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Integrated Risk Assessment Approaches, Methods, and Tools - NRC's Decommissioning & LLW Programs

Rateb (Boby) Abu Eid, Ph. D. (boby.abu-eid@nrc.gov)

Division of Waste Management and Environmental Protection

U.S. Nuclear Regulatory Commission,

Washington D.C., 20555, USA

Recent Developments and Trends in Integrated Risk Assessment Methods, Tools and Decision Analysis Support (Session #103)

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Presentation Topics

- **NRC's risk management regulatory framework & recommendations (NUREG-2150);**
- **Staff approach to risk-informed, performance-based approaches to decommissioning and LLW assessment;**
- **NRC's decommissioning and LLW risk/dose based regulations;**
- **NRC's risk/dose assessment guidance, methods, and tools for LLW and decommissioning; and**
- **PA and Risk/Dose Assessment Issues.**

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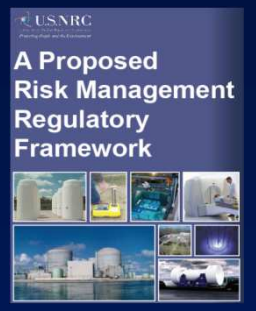
NRC's Integrated Risk Management (NUREG-2150)



Objective

Manage the risks from the use of byproduct, source, and special nuclear materials through appropriate performance-based regulatory controls and oversight

Goal

Provide risk-informed and performance-based defense-in-depth protection to:

- **Ensure appropriate barriers, controls, and personnel to prevent, contain, and mitigate exposure to radioactive material according to the hazard present, the relevant scenarios, and the associated uncertainties**
- **Ensure that the risk resulting from the failure of some or all of the established barriers and controls, including human errors, are maintained acceptably low**

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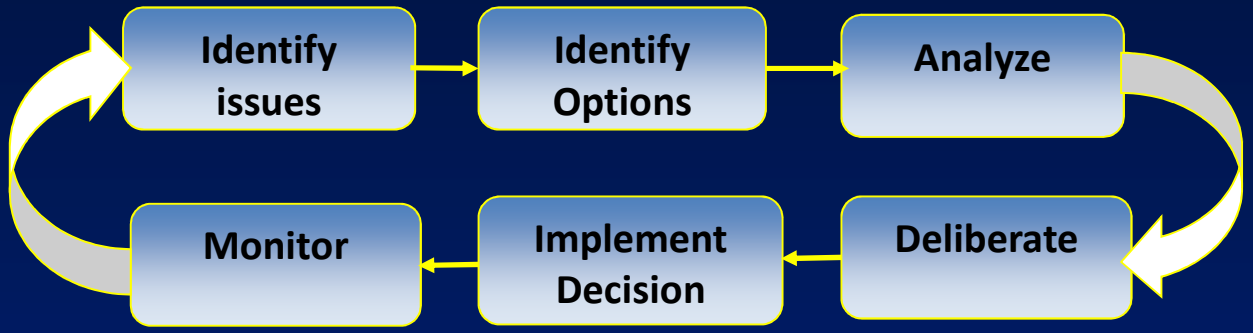
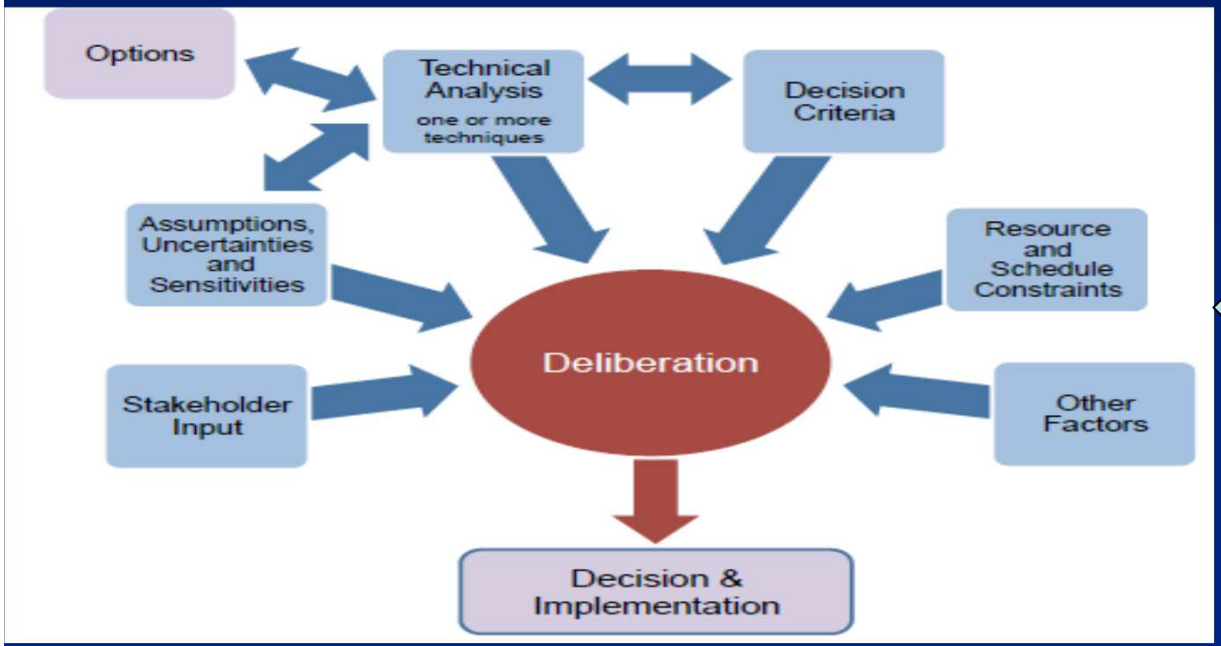
Decision-Making Process



Use a disciplined process to achieve the risk management goal



Deliberation Process

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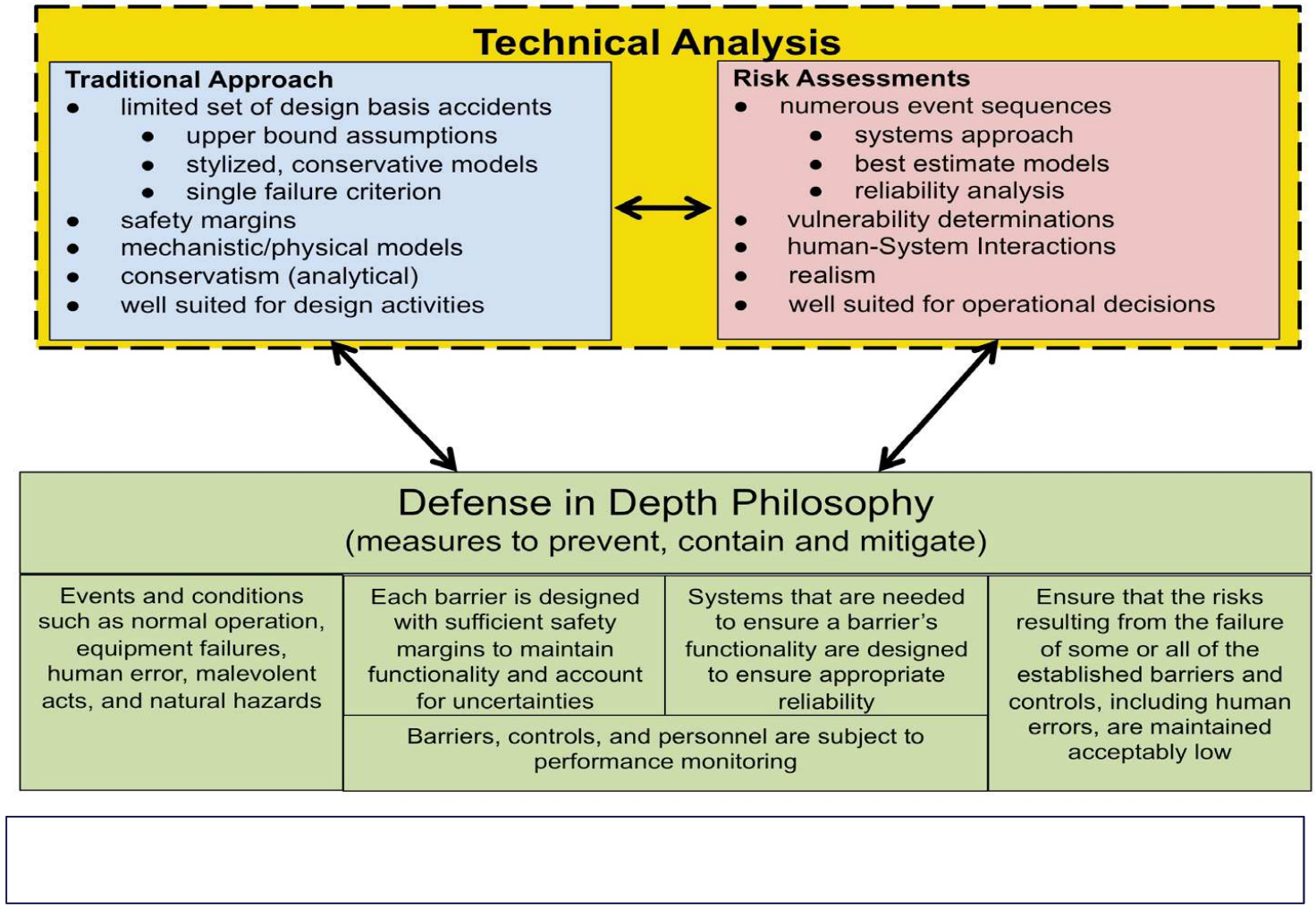
Balancing Risk Assessment, Deterministic Techniques, and Defense-in-Depth Philosophy



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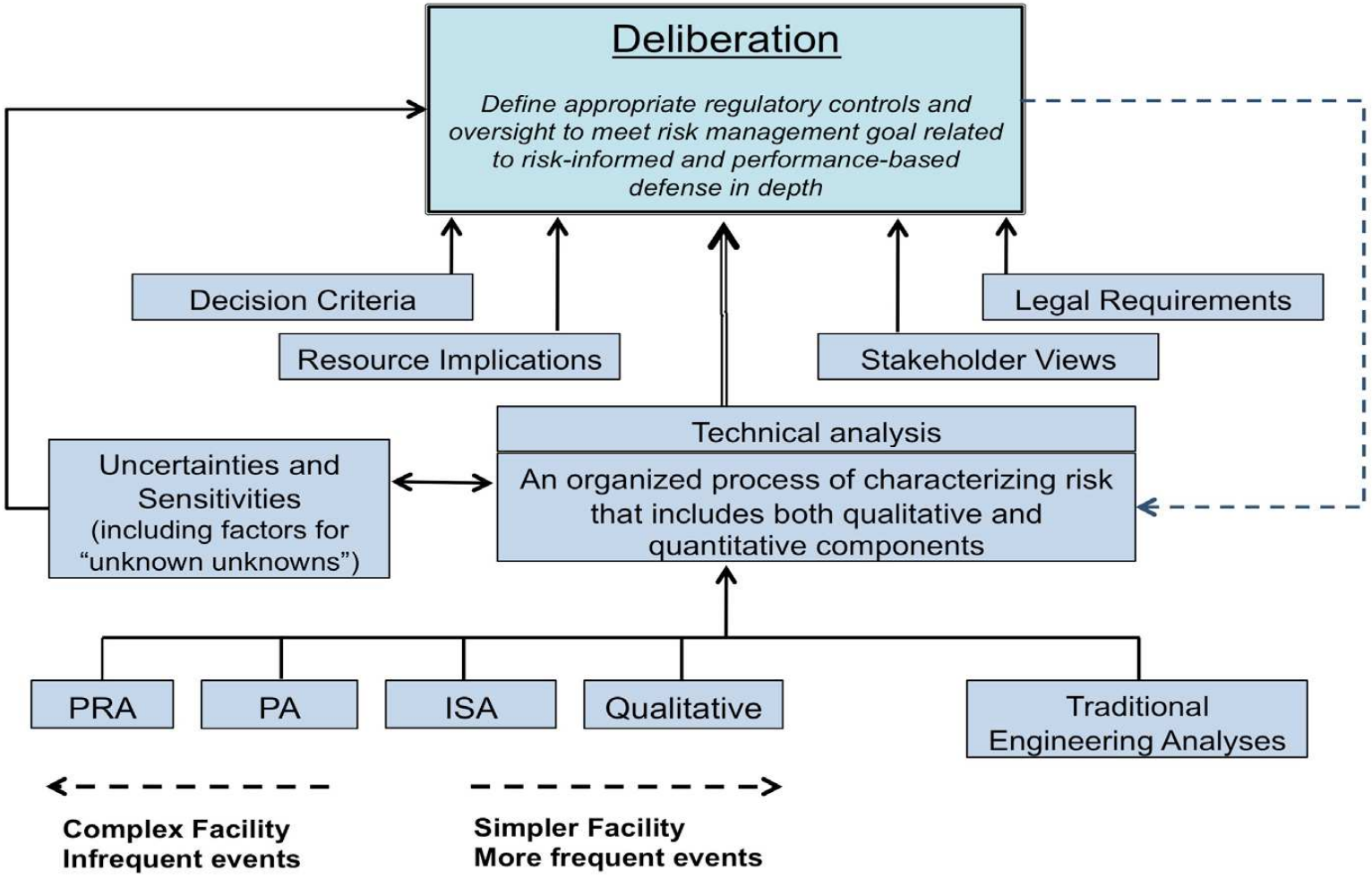
Technical Analysis Techniques and Deliberation



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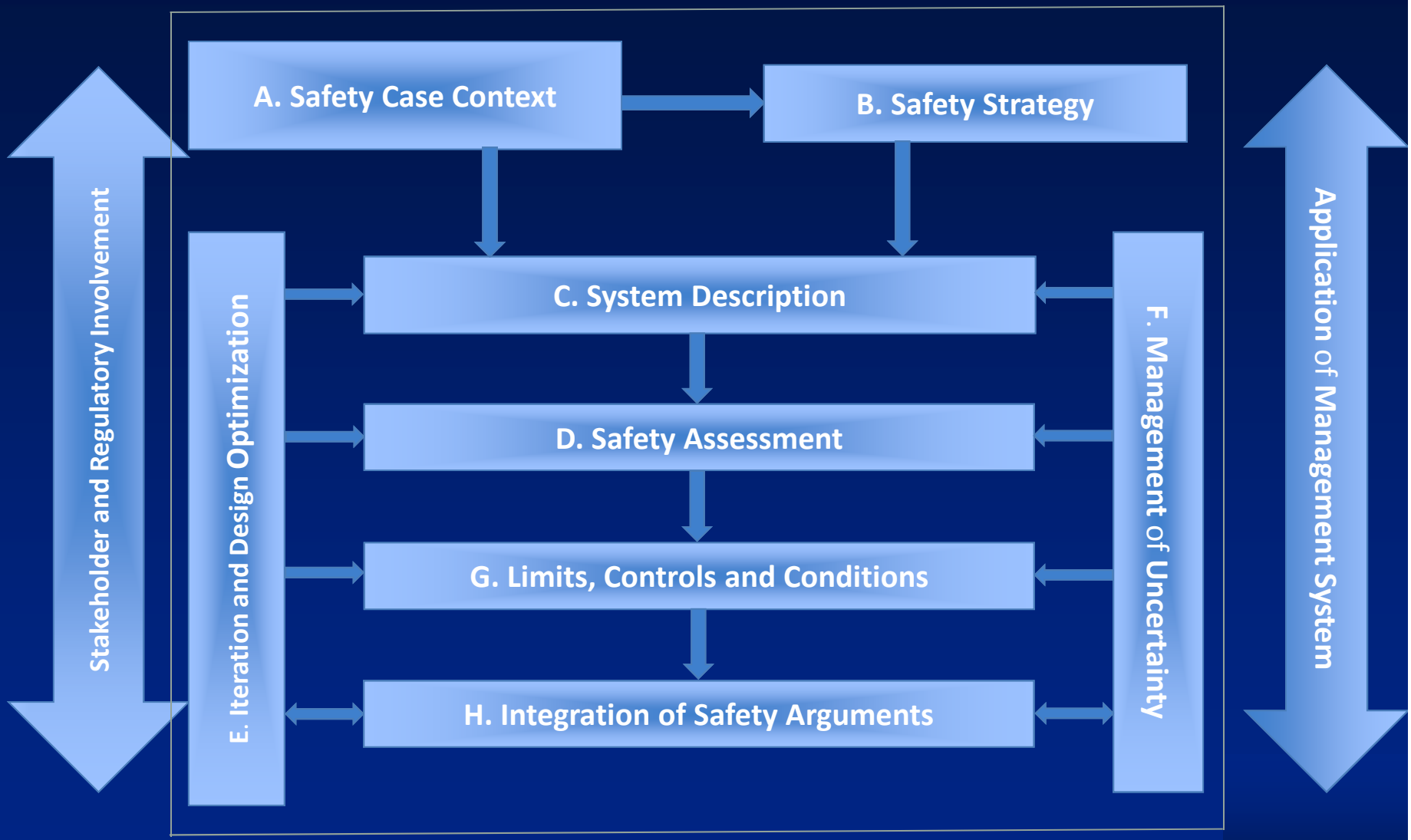
IAEA Safety Case Components



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NRC's Approach to Risk-Informed, Performance Based Assessments for LLW & Decommissioning

- **Facilitate application of risk-informed and performance-based implementation of the NRC's rulemaking, licensing, and oversight functions for LLW, including waste incidental to reprocessing, and decommissioning on a case-by-case basis.**
- **Staff engagement in development, maintenance, and evaluation of probabilistic environmental models and codes for risk/dose analysis.**
- **Use of probabilistic distributions as inputs to uncertain physical and behavior parameters, particularly in independent staff reviews.**
- **In review of DOE waste incidental to processing determination, the staff utilizes risk-informed performance-based approaches including uncertainty/sensitivity analyses and alternate conceptual models. The risk insights gained during the review are utilized to establish the monitoring areas for a site**
- **Use of probabilistic tools with sensitivity/uncertainty analysis to demonstrate compliance with the dose criteria in Subpart E of 10 CFR Part 20, and use of the mean of the peaks dose or peak of the means dose.**

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10 CFR Part 61 Subpart C Performance Objectives

- **§ 61.41 Protection of the general population from release of radioactivity: *(annual doses not to exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ and maintain effluent releases ALARA).***

- **§ 61.42 Protection of individuals from inadvertent intrusion: (Design, operation, and closure of the disposal facility must ensure protection of individuals from inadvertent intrusion).**

- **§ 61.43 Protection of individuals during operations: (Operation must be conducted in compliance with Part 20 and effluent releases shall be governed by § 61.41).**

- **§ 61.44 Stability of disposal site after closure: (the LLW facility must be sited, designed, used, operated, and closed to achieve long-term stability) so that following closure, only surveillance, monitoring, or minor custodial care are required**

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License Termination Criteria

- **License Termination Standards for Unrestricted Use**

  10 CFR 20.1402: Total Effective Dose Equivalent (TEDE) to an average member of the critical group (AMCG) not to exceed 25 mrem per year (≤ 0.25 mSv/yr) and As Low As is Reasonably Achievable (ALARA); All pathways;
  Period of performance - 1000 years (20.1401 (d)).

- **License Termination Standards for Restricted Use**

  10 CFR 20.1403: not to exceed 25 mrem per year (≤ 0.25 mSv/yr) TEDE and ALARA, with institutional controls in effect. If institutional controls were no longer in effect, the TEDE would be ALARA and dose to AMCG would not exceed (100 mrem (1 mSv/yr); or 500 mrem (5 mSv/yr), under provisions of § 20.1403 (e).

- **Alternate Criteria for License Termination**

  10 CFR 20.1404: 20.1404 (a) use of alternate criteria greater than the dose criterion of 20.1402, 20.1403(b), and 20.1403(d)(1)(i)(A) requires that licensee demonstrate that (1) doses to public from all man-made sources other than medical are unlikely to exceed 100 mrem/y, 1 mSv/yr TEDE; (2) restrictions on site according to 20.1403; (3) doses are ALARA; and (4) it has submitted decommissioning or license termination plan specifying use of alternate criteria. 20.1404(b) Commission approves requests to use alternate criteria.

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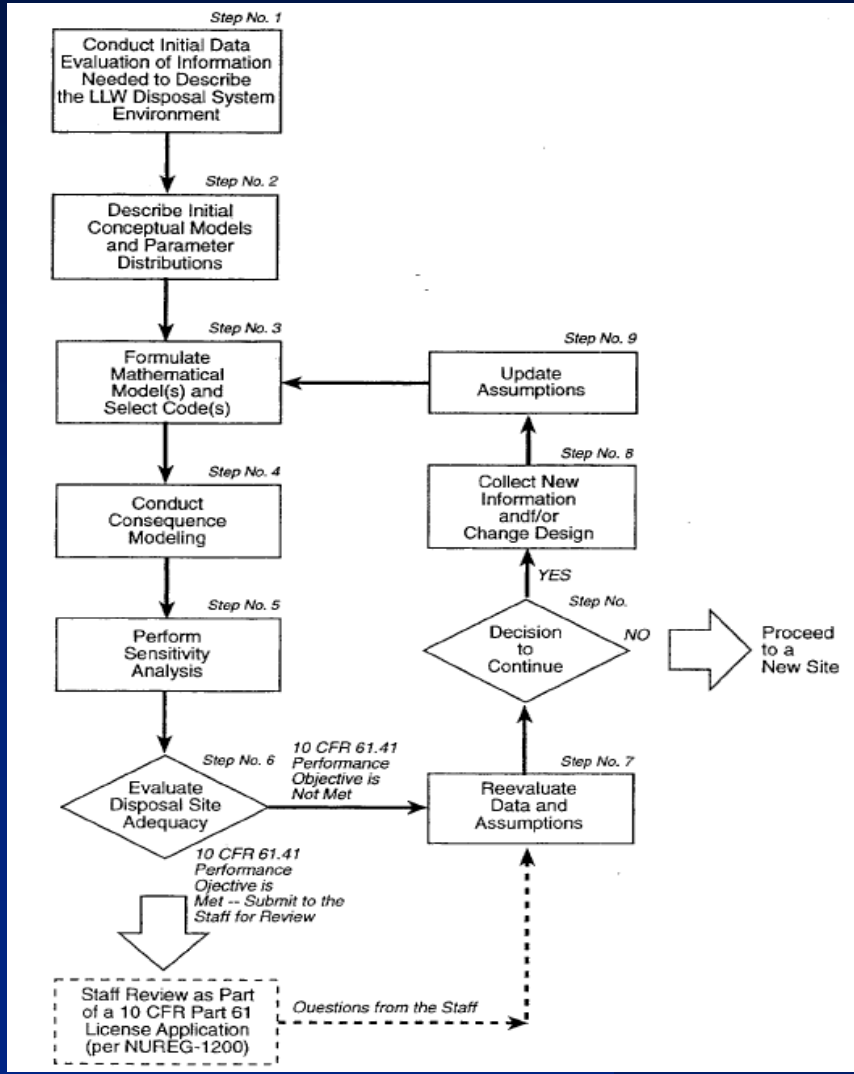
Steps in NRC NUREG-1573 PA Methodology Reviews

- 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



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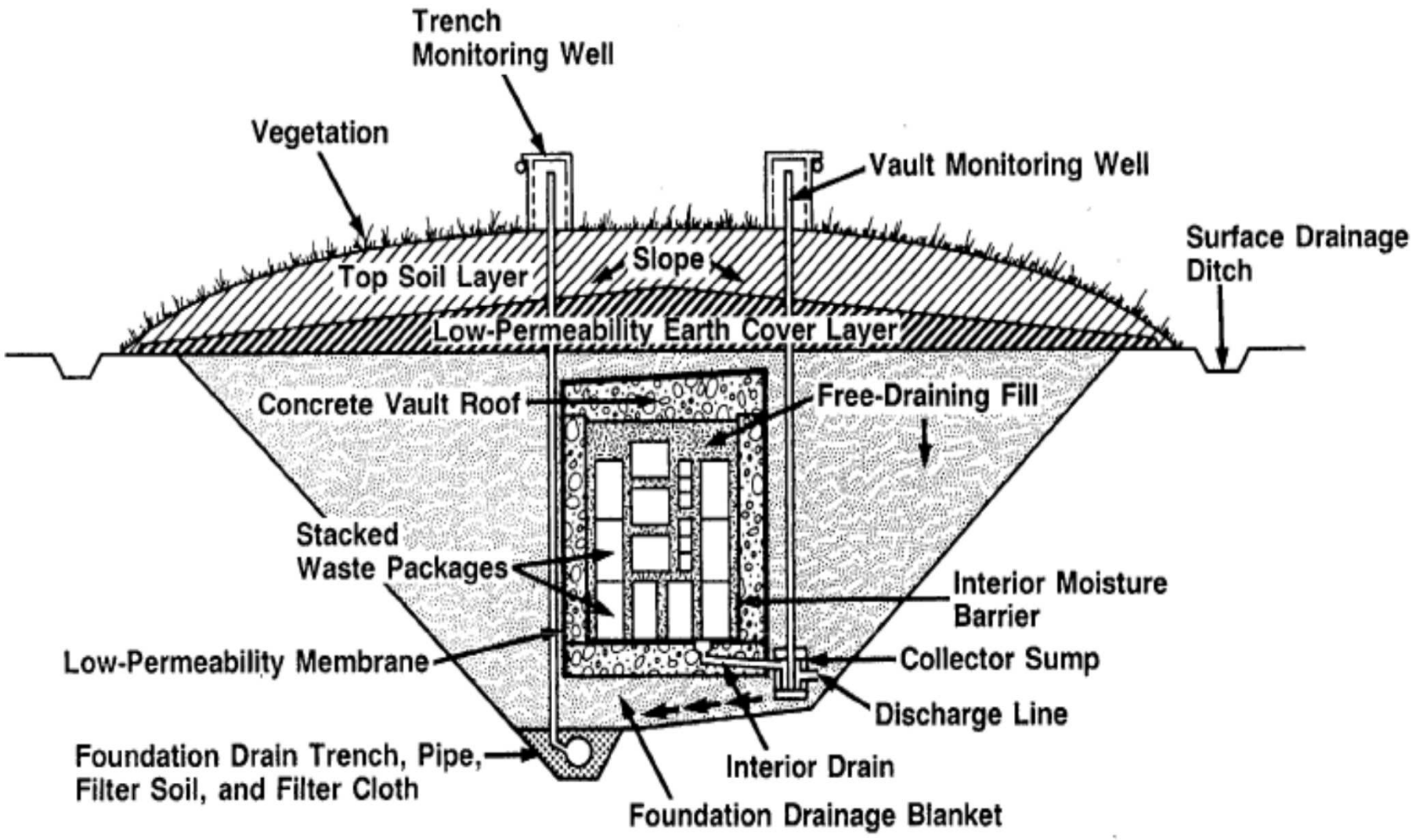
A LLW Disposal Design Concept



NUREG-1573

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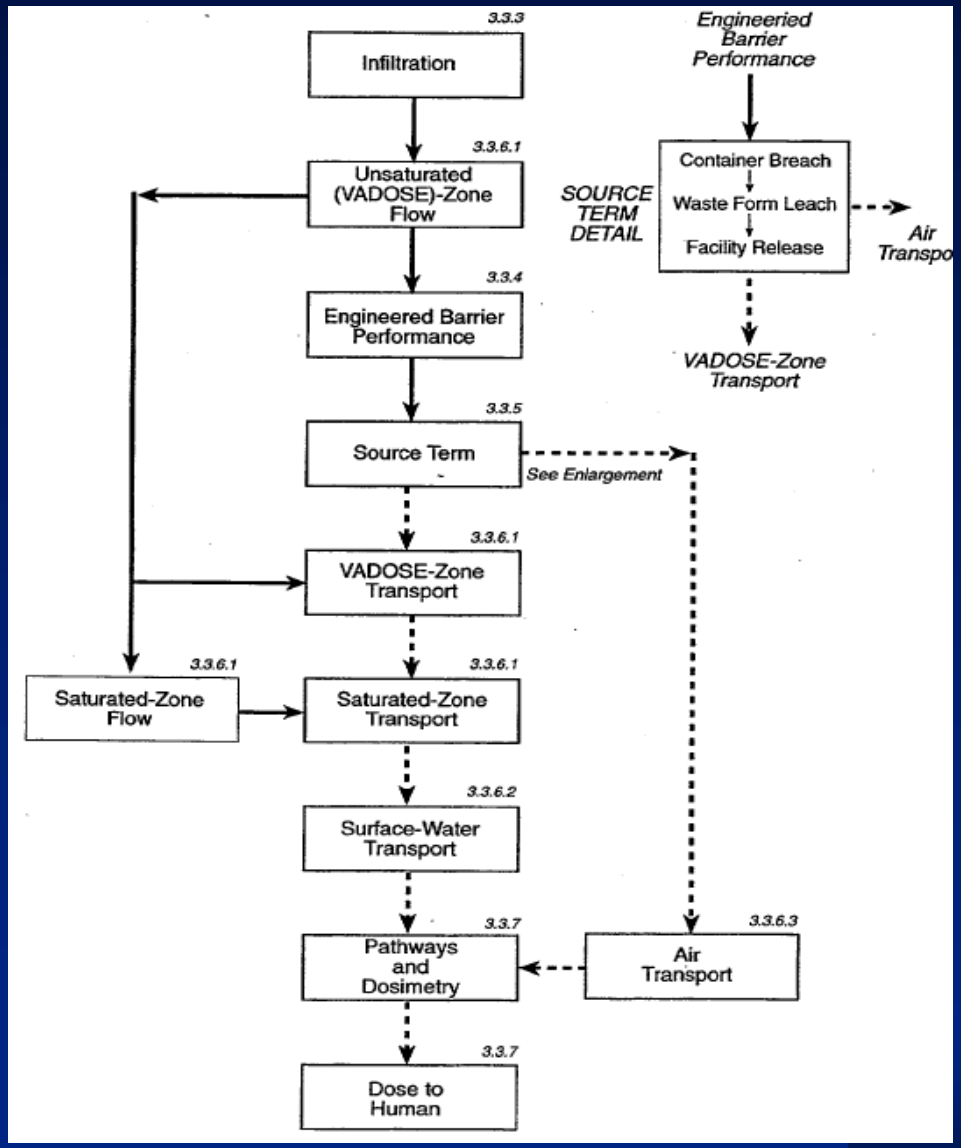
Specific Processes Considered in NRC LLW PA

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

NUREG-1573



NUREG-1854 PA Reviews Generic Approaches

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

- The guidance emphasizes the need for adequate modeling 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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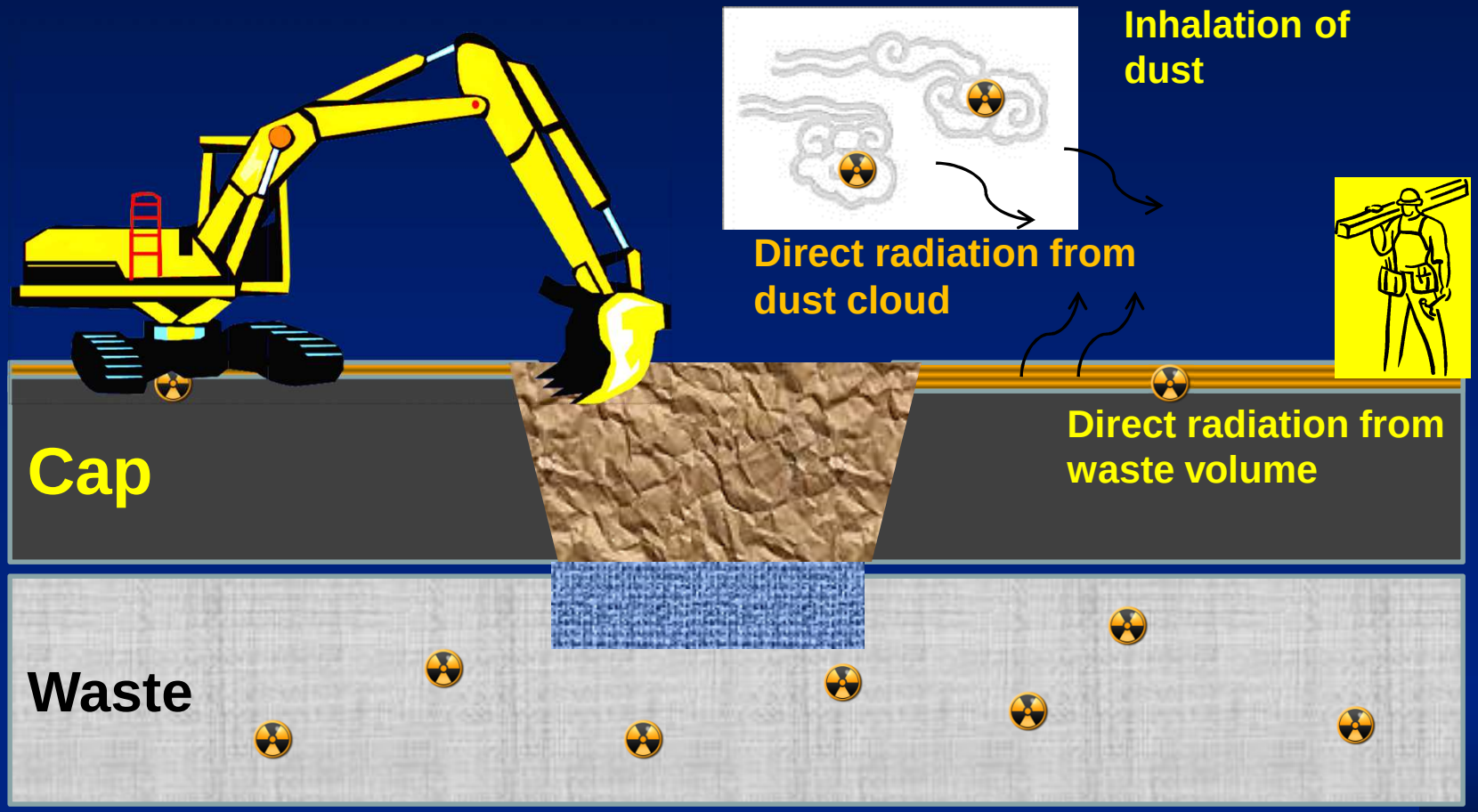
Intruder Scenario Used for LLW PA

Intruder Construction



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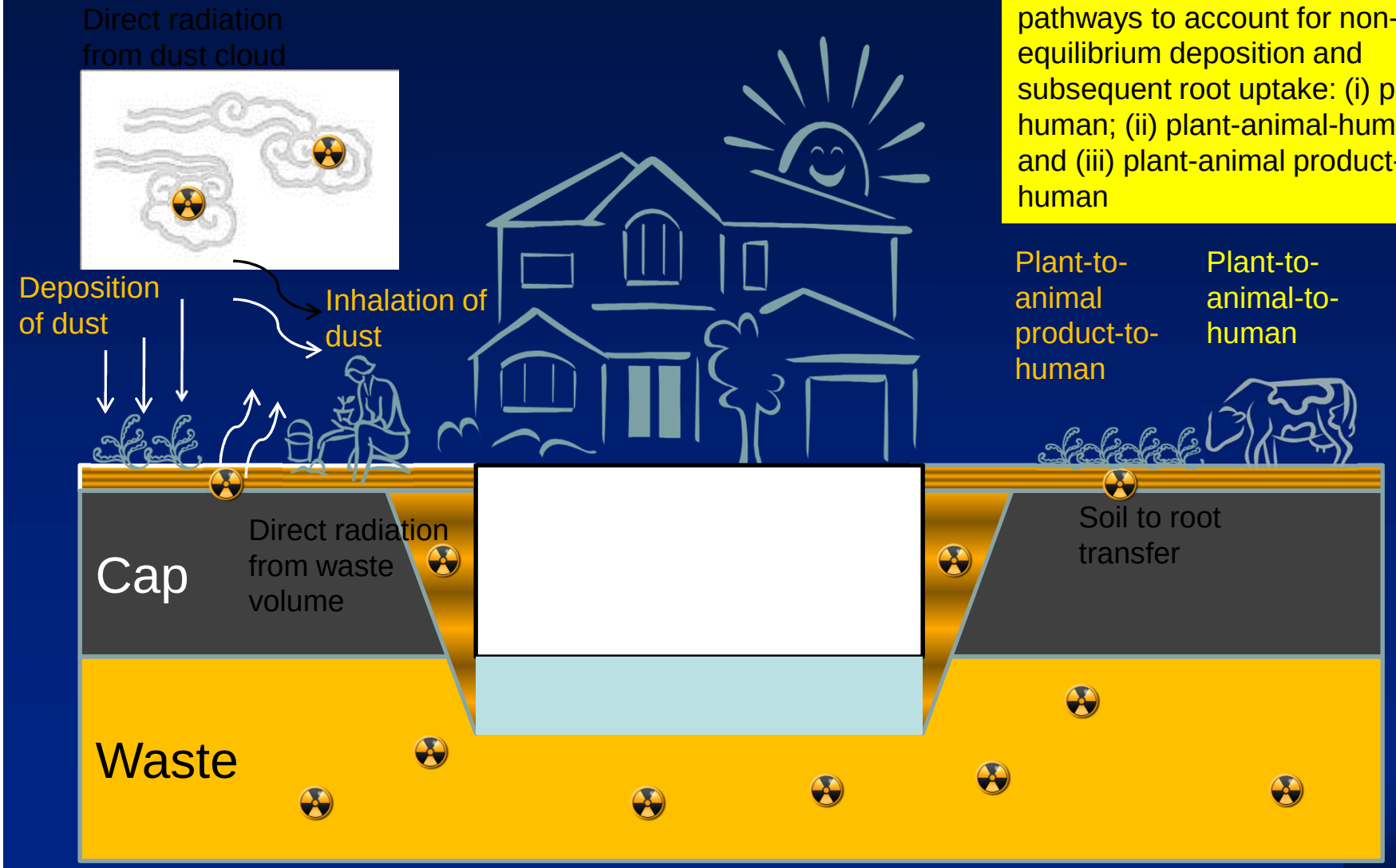
Intruder Agriculture Scenario for LLW PA

NOTE: Includes modified food pathways to account for non-equilibrium deposition and subsequent root uptake: (i) plant-human; (ii) plant-animal-human; and (iii) plant-animal product-human



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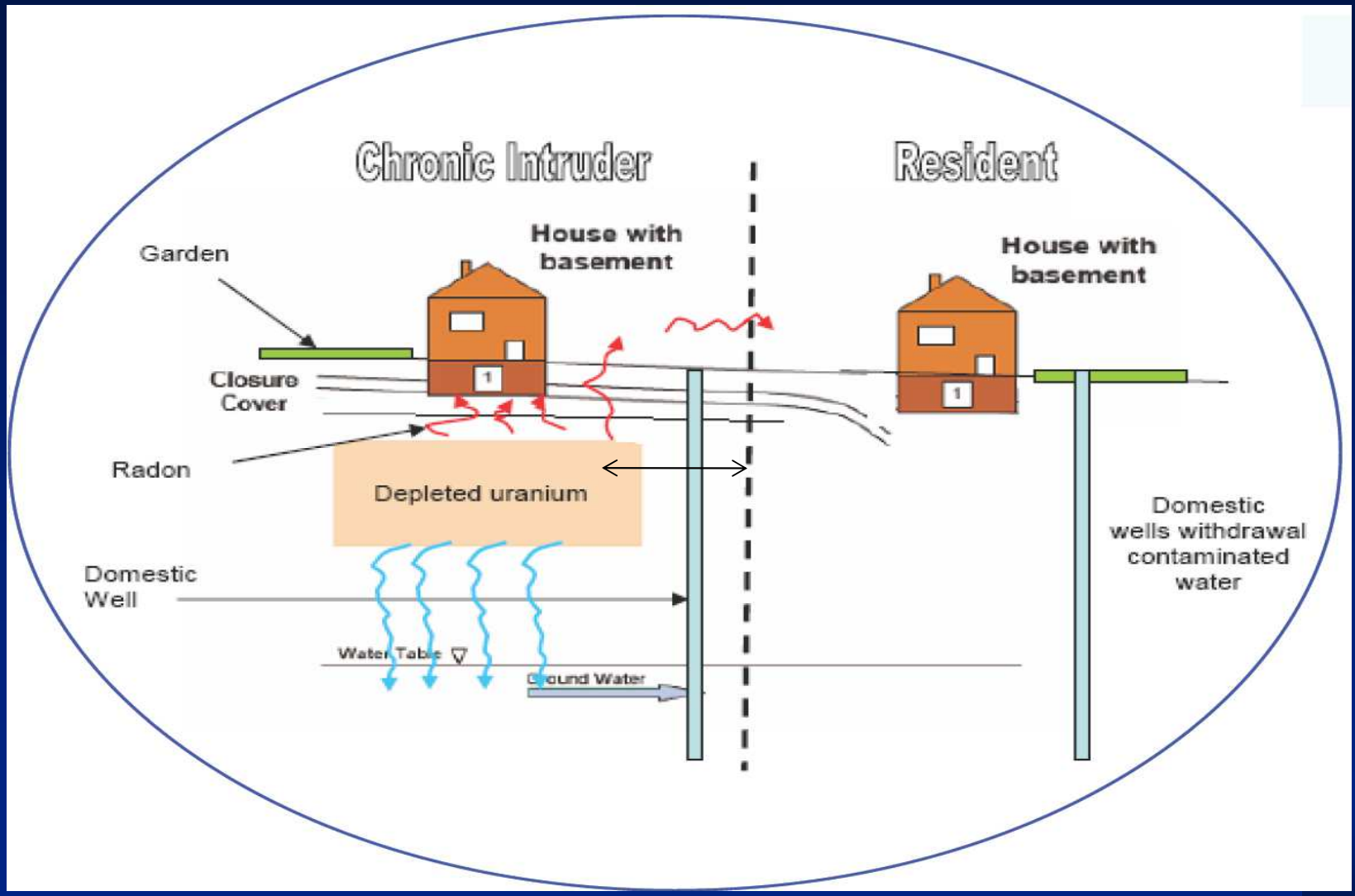
Schematic Illustration of Examples of Exposure Scenarios for DU Disposal



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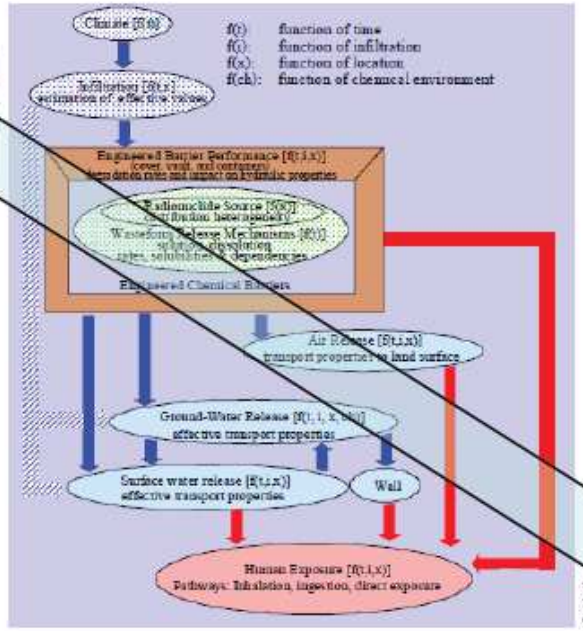
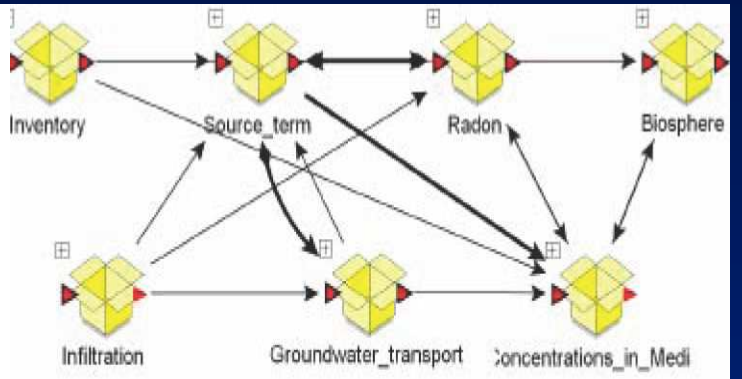
PA Approach: Representation of LLW System, Conceptual & Mathematical Models, and Estimated Performance

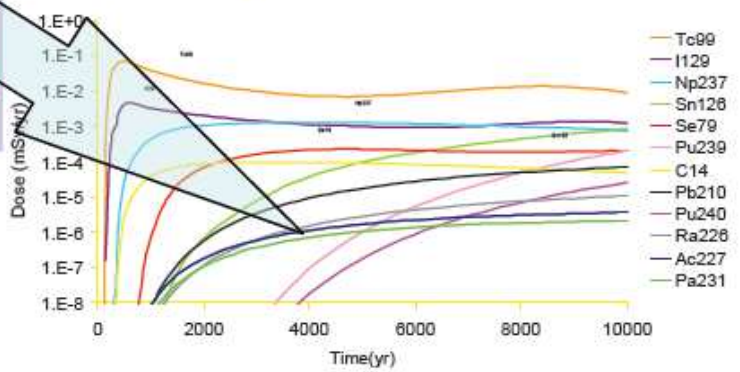
Real system



Mathematical model



Estimated future performance



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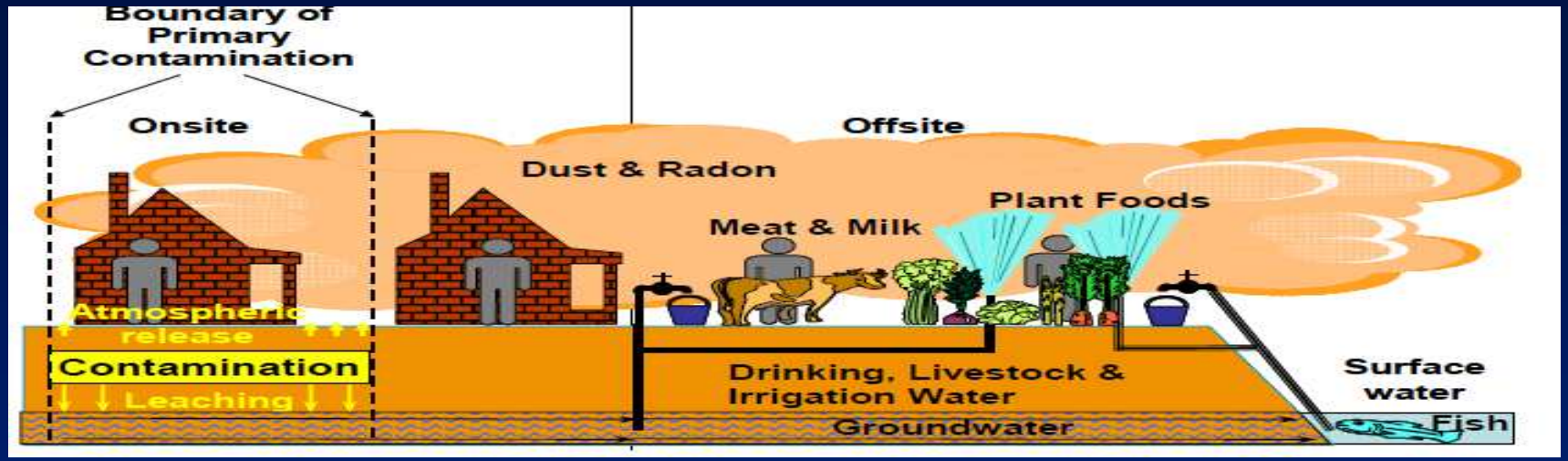
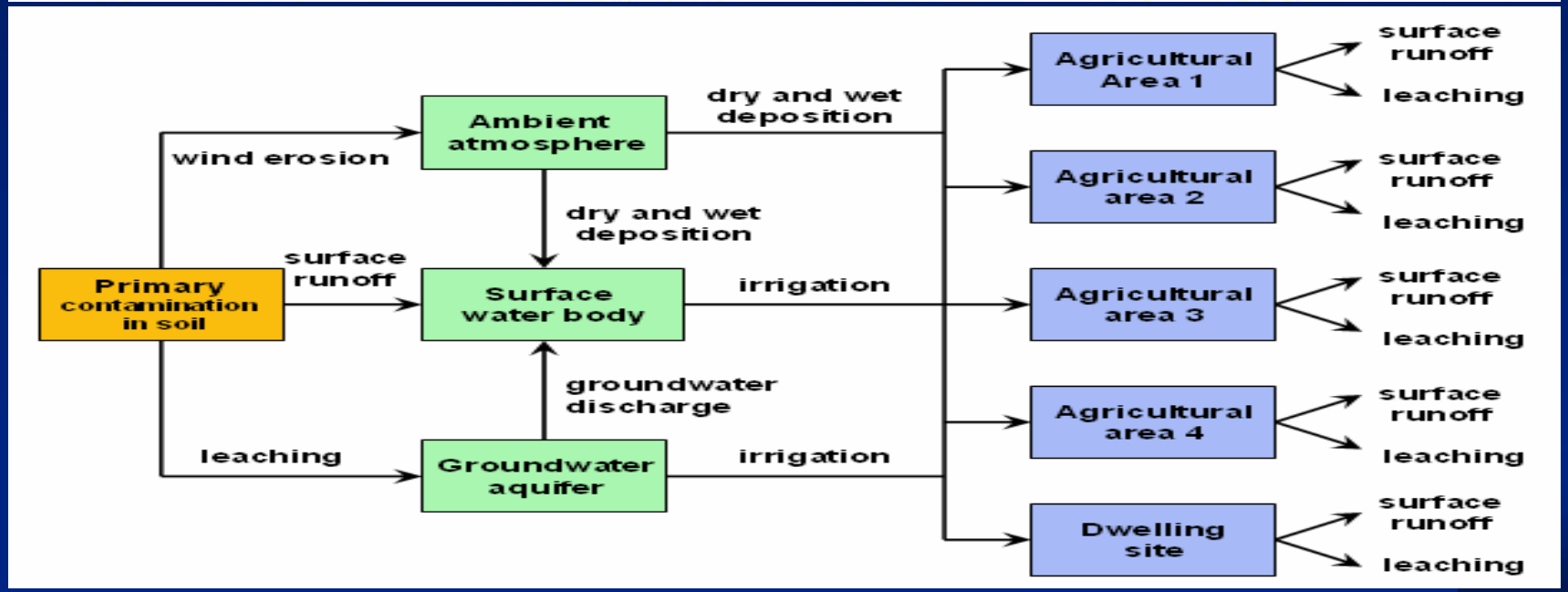
Exposure Scenarios for Complex Decommissioning Facilities





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Common Models/Codes Used In Reviews of Dose Assessments

- **Decommissioning & EIS Analysis**
  - **RESRAD Codes (RESRAD Onsite 6.5; RESRAD-Build 3.5; and RESRAD-Offsite (Beta Version 3.0)**
  - **D&D Screening Code (2.1 Updated Version)**
  - **FRAMES & GENII**
- **LLW & WIR**
  - **GoldSim**
  - **RESRAD 6.5 and RESRAD-OFFSITE**
  - **FRAMES and GENII**
  - **AMBER**
- **UR**
  - **MILDOS-AREA**

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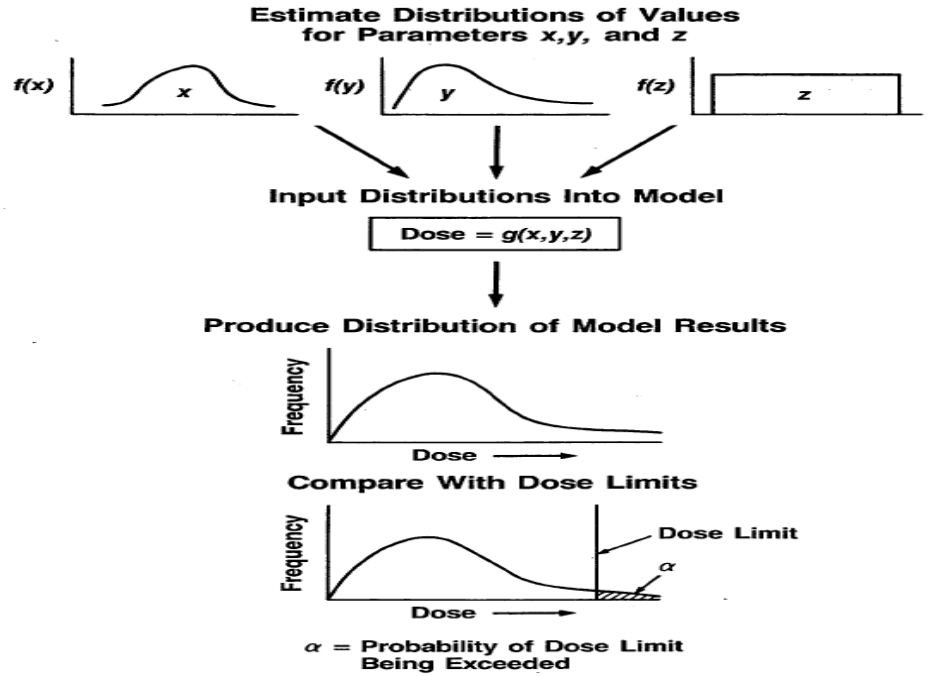
An Approach to Uncertainty Analysis



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

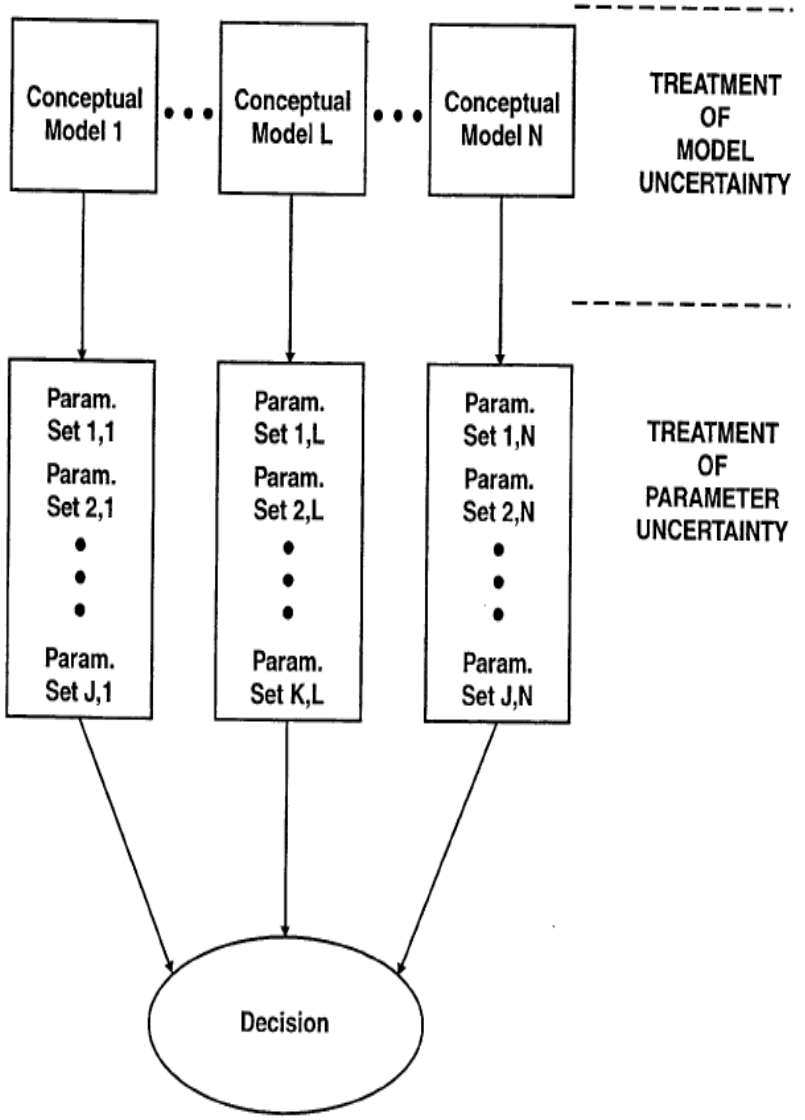
where:

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

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

N = *number of Monte Carlo runs*

t = *time*



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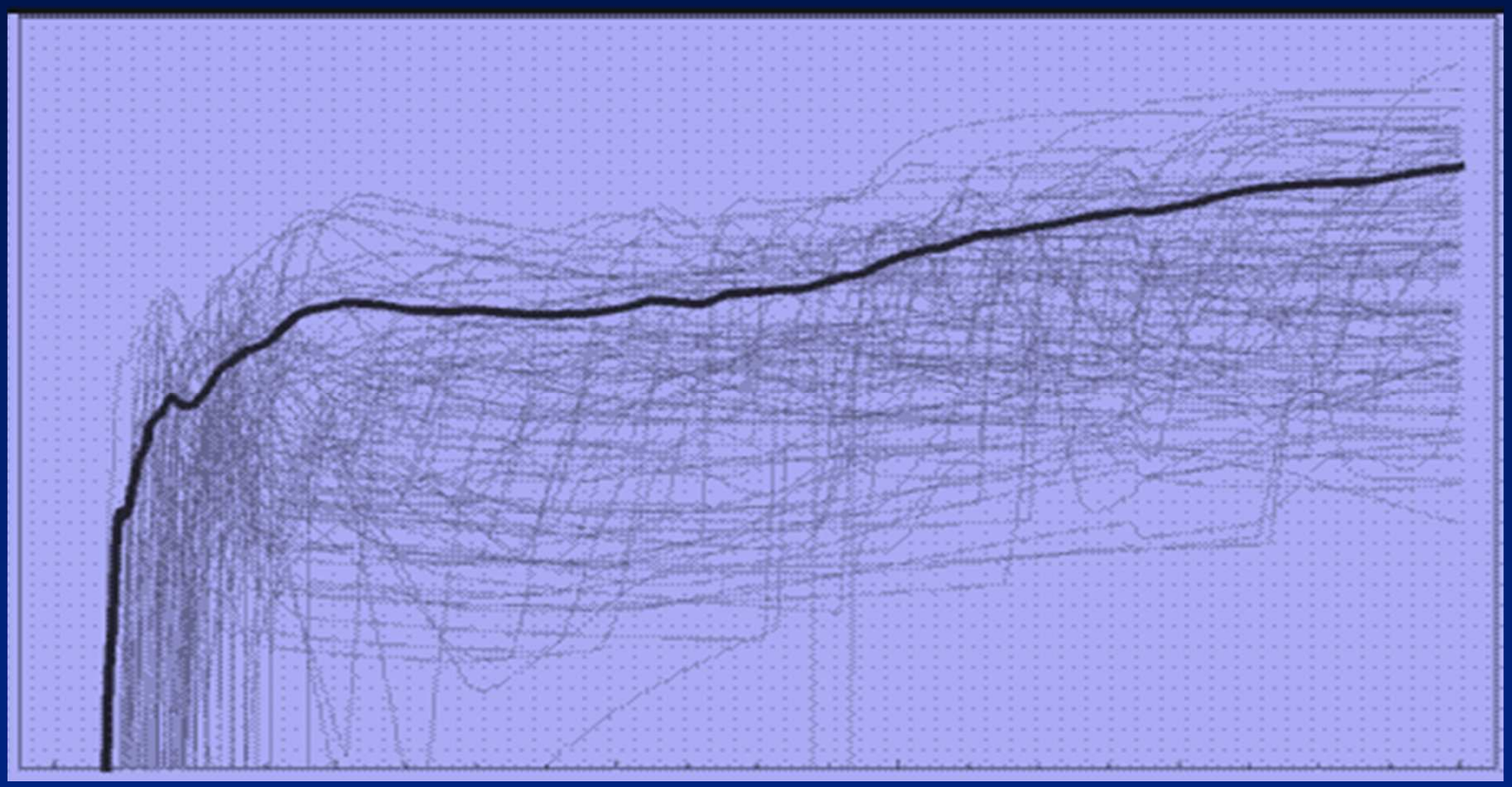
Dose - Time PA Outputs



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PA & Integrated Risk Regulatory Issues

- How to treat future site conditions, processes, events, and climate change
- Exposure scenarios and 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
- Bench-marking and QA/QC issues
- Stakeholders inputs

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Backup Slides

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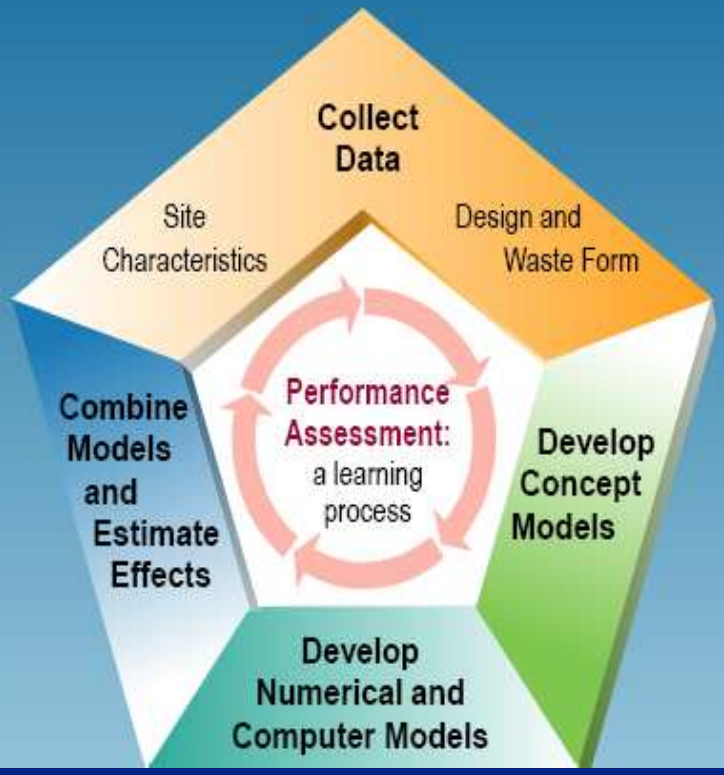
Overview of Performance Assessment

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

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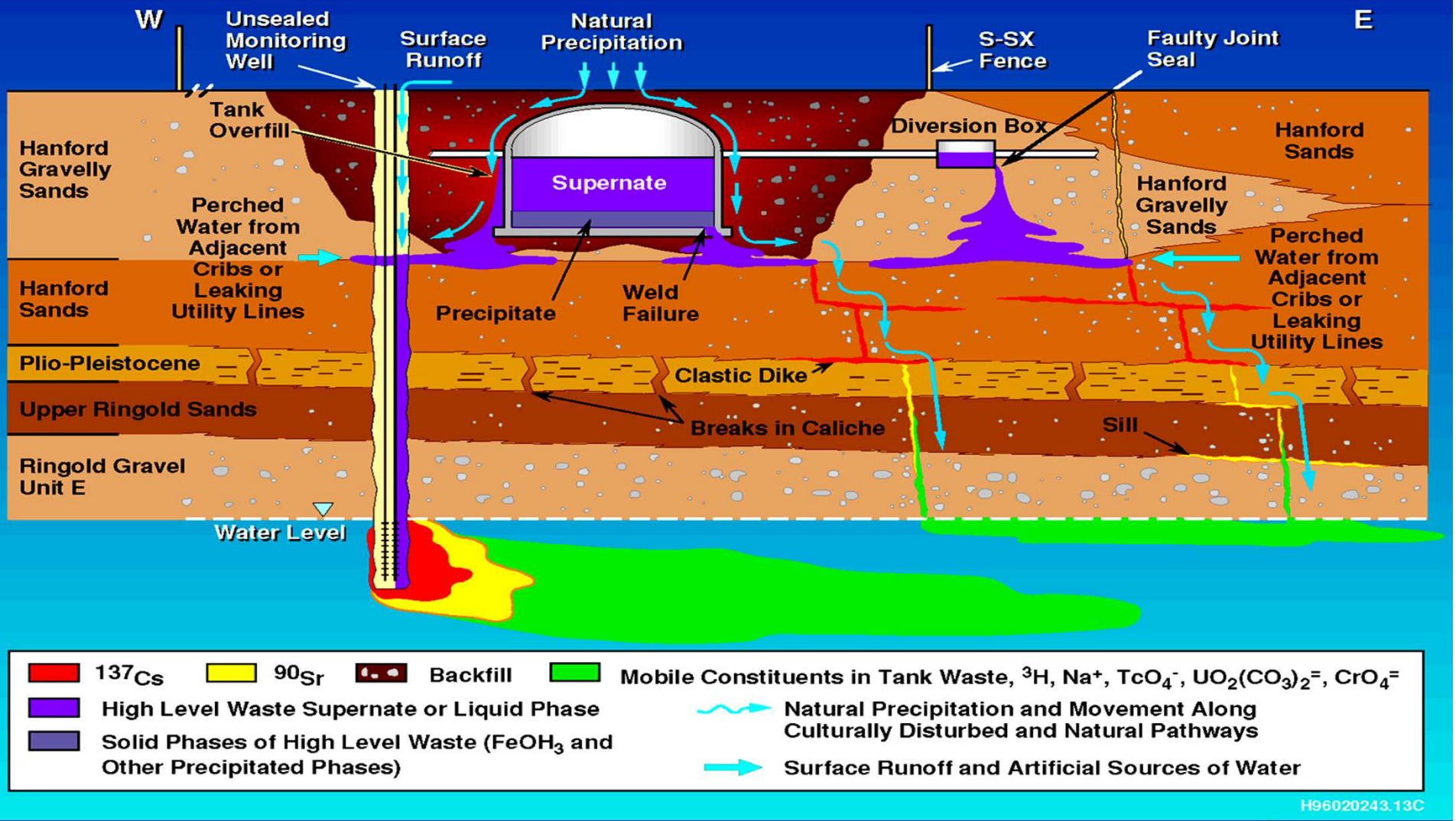
Conceptual Model of Complex Site with Multiple Sources



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