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United States Nuclear Regulatory Commission
Protecting People and the Environment

How NRC Uses RESRAD in Reviews

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Outline

- Types of uncertainty in dose assessment
- Conceptual site model and exposure scenarios
- Parameter value selection
- Accounting for dose from multiple:
  - Radionuclides
  - Sources
  - Exposure scenarios
- Sensitivity and uncertainty analyses

NRC Criteria for Decommissioning
(10 CFR 20, Subpart E)

A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem (0.25 mSv) per year, including that from groundwater sources of drinking water, and that the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA)

Types of Uncertainty in Dose Assessment

- Model Uncertainty
  - Incomplete understanding of all features of site
  - Models are simplifications of reality
- Scenario Uncertainty
  - Lack of knowledge about future land use, receptor behavior, and disruptive events and processes at the site
- Parameter Uncertainty
  - Incomplete knowledge of model coefficients

What to Look for:

Conceptual Site Model and Exposure Scenarios

- Is the site model consistent with the site?
- Does the environmental transport include all key features of the site?
  - Groundwater, rivers, lakes, ponds?
- Do the exposure scenarios consider nearby land use?
  - Farms?
  - Houses?
- Are exposure scenarios that are important to the community considered?
- Are all relevant pathways included?
  - Groundwater consumption?
  - Plant, meat, milk ingestion?

Example: Exposure Scenarios

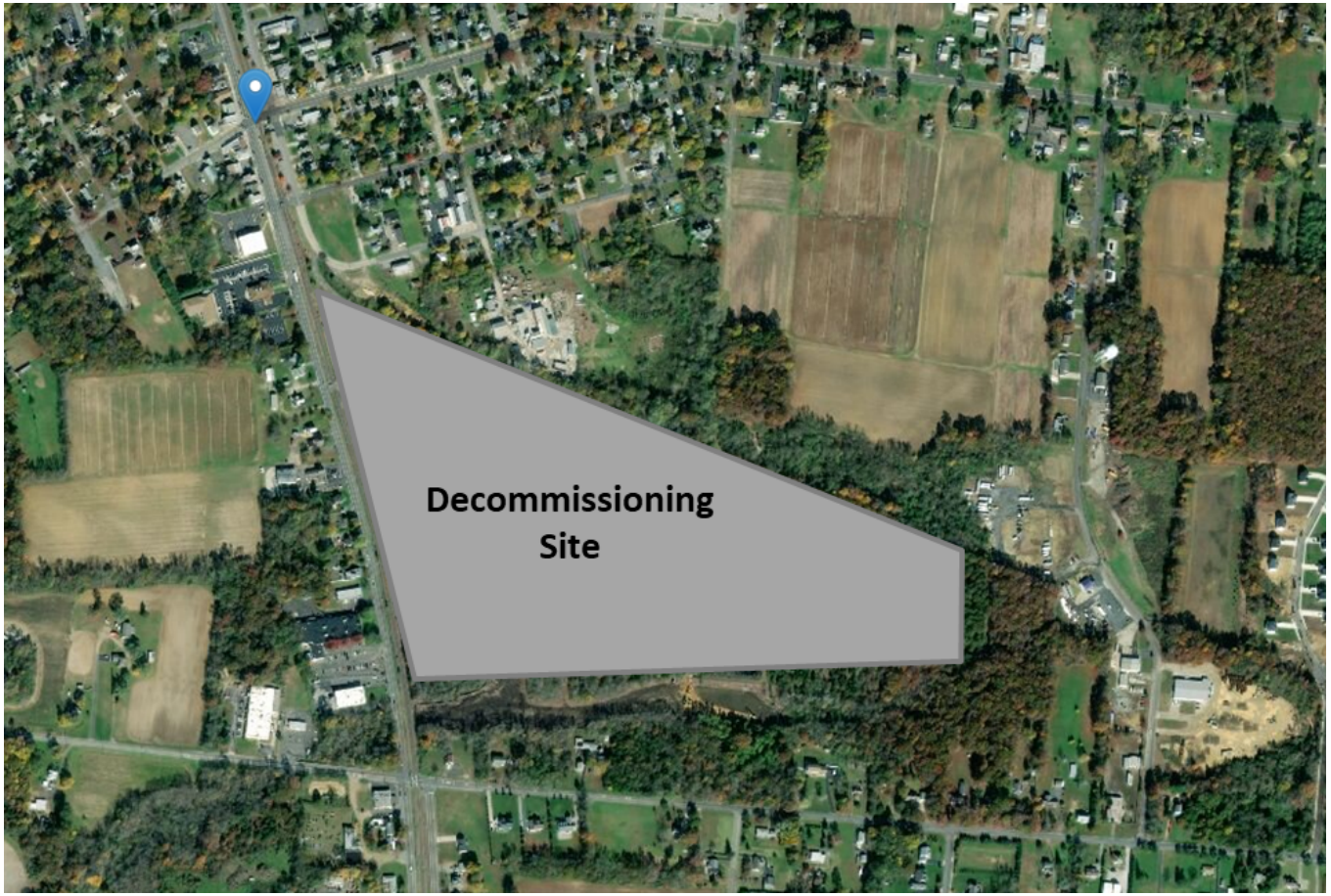

Image from: https://earthexplorer.usgs.gov/

Example: Conceptual Site Model

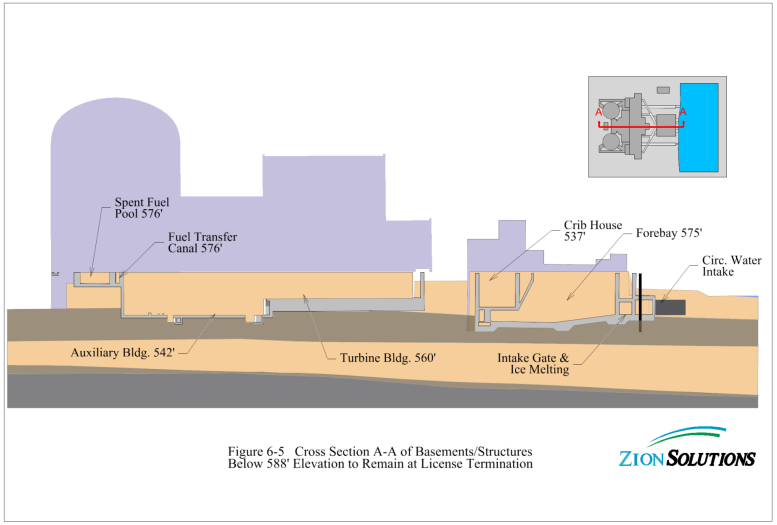

Figure 6-5 Cross Section A-A of Basements/Structures Below 588' Elevation to Remain at License Termination

ZION SOLUTIONS

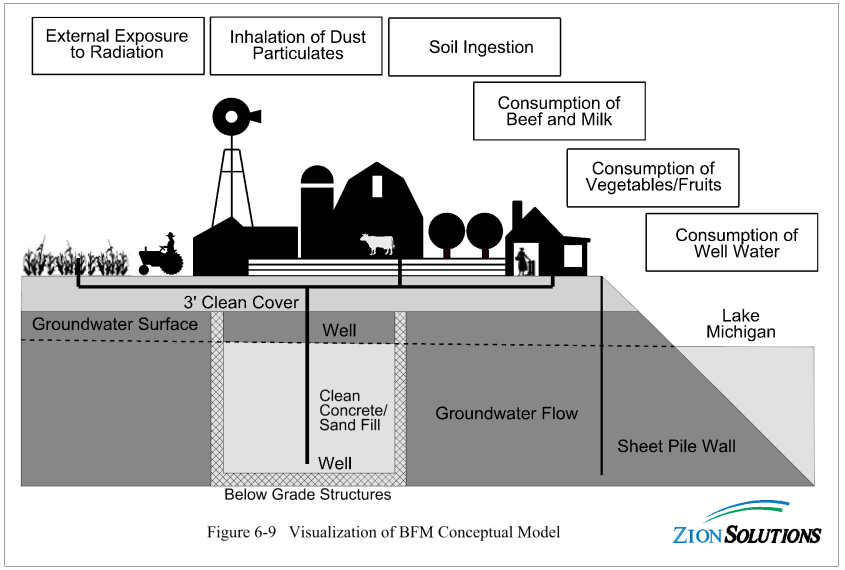

Figure 6-9 Visualization of BFM Conceptual Model

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Groundwater Modeling Limitations

Sites with the following properties may be challenging to model:

- Highly heterogeneous source term
- Wastes other than soils (e.g., slags and equipment)
- Multiple source areas
- Chemicals or a chemical environment that could facilitate radionuclide releases
- Soils that have preferential flow conditions
- Groundwater discharges to springs or surface seeps
- Potential groundwater use is far from the contaminated zone
- Significant transient flow conditions
- Significant heterogeneity in subsurface properties
- Fractured or karst formations
- Potential overland transport of contaminants

What to Look for:
Parameter Value Selection

- Are the parameter values appropriate for the site, scenario, and model used?
- Is the basis for the parameter values selected documented, including the reference for site data used to develop value or range?
- Are the parameter values selected justified sufficiently?
  - Level of justification needed depends on how much parameter could matter and how close to dose limit
  - "Conservative" parameter values generally need less justification

    Note: a parameter value can be "conservative" in some scenarios but "non-conservative" for others (e.g., Kd values)

Behavioral and Metabolic Parameters

- **Behavioral parameters** describe the behavior of the exposed individual and depend on the scenario definition (e.g., exposure time, irrigation rates, ingestion rates, etc.)
- **Metabolic parameters** describe involuntary characteristics of the exposed individual and are independent of the scenario and the site (e.g., breathing rates, dose conversion factors)
- Using consistent behavioral and metabolic parameter values supports a standardized definition of the receptor
- Useful references:
  - NUREG/CR-5512, Volume 3, "Residual Radioactive Contamination from Decommissioning": default, deterministic values for behavioral and metabolic parameters for use by NRC licensees
  - U.S. EPA Exposure Factors Handbook (2011): extensive data on human behavior and characteristics for use in risk assessments

Physical Parameters

- **Physical parameters** describe physical characteristics of site and source term (e.g., soil properties, hydrologic properties, etc.)
- Physical parameters are typically developed on a site-specific basis, except:
  - When using a conservative screening analysis
  - For certain crop and animal parameters
- "Site-specific" parameters can be developed based on:
  - Information or data directly related to the site
  - Information related to the region the site is in that is consistent with site conditions
  - Generic information consistent with the specific conditions at the site

Physical Parameters – Source Term

Source term parameters describe:

- What radionuclides are present?
- What media are they present in?
- What is the physical and chemical form of the contaminated media expected at time of site release?
- What is the area and depth of the residual radioactivity?
- How are the radionuclides expected to be distributed in the contaminated media?

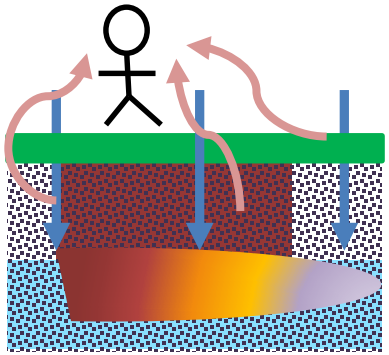
If surrogate DCGLs are used:

- What are the relative ratios of radionuclides?
- What is the range of ratios?

Physical Parameters – Groundwater

- Site-specific values should be developed for parameters related to hydrogeologic conditions (e.g., hydraulic conductivity, hydraulic gradient, soil "b" parameter)
  - Groundwater flow varies widely from site to site
  - Groundwater flow important for dose from water pathways
- If measured site-specific values are unavailable, use conservative values that are appropriate for the site
- **What is "conservative" will depend on pathway and scenario**

Less leaching --> higher dose



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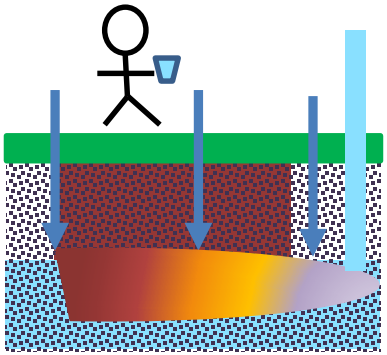
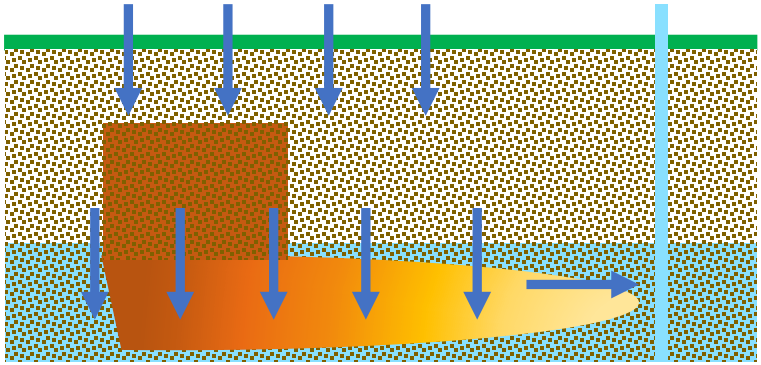


Physical Parameters – Groundwater Monitoring Data

- Operational environmental monitoring of groundwater may provide some useful information for comparing observations to model results but is often insufficient for dose assessments
  - Radionuclides observed in groundwater samples might not be representative of the long-term risk drivers because groundwater monitoring data might only include fast moving radionuclides and might not include slower moving radionuclides that could cause a more significant risk in the future
  - Variable infiltration could cause short-term transport that is not representative of expected long-term conditions
- For dose assessments, information is needed on:
  - Type of contamination (which radionuclides)
  - Extent of contamination (area and depth)
  - Movement of contamination in groundwater at the site



Physical Parameters – Groundwater Monitoring Wells

- The number, location, and design of monitoring wells depends on type and extent of contamination, hydrogeologic system, background, and objectives of monitoring program
- Use well data to develop parameters and to validate model
- Other considerations for monitoring wells:
  - Data from wells screened across multiple aquifers is difficult to interpret (hybrid wells, damaged well casing)
  - Monitoring wells should not be closed if unexpected results are seen
  - Make sure monitoring well data is not affected by remediation activities (e.g., nearby pump and treat)

Physical Parameters – Geochemical

- Sorption of radionuclides affects how radionuclides are released and transported
- Sorption is modeled using a Kd
- Kd values are dependent on:
  - the specific contaminant and form of the contaminant
  - the specific soil or sediment
    - minerals present
    - particle size
    - amount of organic matter
    - clayey soils tend to have higher sorption than sandy soils
  - the geochemical conditions (e.g , pH, salinity, redox conditions)
- **Use site specific measurements when possible**

Accounting for Dose from Multiple Source Terms and Pathways in DCGL Calculations

- Gross DCGL based on expected fractions of radionuclides:

$$DCGL_{gross} = \frac{1}{\frac{f_1}{DCGL_1} + \frac{f_2}{DCGL_2} + \cdots + \frac{f_n}{DCGL_n}}$$

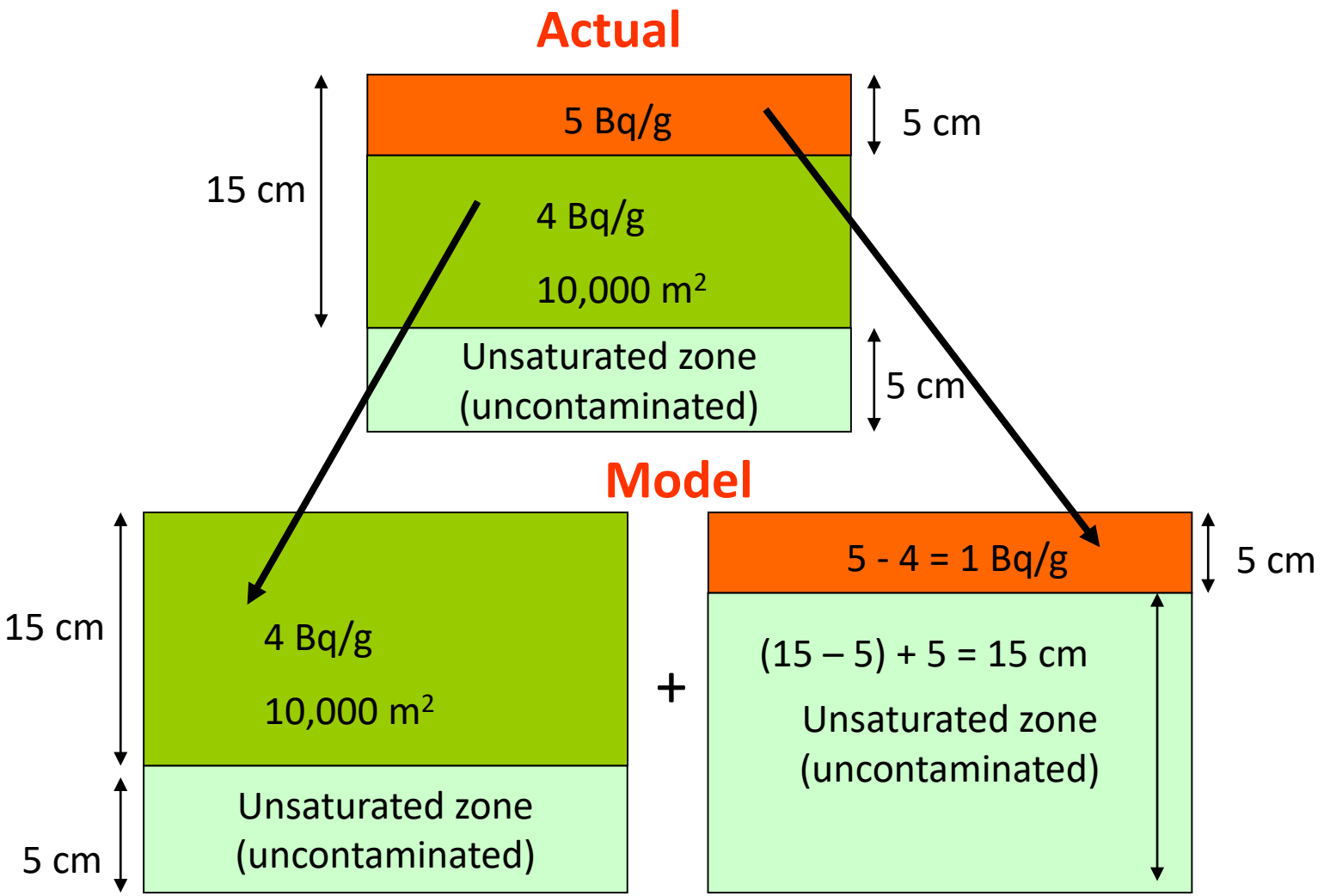
- Surrogate DCGL for hard-to-detect radionuclides:

$$DCGL_{adj\ sur} = \frac{1}{\frac{1}{DCGL_{sur}} + \frac{R_2}{DCGL_2} + \cdots + \frac{R_n}{DCGL_n}}$$

Note: the relative fractions of different radionuclides, especially the hard-to-detect radionuclides, is a major source of uncertainty

- When multiple sources are present (e.g., soil and groundwater contamination), operational DCGLs can be developed to ensure that the final total dose is within the dose limit

Accounting for Non-homogenous Contamination

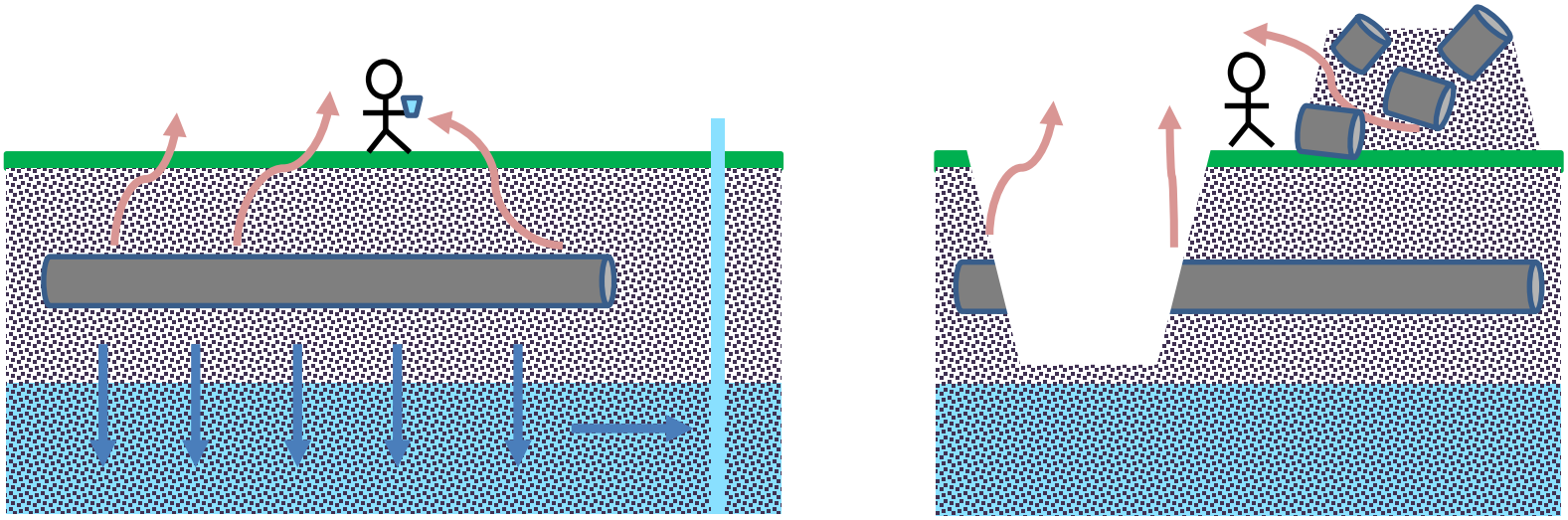


Note: developing and using different DCGLs for different depths can be very challenging

Calculating DCGL Values from Multiple Scenarios Example

A person could be exposed to radioactivity in a buried pipe by:

- External exposure from buried pipe
- Consumption of groundwater contaminated from pipe
- Exposure to radionuclides in pipe if pipe is dug up in future



Calculate DCGLs for both scenarios and use the limiting DCGLs for decommissioning

Determining Sensitive Parameters

- Goal is to identify input parameters that are major contributors to variation or uncertainty in calculated dose
- Focus on pathways and radionuclides providing greatest dose
- Range of parameter values considered needs to be justified
  - An overly narrow range can result in missing important parameters
  - An overly broad range can result in risk dilution
- Use expected concentrations of radionuclides at time of site closure
  - Also consider uncertainty in the concentrations and relative ratios
- Consider correlations between parameters when correlations are expected based on the physical system

Conclusions

- When reviewing dose assessments to support decommissioning, the NRC staff focuses on the most risk-significant and uncertain aspects of the model
- Conceptual site model needs to be appropriate for the source term, environmental transport, exposure scenarios, and pathway selection
- Parameter values need to be appropriate for the site, scenario, and model and should be well documented and justified
  - Behavioral and metabolic parameters are independent of the site and are typically modeled using generic deterministic parameter values
  - Physical parameters should be developed on site-specific basis
- The potential dose from multiple radionuclides and source terms must be considered in the development of DCGLs – it can be very challenging to manage this in a way that is practical to implement during decommissioning