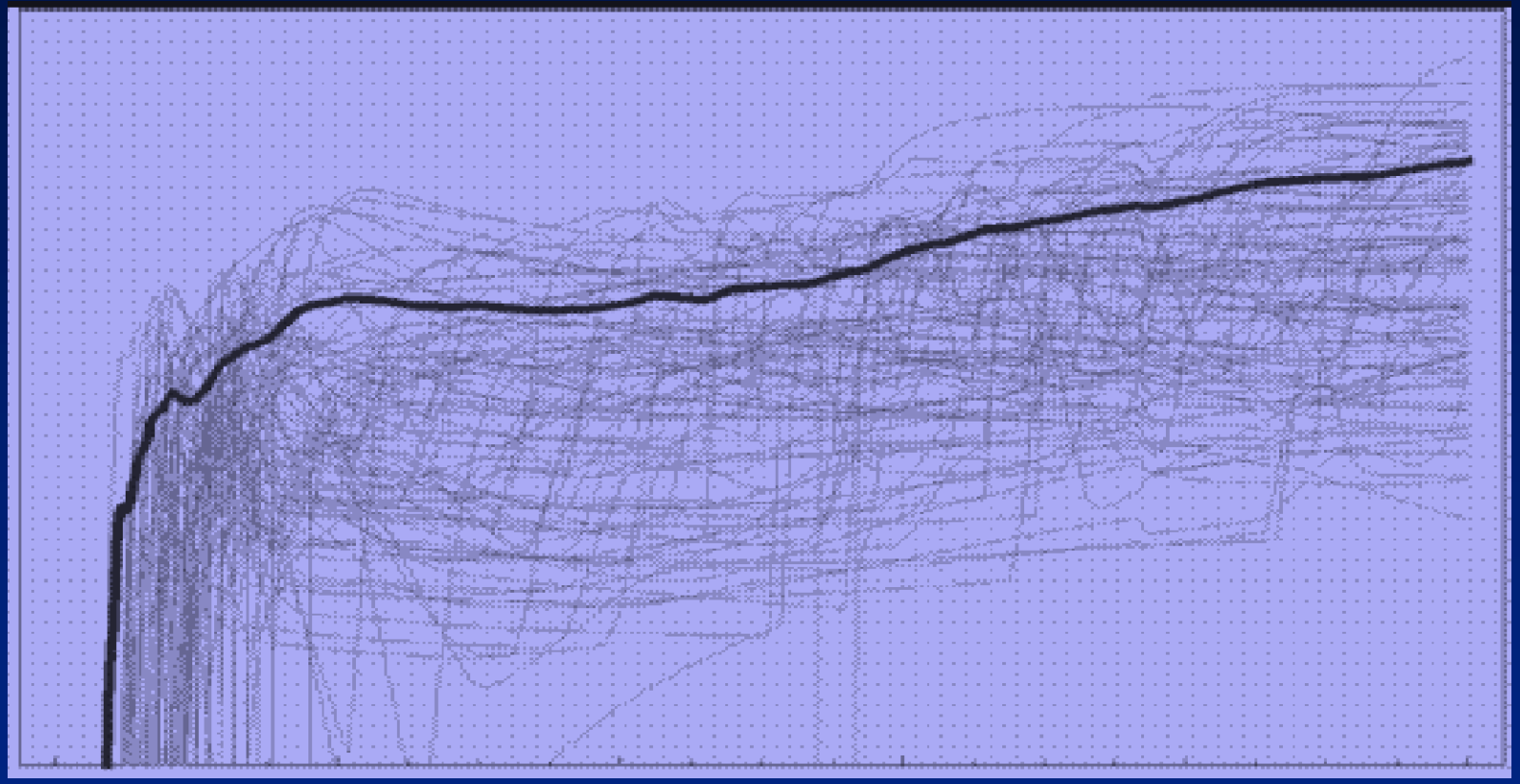
Dose - Time PA Outputs



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The Concept of IAEA Safety Case (SC)

- **NEA SC Definition: "The synthesis of evidence, analyses and arguments that quantify and substantiate a claim that the repository (i.e.; disposal facility) will be safe after closure and beyond the time when active control of the facility can be relied on".**

- **IAEA SC Definition: A collection of arguments and evidence to demonstrate the safety of a facility and to assist in key decision-making.**

- **The SC has to be developed in the early phases of the development of a project. It constitutes the basis for internal decisions by the operator/licensee (e.g.; site selection, safety evaluation, design conceptualization and optimization, etc.…) as well as to establish a dialogue with the regulator and stakeholders.**

IAEA SC Requirements

- **Requirement 12: Preparation, Approval and use of the safety case and safety assessment for a disposal facility**

"A safety case and supporting safety assessment shall be prepared and updated by the operator, as necessary, at each step in the development of a disposal facility, in operation and after closure. The safety case and supporting safety assessment shall be submitted to the regulatory body for approval. The safety case and supporting safety assessment shall be sufficiently detailed and comprehensive to provide the necessary technical input for informing the regulatory body and for informing the decisions necessary at each step"

- **Requirement 13: scope of the Safety Case and safety assessment**

The safety case for a disposal facility shall describe all safety relevant aspects of the site, the design of the facility, and the managerial control measures and regulatory controls. The safety case and supporting safety assessment shall demonstrate the level of protection of people and the environment provided and shall provide assurance to the regulatory body and other interested parties that safety requirements will be met"

- **Requirement 14: Scope of the Safety Case and Safety Assessment**

The safety case and supporting safety assessment for a disposal facility shall be documented to a level of detail and quality sufficient to inform and support the decision to be made at each step and to allow for independent review of the safety case and supporting safety assessment"

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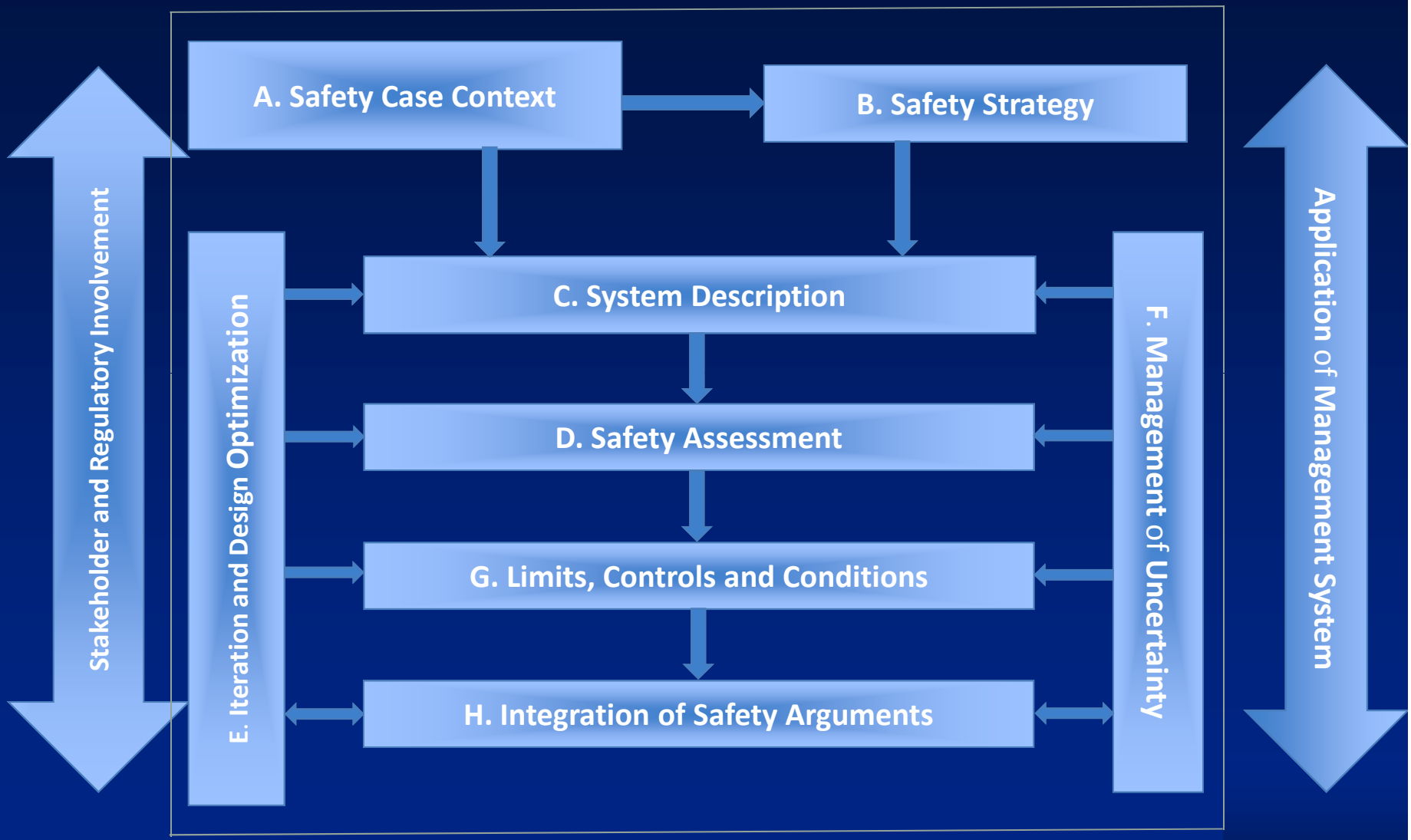
IAEA Safety Case Components



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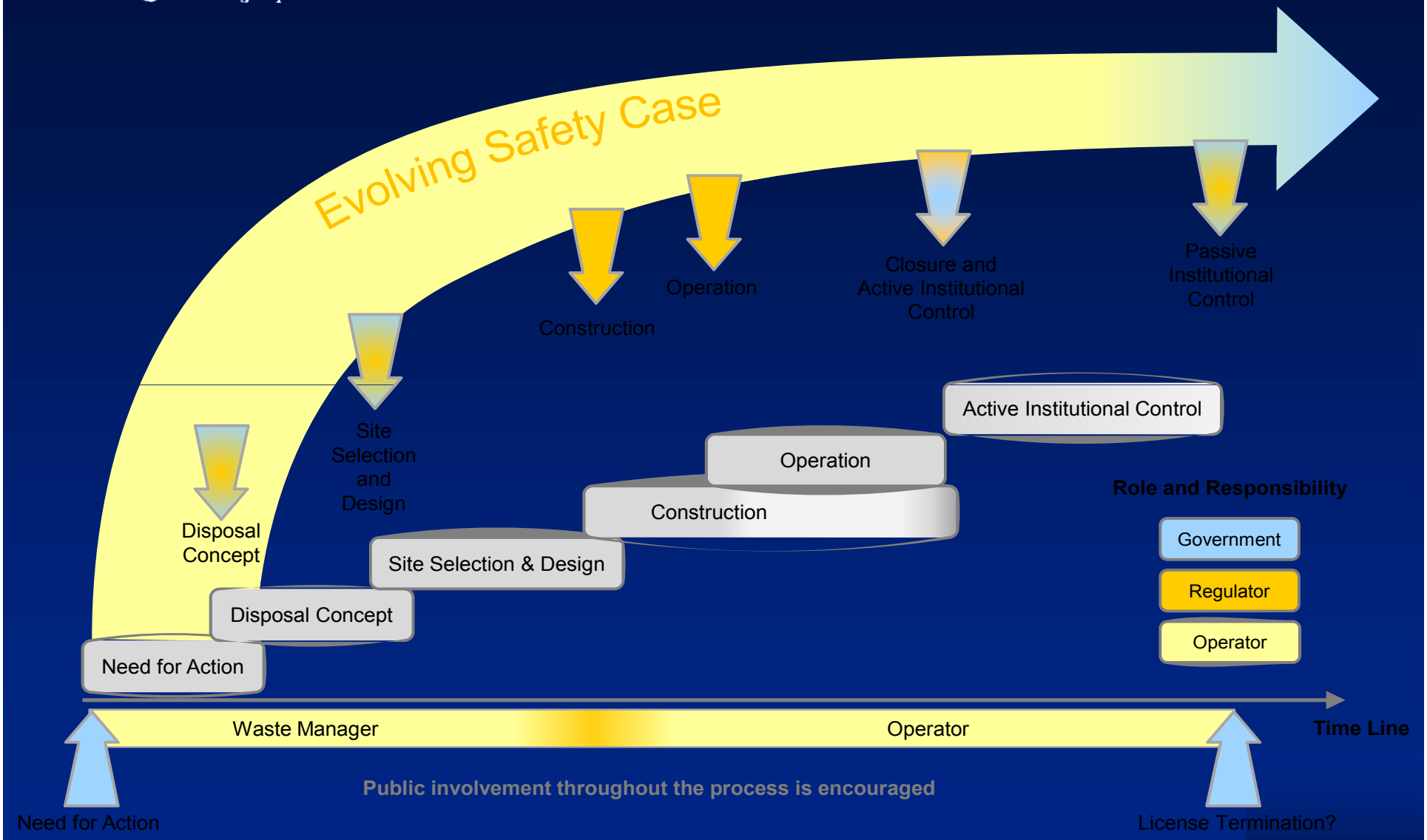
Safety Case & Decision Steps



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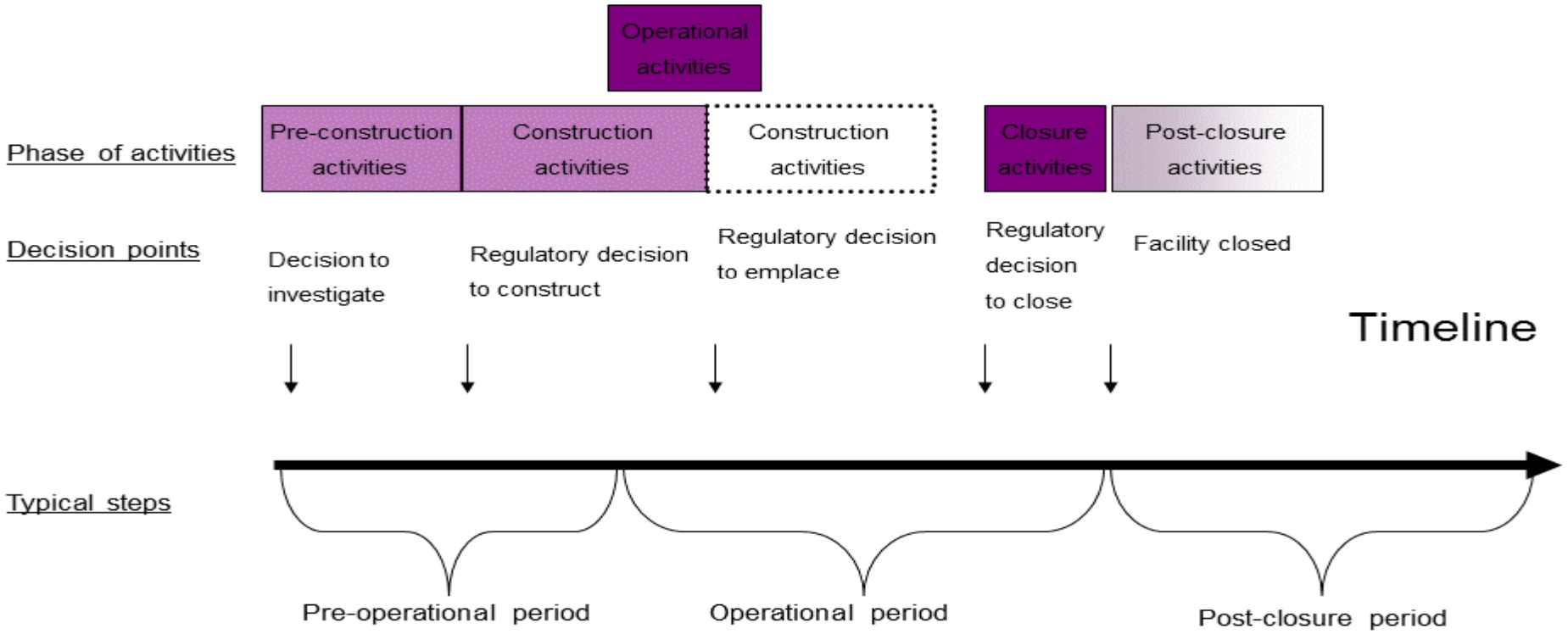
Life Cycle Periods of SC



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IAEA PRISM

Waste Characteristics
Comparison of Options
National Strategy
Regulations
International Guidance and Duties /Commitments
Involvement of Stakeholders
Safety Strategy
Site Characteristics
Financial Considerations
Regulatory Process
Environmental Impacts Assessment
Radiological Impact and Performance Assessment
Management System
Monitoring
Security
Additional Measures to Increase Confidence
R&D
Operational Safety

Safety Case

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Analysis and Ranking of Safety Functions, Safety Arguments and Related Decisions

Main Decision-Making Steps	Need for Action	Disposal Concept	Site Selection and Design	Construction		Operation		Closure and Active Institutional Control	Passive Institutional Control	Post Licensing
Safety Case Component	Decision: Go for disposal or/and Decision for reassessment of an existing facility	Decision on the disposal concept and the Safety Strategy in a given environment (conditions)	Decision: choose the site and associated design	Decision for construction (operator)	Decision: Authorization and/or license for construction (authorities)	Decision to operate (operator)	Decision: Authorization and license for operation (authorities)	Decision to close and initiate the active institutional control period	Decision to initiate the passive institutional control period	Decision or not to release the regulatory control
Safety Case Context										
Management										
Stakeholder and Regulatory Process										
Optimisation										
Uncertainties										
Safety Strategy										
System Description										
Safety Assessment										
Integration of Safety Arguments										
Limits, Control & Conditions										

=> Not relevant to the decision at hand
=> Of value but less significant
=> Significant
=> Mandatory

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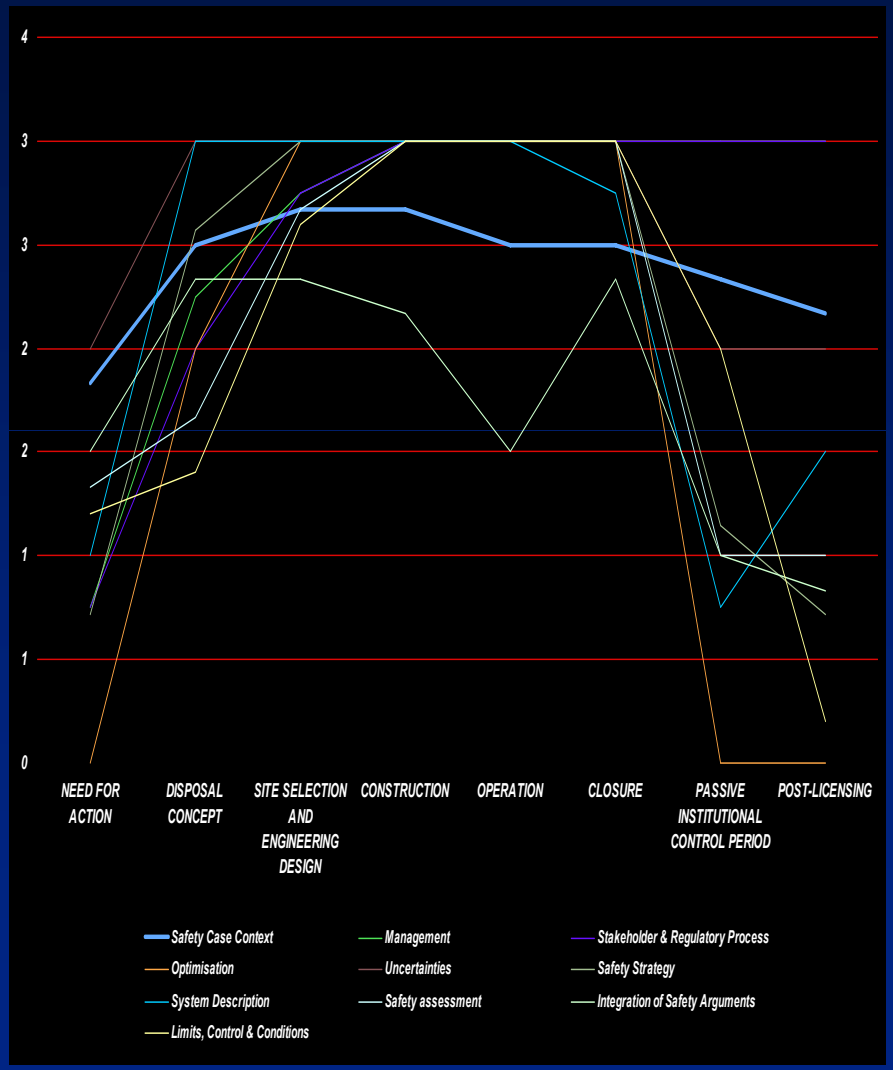
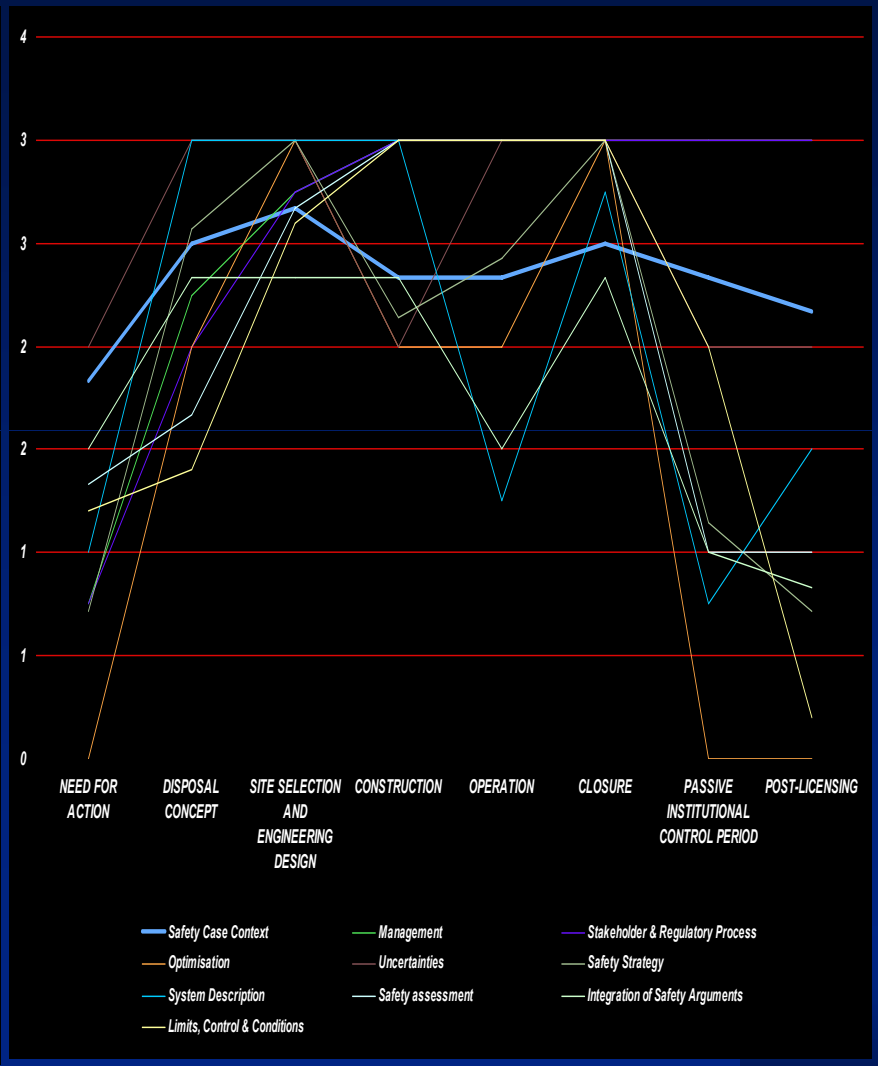
Time Dependence of the Safety Arguments





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PA & Safety Case Issues

- How to treat future site conditions, processes, events, & climate change
- Exposure scenarios assumptions, probability & compliance dose criteria
- Performance of engineered barriers
- Timeframe for LLW performance assessment
- Treatment of sensitivity and uncertainty and integration of uncertainties
- Role of performance assessment during operational and post-closure periods
- Overall integration of site characterization, facility design performance assessment, and safety analysis during facility life cycle and update of the safety case
- Bench-marking and QA/QC issues
- Stakeholders Inputs

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Summary, Conclusion, and Path Forward

- Basic approaches and methodologies of generic NRC LLW PA, addressing 10 CFR Part 61 performance objectives, are well established in NUREG-1573
- NRC PA approaches and methodologies for review of U.S. DOE Waste Determinations are well established in NUREG-1854
- PA analysis for LLW evaluation of specific sites, or specific waste streams, can be developed as necessary based on a case-by-case basis. PA regulatory issues are typically addressed through coordination of staff technical analysis and managers, as directed by the Commission, in consideration of stakeholders inputs.
- PA analysis and management decisions will continue to be based on "Risk-Informed Performance Based Approach and Realistic Conservatism"
- IAEA safety case is a comprehensive approach involving decision-making and safety assessments by operators, regulators, and governments, with stakeholders' inputs. It applies to actions and decisions during all phases facility life cycle.
- NRC staff welcome international PA collaboration and continued dialogue and exchange of information

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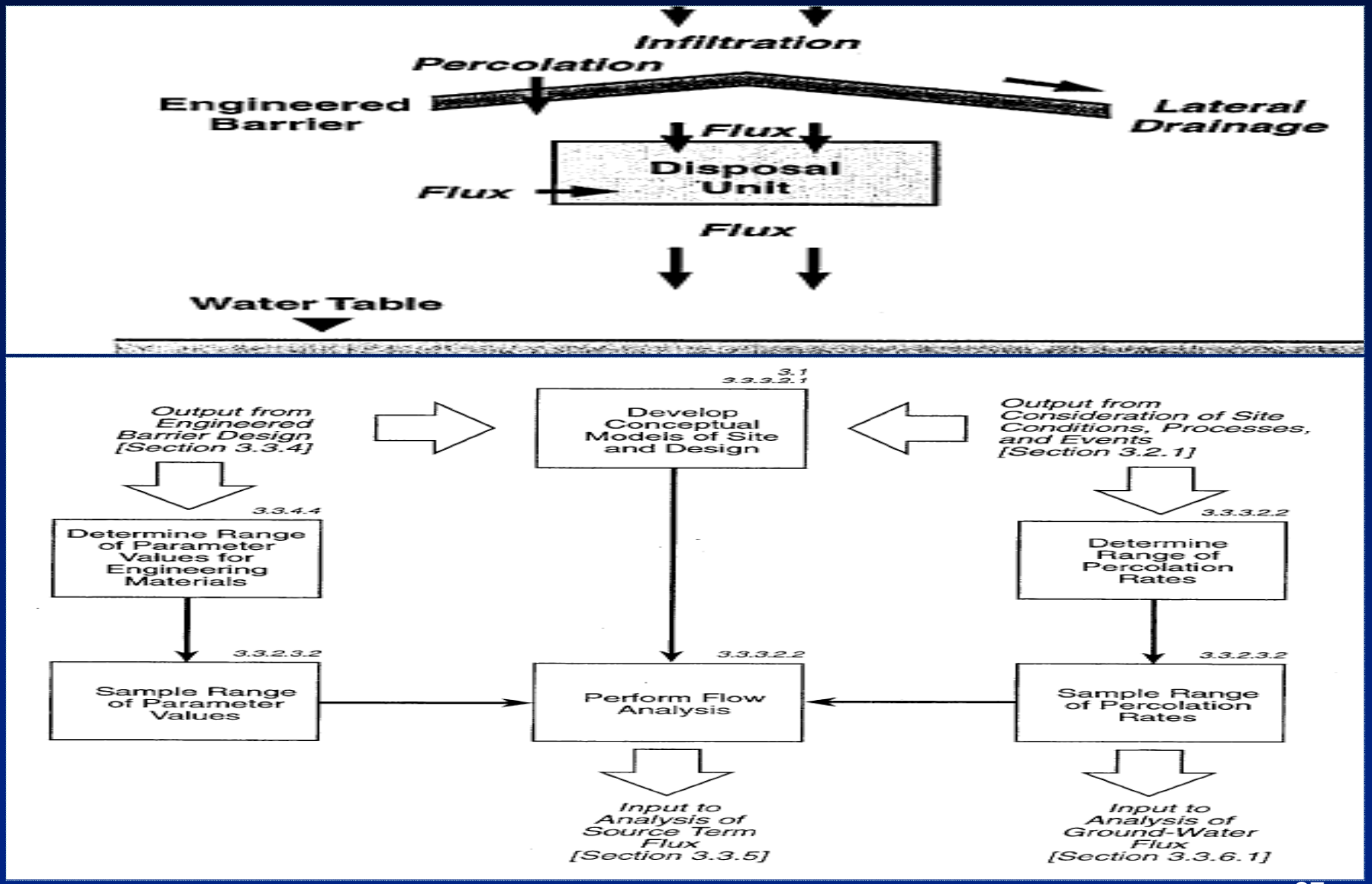
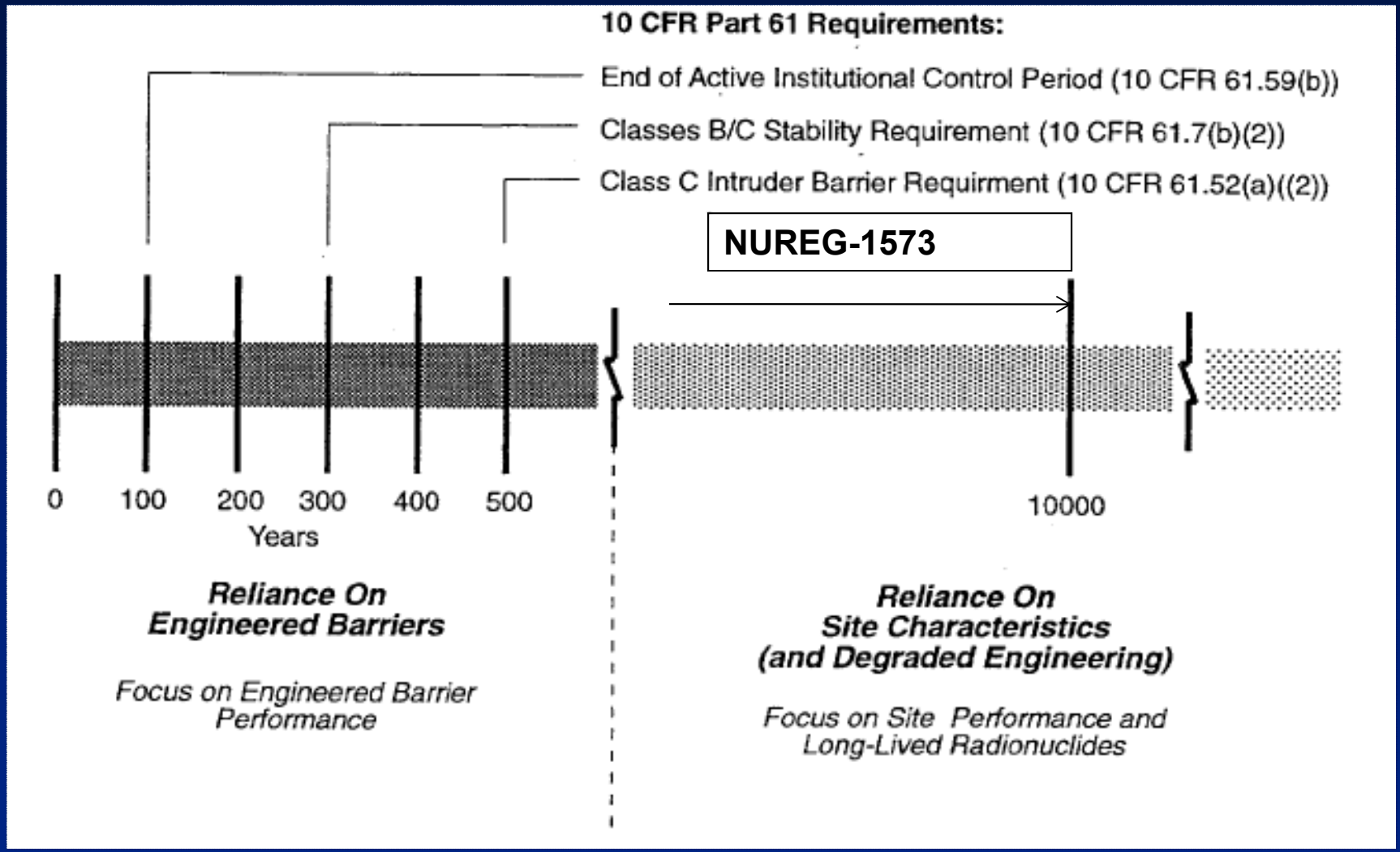
BACKUP SLIDES

Infiltration Process and Recommended Approach for LLW PA Analysis



LLW Timeframe and Performance Period



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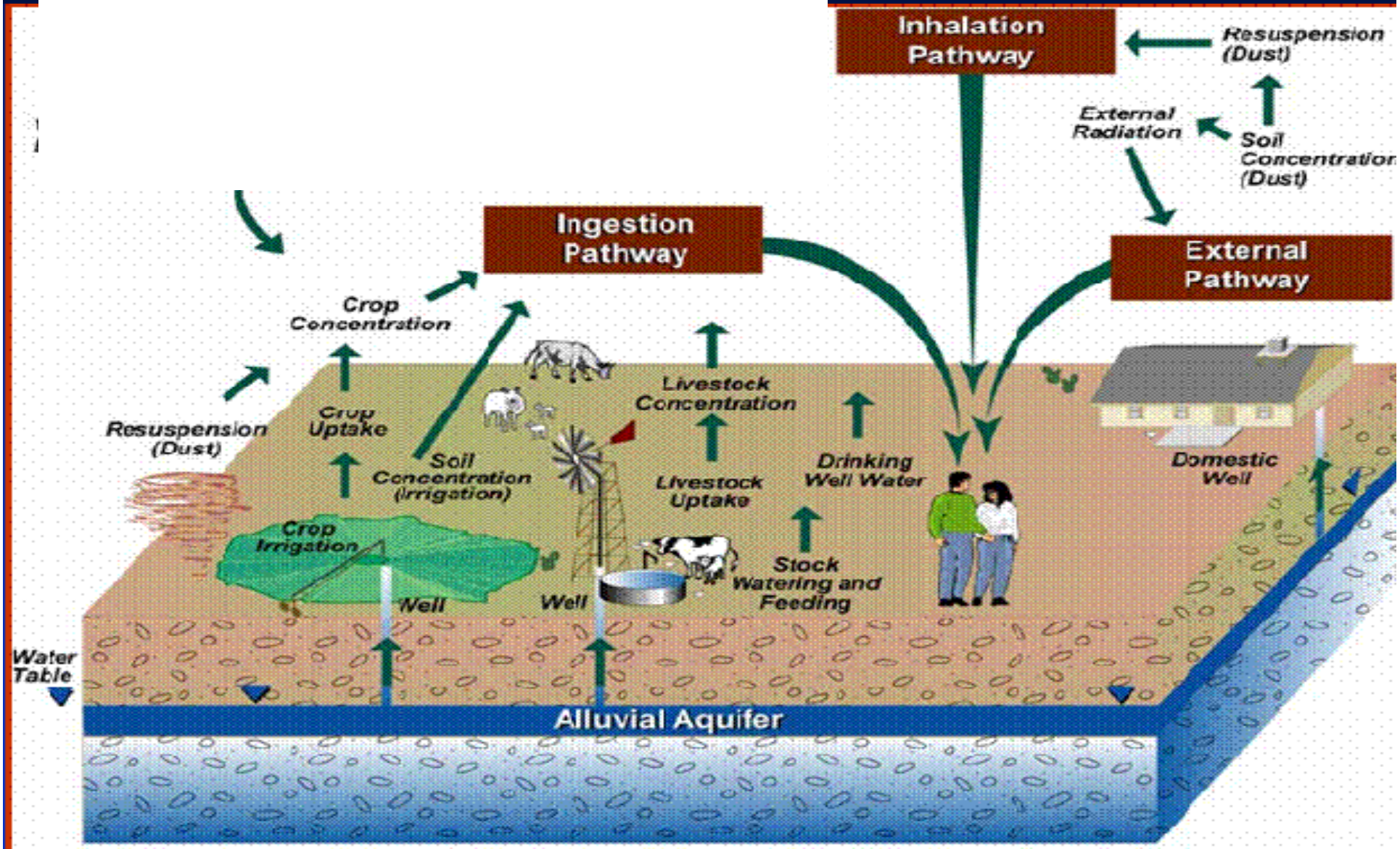
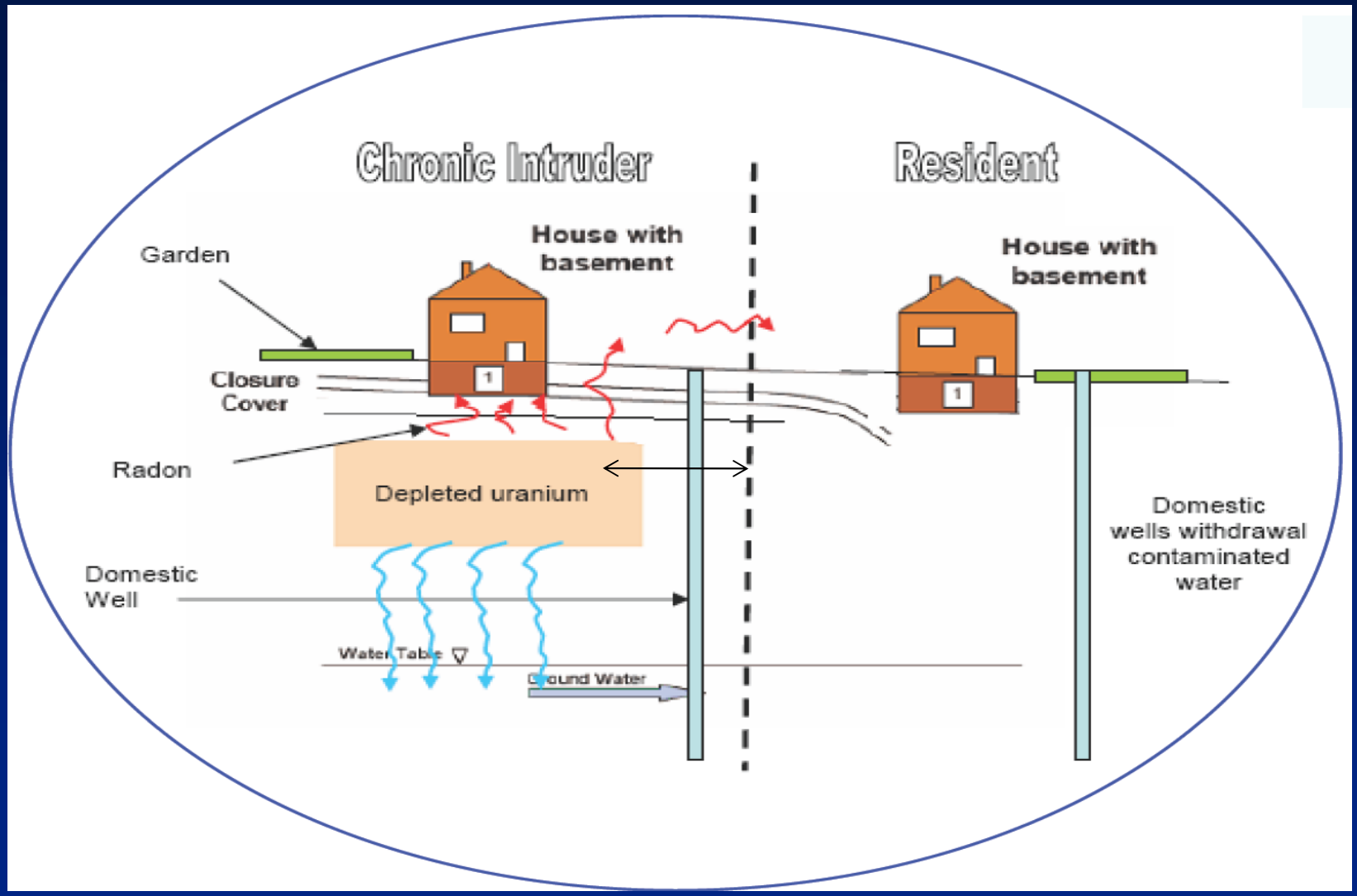
Schematic Illustration of Potential Exposure Pathways



Schematic Illustration of Examples of Exposure Scenarios



Examples of Key Elements and Parameters in PA Analysis

- Key PA Elements:
  - Period of performance, disposal depth, receptor scenario (pathways and location), correlation of parameters, integration and consistencies of sub-models particularly and transport and dose impact calculations, and bench-marking and QA/QC
- Examples of Parameters
  - Hydraulic: conductivity, gradient of aquifer, infiltration rate
  - Chemical & Geochemical: solubility, liquid saturation, retardation
  - Exposure Scenario: sources of exposure, and occupancy time, residence parameters, location of receptor, and intake parameters

PA Regulatory Issues

- How to treat future site conditions, processes, events, and climate change
- Exposure scenarios & compliance dose criteria
- Performance of engineered barriers
- Timeframe for LLW performance assessment
- Treatment of sensitivity and uncertainty
- Role of performance assessment during operational and post-closure periods
- Overall integration of site characterization, facility design performance assessment, and safety analysis
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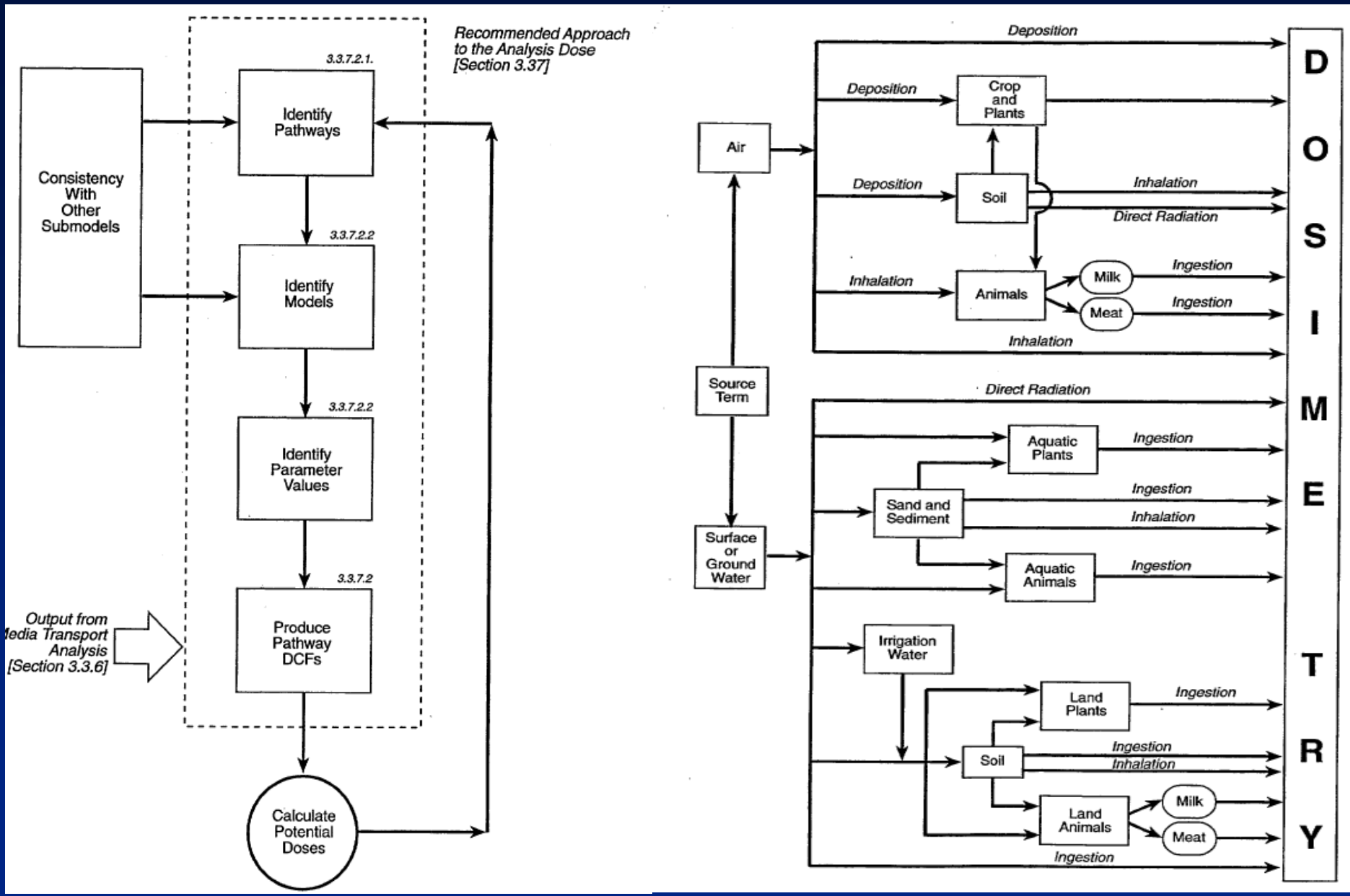
- Stakeholders Inputs

NRC's Recommended Approach to Dose Impact Analysis Calculations



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Safety Case Context	↑					↑			↑	↑
Management		↑								
Stakeholder and Regulatory Process		↑								
Optimisation		↑		↑		↑				
Uncertainties	↑			↑					↑	↑
Safety Strategy				↑		↑				
System Description										↑
Safety Assessment	↑	↑								
Integration of Safety Arguments	↑	↑	↑	↑	↑	↑	↑	↑		
Limits, Control & Conditions										

	=> Not relevant to the decision at hand
	=> Of value but less significant
↑	=> Significant
	=> Mandatory

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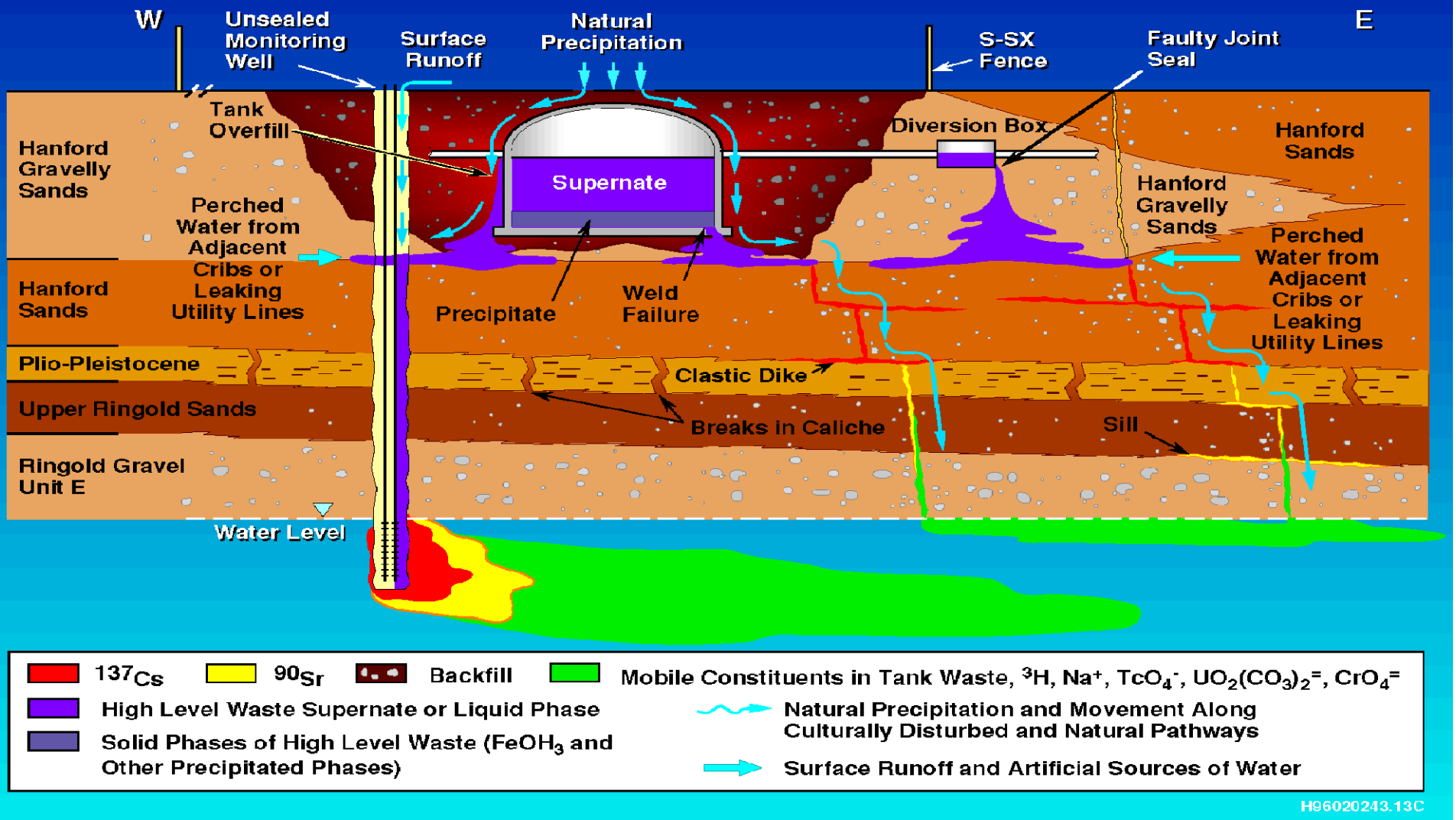
Conceptual Model of Complex Site with Multiple Sources



from Ward et al. (1997) after Caggiano et al. (1996)

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SC Context Main Arguments

Safety Case Context	-**National Strategy** -**National Legal Framework** **- Regulations** **- International Commitments** **- International Guidances** **- Licensing Process** **- Financial Considerations**