APPLIED RISK ASSESSMENT SKILLS FOR BLM PROJECT MANAGERS: A 3-day Professional Development Course

September 28 – October 8, 2020 on-line!

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WHY THIS COURSE?

BLM project managers are tasked with prioritizing and scoping actions at numerous abandoned mine sites and other orphaned contaminated sites on BLM-administered land.

OUTCOME OBJECTIVES

1. Understand the risk assessment process.
2. Know key guidance & key sources of information.
3. Be able to complete screening level risk assessments.

Overview and Approach

1. Course book: course overview and slides
2. Hands on exercises!
3. Workshop orientation:
    - All have experiences to share
    - Let's emphasize questions & discussions over lecture
- On-line format involves independent homework.

Your Turn

Introductions

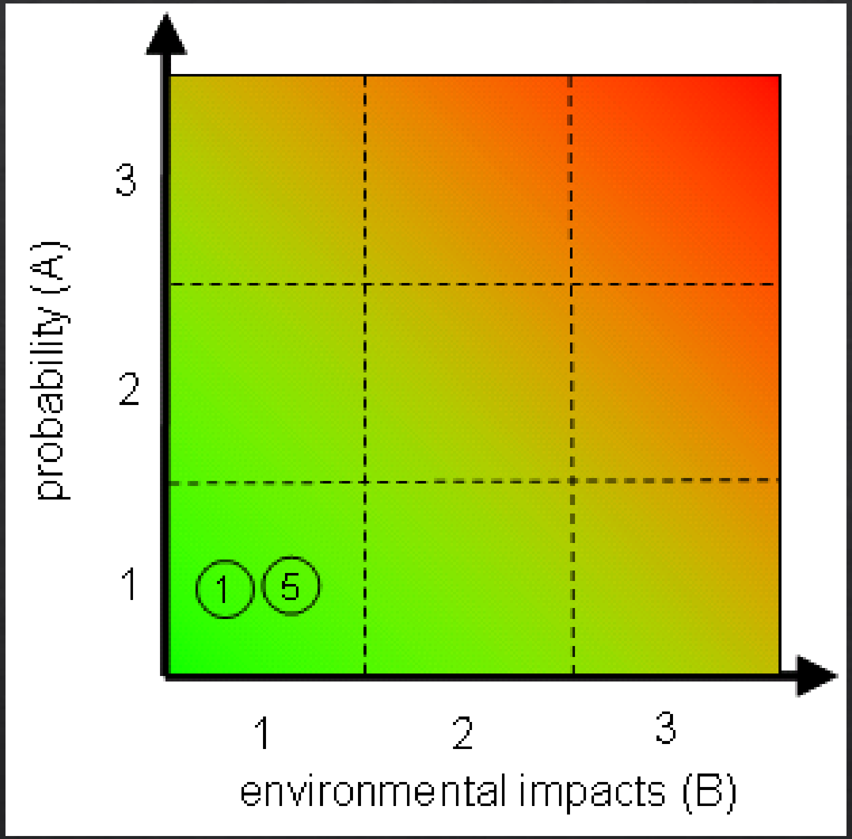
- Name, title
- Current responsibilities
- Prior risk assessment exposure, training or experience
- Aspirations for the course:
  - Specific near-term project application
  - Topic of specific interest (e.g. lead model for adults), if you have one.

Course Organization

- Overview
- Site Characterization
- Exposure Assessment
  - Qualitative
  - Quantitative
- Screening Level Assessment
- Toxicity Assessment
  - Human
  - Ecological
- Risk Characterization
- Uncertainty Assessment
- Lead
- Acute Arsenic & Lead
- Radionuclides

Defining Risk and Risk Assessment

What is Risk?

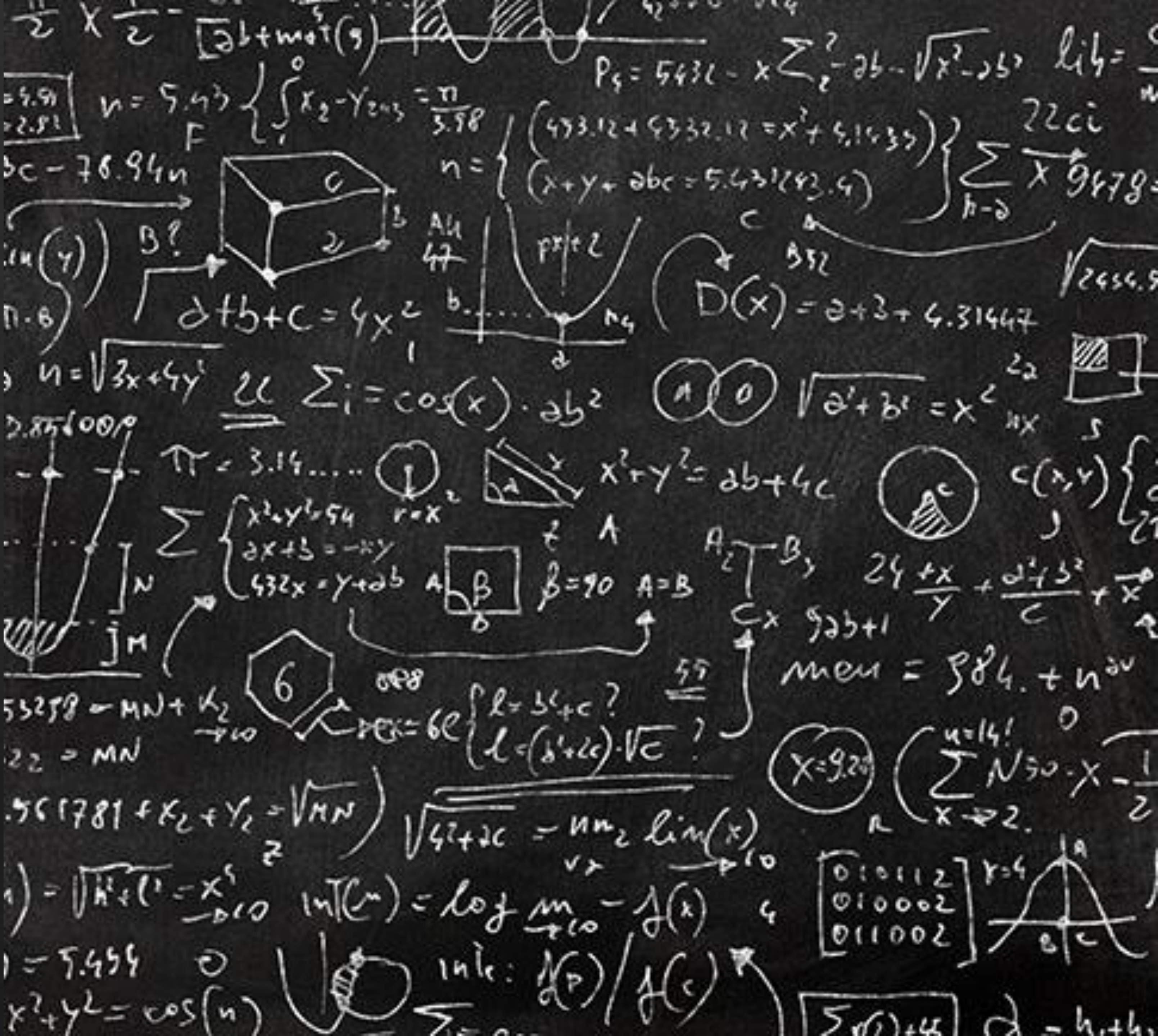


"The effect of uncertainty on objectives" (ISO 13000) Risk Management Guidelines

- Involves both hazard and opportunity
- Objectively measured by probability and magnitude
- Subjectively understood through many social and psychological influences.

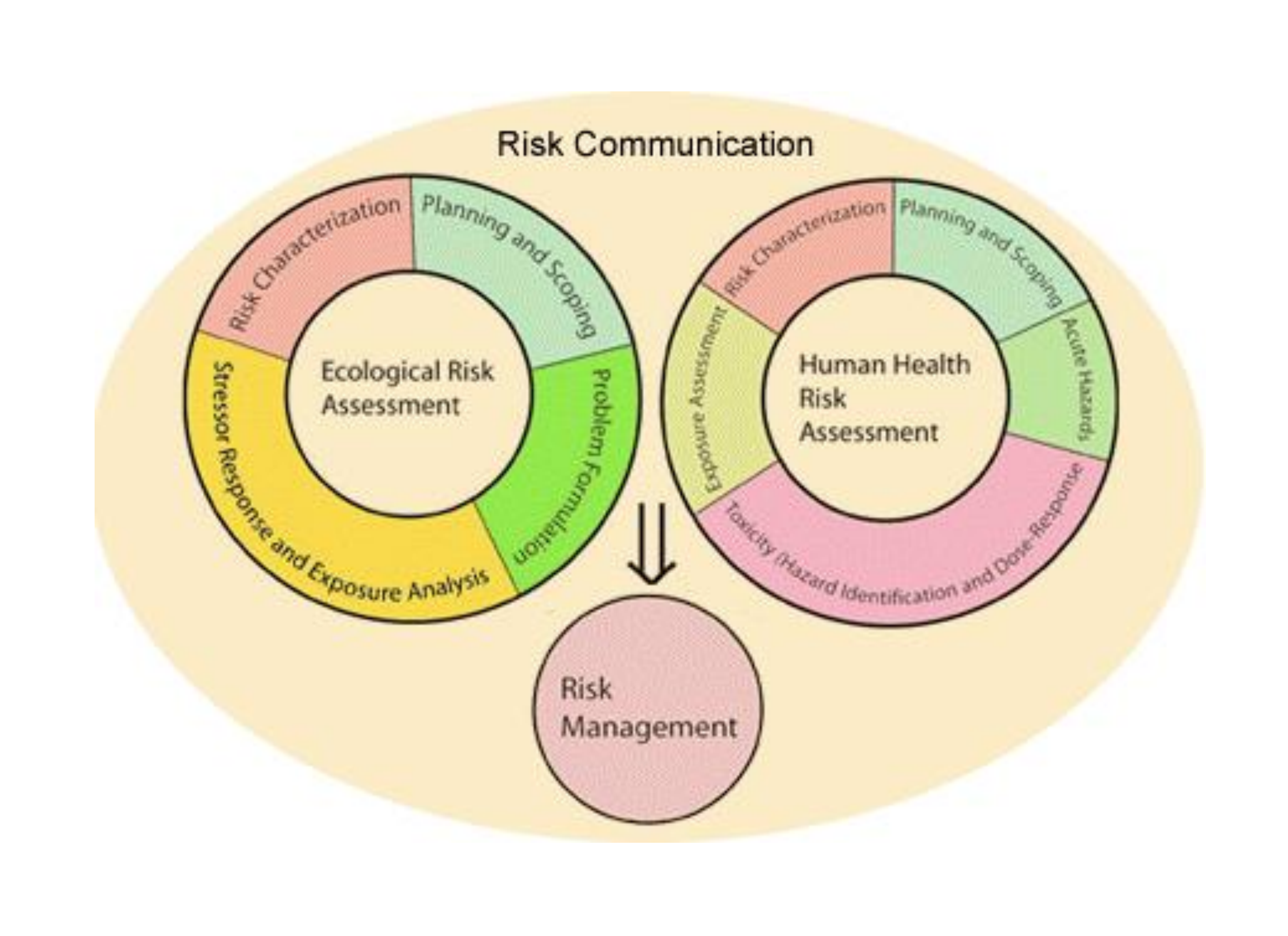
Risk Assessment – Who Cares?

- Seeks to quantify risk using a consistent methodology.
- Risk thresholds are used to determine remediation need.
- Even simple comparison to standards is a risk assessment.



Relationship of RA to RM and RC

- RA, RM and RC are often presented as distinct actions.
- However, RC provides the frame: what are we concerned about, what drives decision, etc.
- RC is important for:
  - Planning, Scoping, Problem Formulation.
  - Presentation



Source: https://www.epa.gov/risk/risk-communication

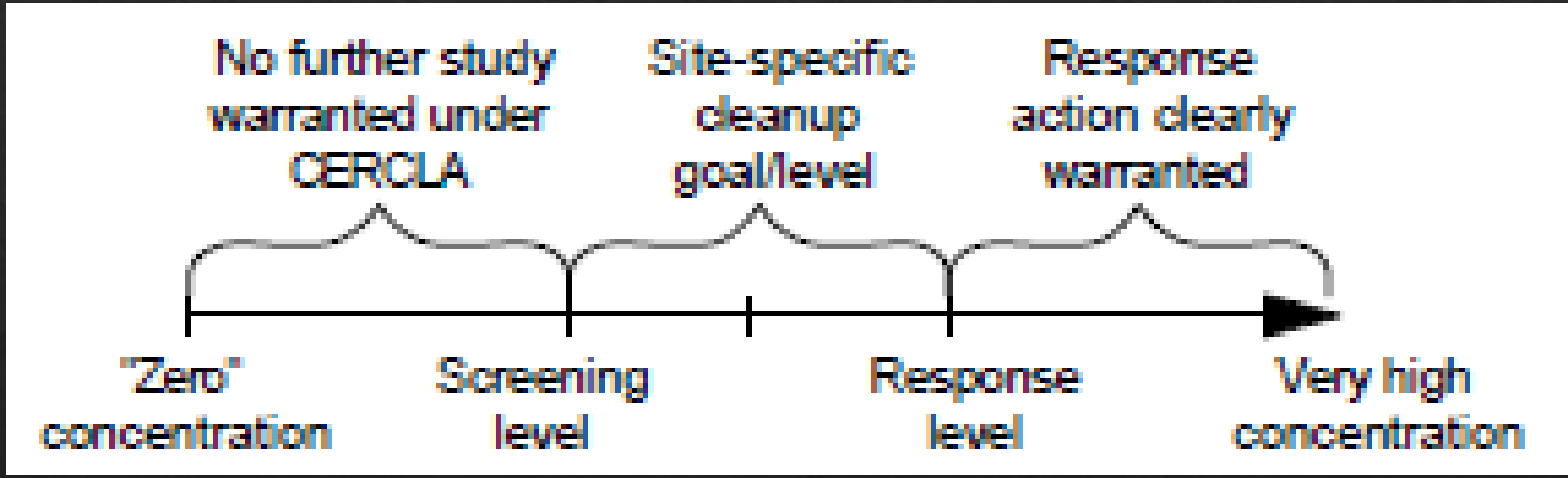
Risk Assessment Terminology

- **Risk**: "*the chance of harmful effects to human health or to ecological systems"* EPA
- **Screening Level**:
  - Often means use of media-based lookup values
  - Some screening level ecological risk assessments (SLERAs) are detailed.
- **Streamlined**: less documentation
- **Baseline**: absent any controls
- **Assessment**: More detailed. Site Specific. Pathway specific.
- **Evaluation**: Less detailed. Default residential or industrial scenarios.

Conceptual Framework

- Cleanup goals/levels are based on "acceptable" cancer risk and non-cancer hazard

- Scope:
  - Screening Level
  - Site-Specific Baseline
  - Remedy Justification

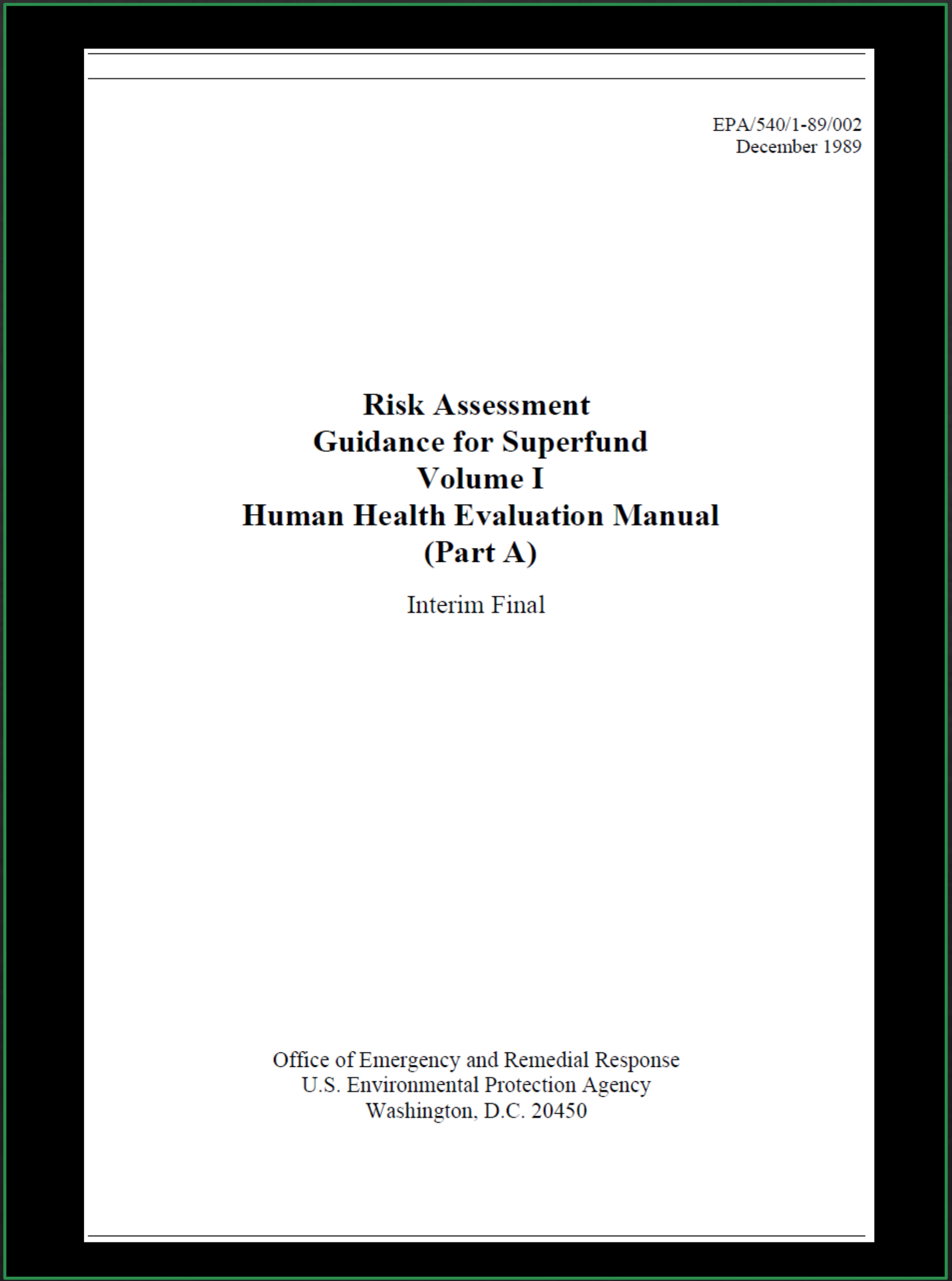


U.S. Environmental Protection Agency (EPA), 1996. *Soil Screening Guidance: Users Guide, Second Edition*, Office of Emergency and Remedial Response, EPA540/R-96/018, July.

Component Parts of Risk Assessment

Typical Report Elements

1. Purpose
2. Site Description/Characterization
   a. General environment
   b. Data
   c. Data quality (usability for risk assessment)
3. Exposure Assessment
   a. Conceptual Site Model
   b. Quantitative Exposure
4. Toxicity Assessment
5. Risk Characterization (quantitative)
6. Uncertainty Assessment (qualitative)



EPA/540/1-89/002
December 1989

Risk Assessment
Guidance for Superfund
Volume I
Human Health Evaluation Manual
(Part A)

Interim Final

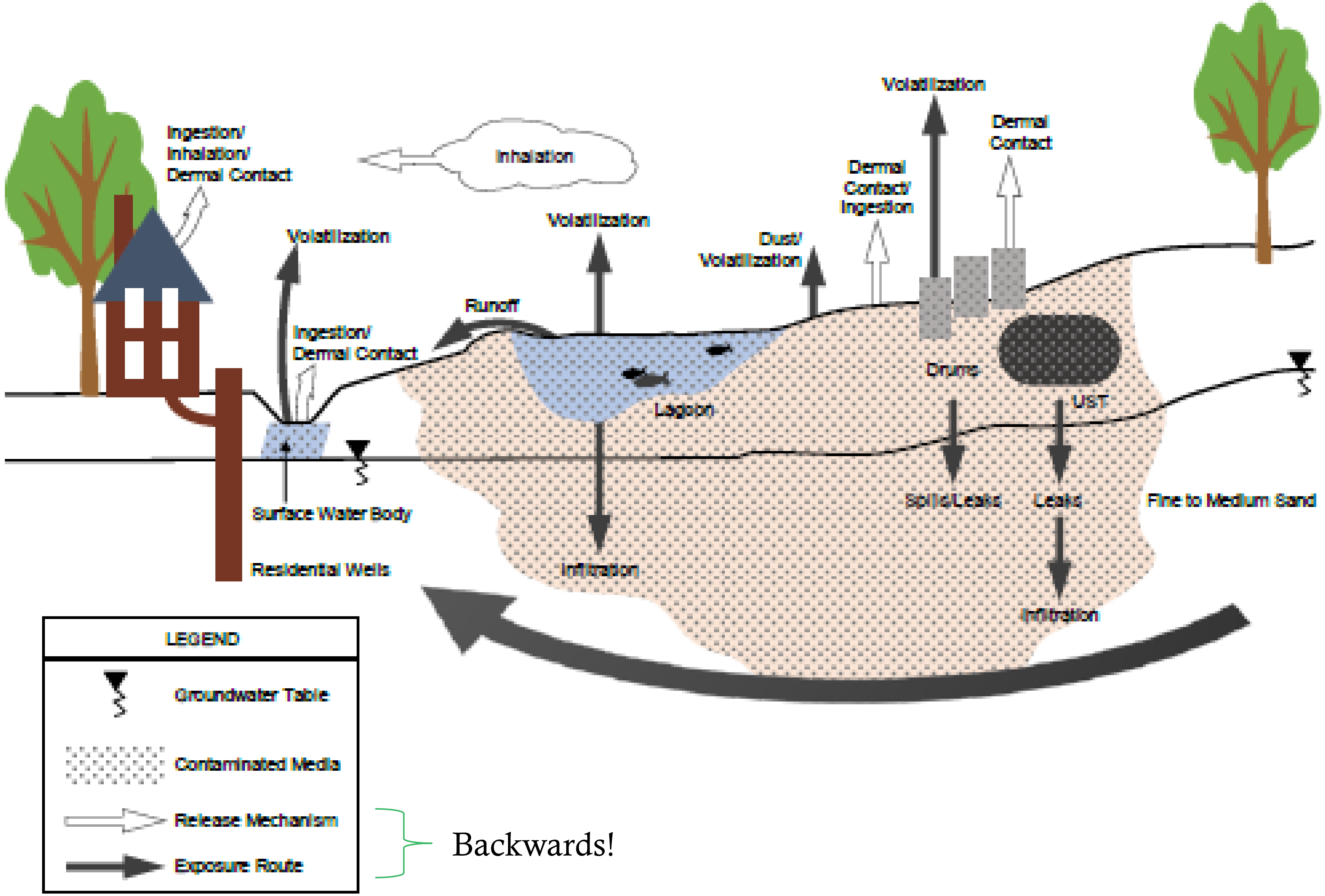
Office of Emergency and Remedial Response
U.S. Environmental Protection Agency
Washington, D.C. 20450

https://www.epa.gov/risk/superfund-risk-assessment

Exposure

Exposure can be assessed in one of two ways:

1. Media Concentration: concentration in soil, water, air, etc. to which one is potentially exposed.
2. Dose: amount absorbed over time (mg/kg/day)



Backwards!

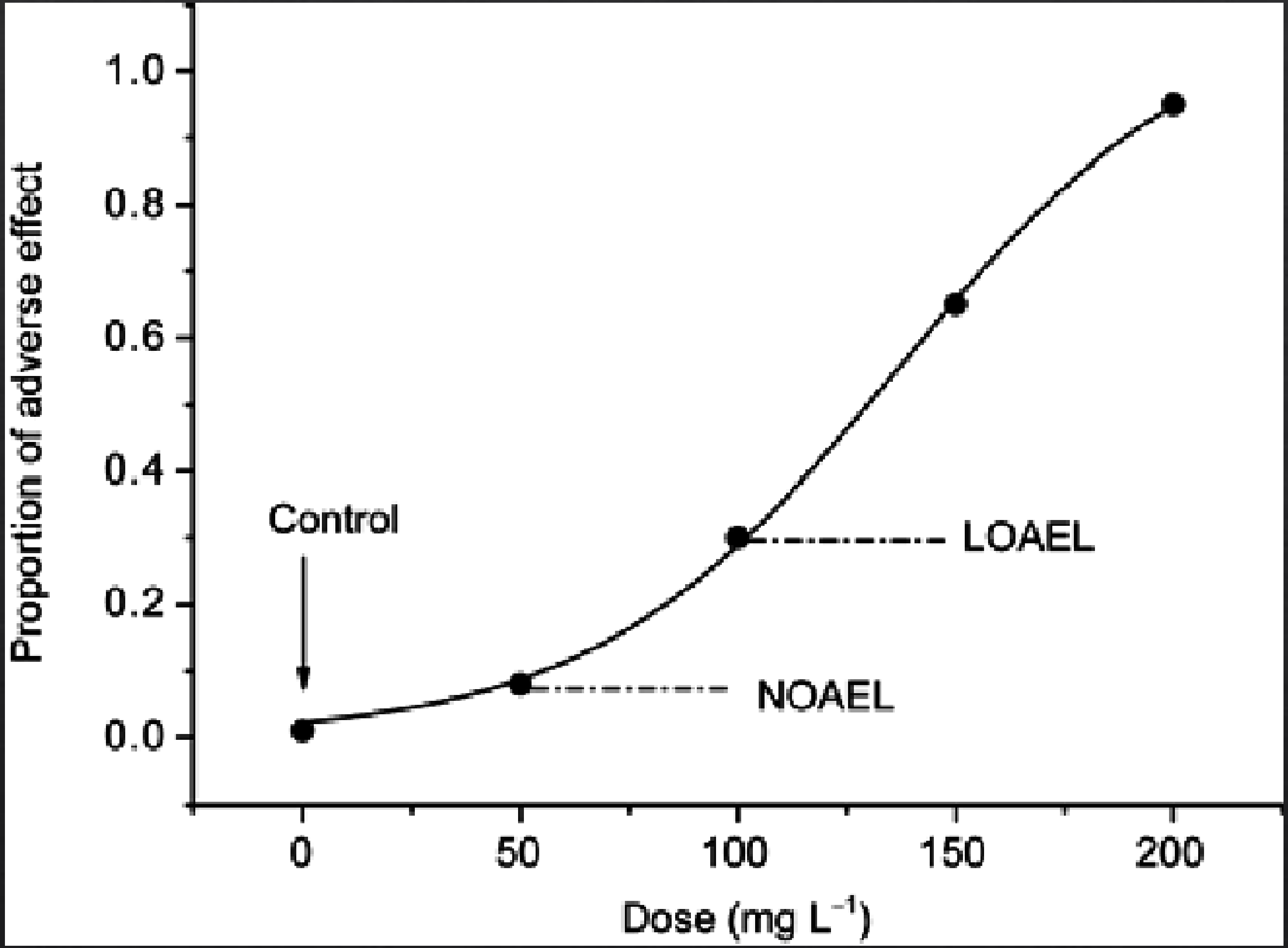
Exposure: typical equation

Dose = Csoil x GRAF x SIR x EF x ED x CF / AT

	Value			
where:	non-carcinogen		carcinogen	
	average	high end	average	high end
Dose = dose from soil ingestion (mg/kg BW/day)				
Csoil = concentration of contaminant in soil (mg/kg)	chemical specific			
GRAF = gastrointestinal relative absorption fraction, unitless				
Dioxin	0.45	0.45	0.45	0.45
Other chemicals	1	1	1	1
SIR = soil ingestion rate (mg/kg BW/day)	1.7	1.7	1.7	1.7
EF = exposure frequency (days/year)	350	350	350	350
ED = Exposure duration (years)	30	70	30	70
AT = Averaging time period over which exposure is averaged (days)	10950	25550	25550	25550
CF = Conversion Factor (kg/mg)	10^{-6}	10^{-6}	10^{-6}	10^{-6}

$$\frac{mgc}{k\cancel{g}s} \; x \; \% \; x \; \frac{m\cancel{g}s}{kgb/day} \; x \; \frac{d\cancel{a}y}{\cancel{y}r} \; x \; \cancel{y}r \; x \; \frac{k\cancel{g}s}{m\cancel{g}s} \; / \; d\cancel{a}ys = mgc/kgb/day$$

Toxicity: Dose-Response Curve



Feng, C. et al., 2012. Water quality criteria research and progress, Science China Earth Sciences

Time matters

- Chronic: Long-term; seven years to lifetime.
- Subchronic: two weeks to seven years.
- Acute: short-term; less than two weeks.

Quantitative Risk Characterization

Dose ÷ Toxicity = Non-Cancer Hazard Quotient

- **Exposure (dose)**: mg of chemical/kg body weight/day
- **Toxicity**: mg of chemical/kg body weight/day
  - No Observed Adverse Effect Level (NOAEL)
  - Lowest Observed Adverse Effect Level (LOAEL)
- **Hazard Quotient**: unitless ratio
  - ≥1 = Potential adverse effects (not a linear function)
  - < 1 = No known effects
- Hazard Index: Additivity assumed for multiple chemical exposures (versus synergistic or antagonistic).

Quantitative Risk Characterization

Dose x Toxicity = Cancer Risk

- **Exposure (dose)**: mg of chemical/kg body weight/day
- **Toxicity – slope factor**: 1/(mg of chemical/kg body weight/day)
- **Cancer risk**: unitless probability.
  - 1×10^{-6} = 1E-6 = 1 in 1,000,000 exposure per assumptions (lifetime) to initiate cancer.
  - In Superfund, exceeding 1×10^{-4} is the threshold for taking action.
- Sum risks for multiple carcinogenic exposures

Screening vs. “Baseline”: Different Levels of Detail

“Baseline”, Dose-based, or Site-specific Risk Assessment

Organization follows RAGs guidance with all report elements:

- Site Characterization
- **Detailed** exposure assessment: CSMs, exposure pathways and assumptions, dose estimation for the RME scenario.
- Toxicity assessment: uses cancer slope factors and non-cancer hazard quotients.
- Risk Characterization and Uncertainty Assessment.

Screening Level Risk Assessment

- Exposure is typically defined to be a **media concentration** (soil, air, water);
  - o Often uses maximum values but can us 95UCL of the mean
  - o SLERAs: uses the screening term but often uses dose and pathway analysis.
- Toxicity: Assumptions on hazard/risk and exposure are **incorporated**.
- Risk Characterization and Uncertainty: Generally intended to be more conservative. For example…
  - o Aquatic life criteria: most species most of the time across the country
  - o Lead: child as sensitive receptor with Reasonable Maximum Exposure (RME) assumptions
- Can be adapted if you understand how they are calculated…

What's the difference between dose-based and screening level risk assessment?

$$\textbf{Dose} = \text{HQ x Toxicity}$$

or

$$\text{Cs x Exposure Assumptions} = \text{HQ x Toxicity}$$

or

$$\textbf{Cs} = \frac{\text{HQ x Toxicity}}{\text{Exposure Assumptions}}$$

Answer: there is no difference, except in level of transparency.

Screening Level vs. Baseline Risk Assessments

- What outputs do you get from each?
  - Baseline: cancer risk and non-cancer hazard
  - Screening: hazard quotients
- When to use which approach?
  - Level of site-specificity needed
  - Level of detail in presentation needed
  - Budget

Your Turn


Break
Site Characterization: Unique Data Needs for Risk Assessment

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Unique Data Needs for Risk Assessment

- Risk assessment data needs can be considered (too) late in the project cycle.
- Plan and implement site investigations to meet risk assessment needs:
  - How do risk assessment needs differ from site characterization needs?
  - What does EPA say about the matter?
  - What are key needs at BLM sites?

Relative Emphasis of Data Needs

Site Characterization

- Hot spots
- General parameters
- Relative concentrations
- General comparison to background
- Less rigorous data quality consideration

Risk Assessment

- Exposure area averaging
- Chemical specific
- Target concentrations
- Statistical comparison to background
- More rigorous data quality consideration (e.g. a few high result often define risk)

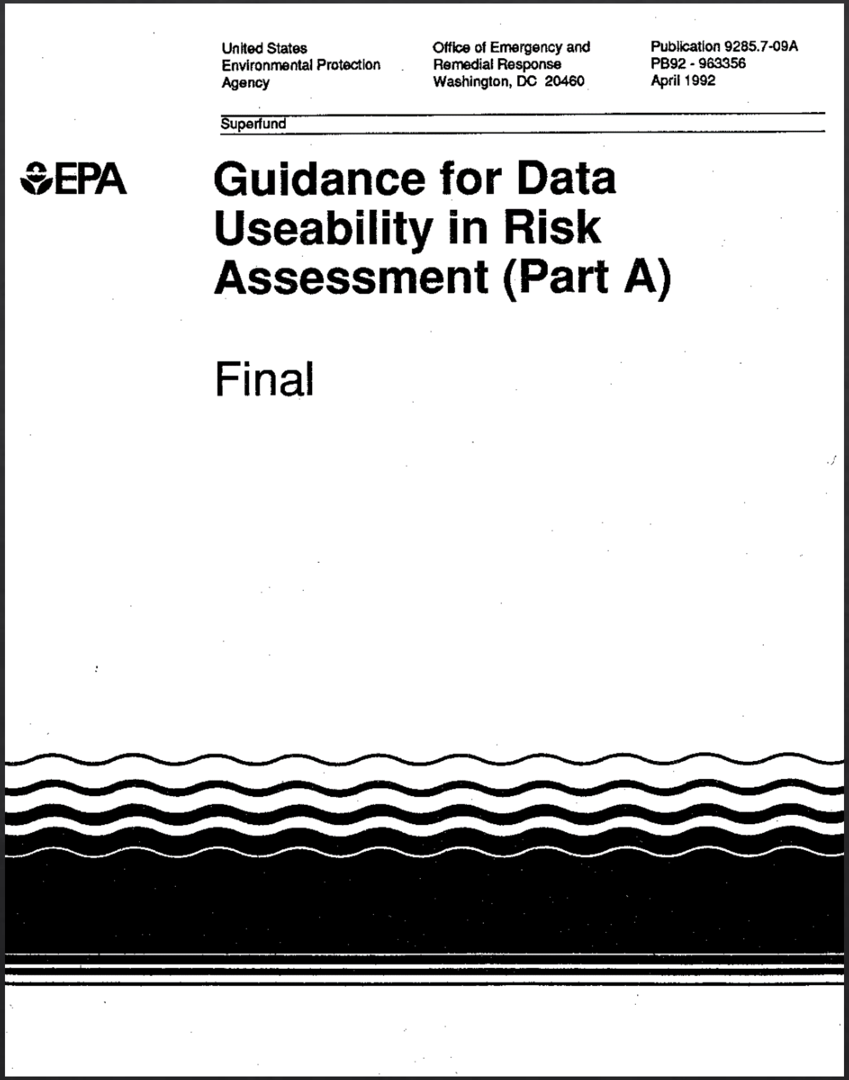
Approximately 90% of **data failure** due to:

- *Poor* sample planning
- *Improper* sample collection procedures
- *Incorrect* sampling equipment
- *Inexperienced, improperly* trained individuals
- *Missing or lost* data

*Navy/USEPA

Primary Quality Considerations in EPA Parlance

- **P**recision
- **A**ccuracy
- **R**epresentativeness
- **C**omparability
- **C**ompleteness
- **S**ensitivity (QA/G-4)


United States Environmental Protection Agency | Office of Emergency and Remedial Response Washington, DC 20460 | Publication 9285.7-09A PB92 - 963356 April 1992

Superfund

EPA

Guidance for Data Useability in Risk Assessment (Part A)

Final

Precision, Accuracy & Sensitivity (EPA)

Importance

- Accuracy (bias) & Precision (reproducibility) become more critical for result near the concentration of concern.
- Sensitivity: Ability to confidently quantify low level concentrations.

Suggested Action

- Collect QC data (duplicates, replicates for precision – blanks, spikes, surrogate recoveries, calibration standards for accuracy)
- Instrument and method selection critical during planning stage
- Use data qualifiers!

Precision, Accuracy & Sensitivity (BLM)

Detection Limits

- Establish level of potential concern (i.e. risk-based screening levels) in the work plan.
- Consider prior work.
- Work with the lab – compare reporting limits to RBSLs!

Data Validation

- Level 3+ for risk assessment
- Consider different levels.
- Lab qualifiers are not sufficient.
- Use qualifiers in data tables.

Representativeness (EPA)

Importance

- Sample data must accurately reflect the site characteristics…Hot spots and exposure area media must have representative data.

Suggested Action

- Collect a sufficient number of samples, accounting for <u>exposure area</u> media, for risk assessment use.

Representativeness (BLM)

- Spatial Representation
  - Spatial and temporal trends
  - Hot spots:
    - Often a site characterization focus (biases exposure).
    - How big an area is a problem? Define exposure area(s).
  - Background - critical for risk assessment:
    - Adequate and comparable number of measurements
    - Natural background concentrations of metals in soil in the US: http://pubs.usgs.gov/pp/1270/
    - The Risk information System: https://rais.ornl.gov/tools/bg_search.php

Representativeness (BLM – continued)

- Statistical Assessment Needs
  - Inadequate sample sizes (max vs. RME)
    - Use the maximum value for small (e.g. 3 – 9) samples.
  - Unequal sample sizes
  - Percent non-detects
  - Data distributions
- EPA's ProUCL Statistics Software
  - Upper Confidence Limit Calculations
  - Hypothesis testing (e.g. background evaluations)
  - Outlier testing
  - Non-parametric methods
- Geostatistical software for Krieging

Representativeness (BLM - continued)

- Modeled vs. Measured
  - VOCs
    - Soil vs. soil gas measuring
    - Indoor air modeling
  - Groundwater
    - Exposure points & property boundaries
    - Soil standards protective of groundwater
    - Acid generating rock (potential bias)
  - Air
    - Stack emissions and dispersion modeling
      - Grid size and exposure points
      - Averaging periods for acute and chronic
    - Wet and dry deposition to soil and water.

Comparability (EPA)

Importance

- Quantitative risk assessment results may be questionable if incompatible data sets are used together.

Suggested Action

- Use comparable methods, apply sufficient quality control, and use consistent units.

Comparability (BLM)

Historic data

- Multiple consultants or labs
- Different parameter lists & detection limits
- Different amounts and levels of supporting data quality information

Sampling differences

- Groundwater
  - Sampling technique
  - Well design features
- Soil
  - Grab vs Composite samples
  - Sample depth & particle size
  - XRF vs. Wet Chemistry

Completeness (EPA)

Importance

- Must be 100% for critical samples…(e.g. exposure point/area)

Suggested Action

- Define completeness in the SAP:
  - Identify critical samples
  - Define useable data needed to meet performance objectives.

Completeness (BLM)

- Parameter lists
  - Chemical specific data (e.g. TPH)
  - Speciation (e.g. chromium III vs VI)
- Coverage
  - Worst case locations
  - Points of exposure
  - Area averaging
- Statistical assessment
- Use of estimated (J) vs rejected (R) data

Summary of Key Messages

1

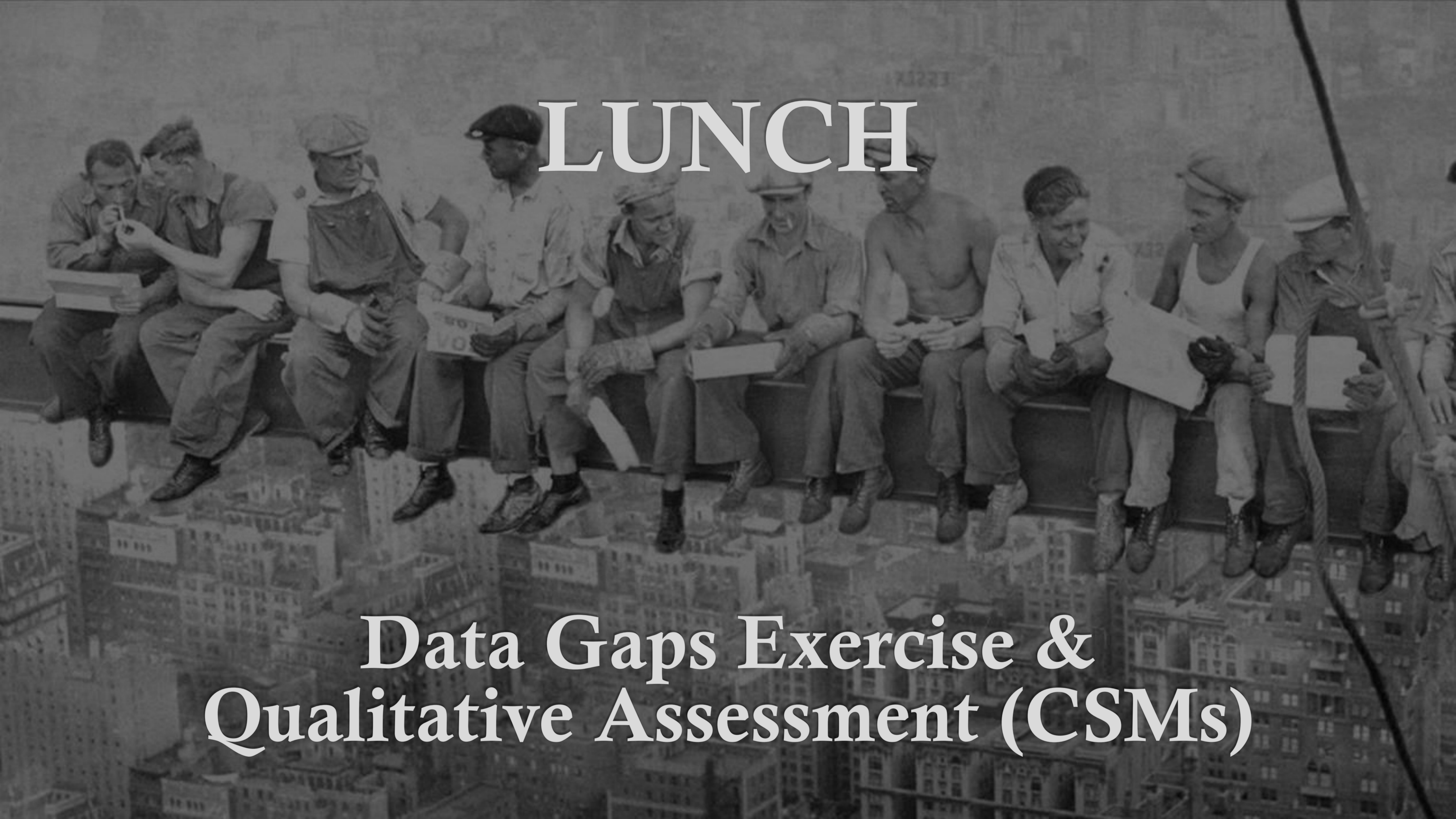
Compare parameter lists and detection limits to risk-based screening levels.

2

Define DQOs for risk:
- Worst case & point/area of exposure
- Modeled vs. measured
- Background comparison
- Statistical needs & ProUCL
- Use of historic data

3

Use data validation/quality information.



LUNCH

Data Gaps Exercise & Qualitative Assessment (CSMs)

Your Turn

Identify Data Gaps

Evaluate existing data for the Lewis Lake Tailing Site within the Bonita Peak mining district to identify data gaps supporting risk assessment needs.

Consider:

1. Data quality and quantity (e.g. representativeness, statistical needs, etc.)
2. Degree and extent of identified contamination.
3. Potential contaminant transport pathways.
4. Exposure area and exposure considerations.
5. Natural background.

Lewis Lake Tailings

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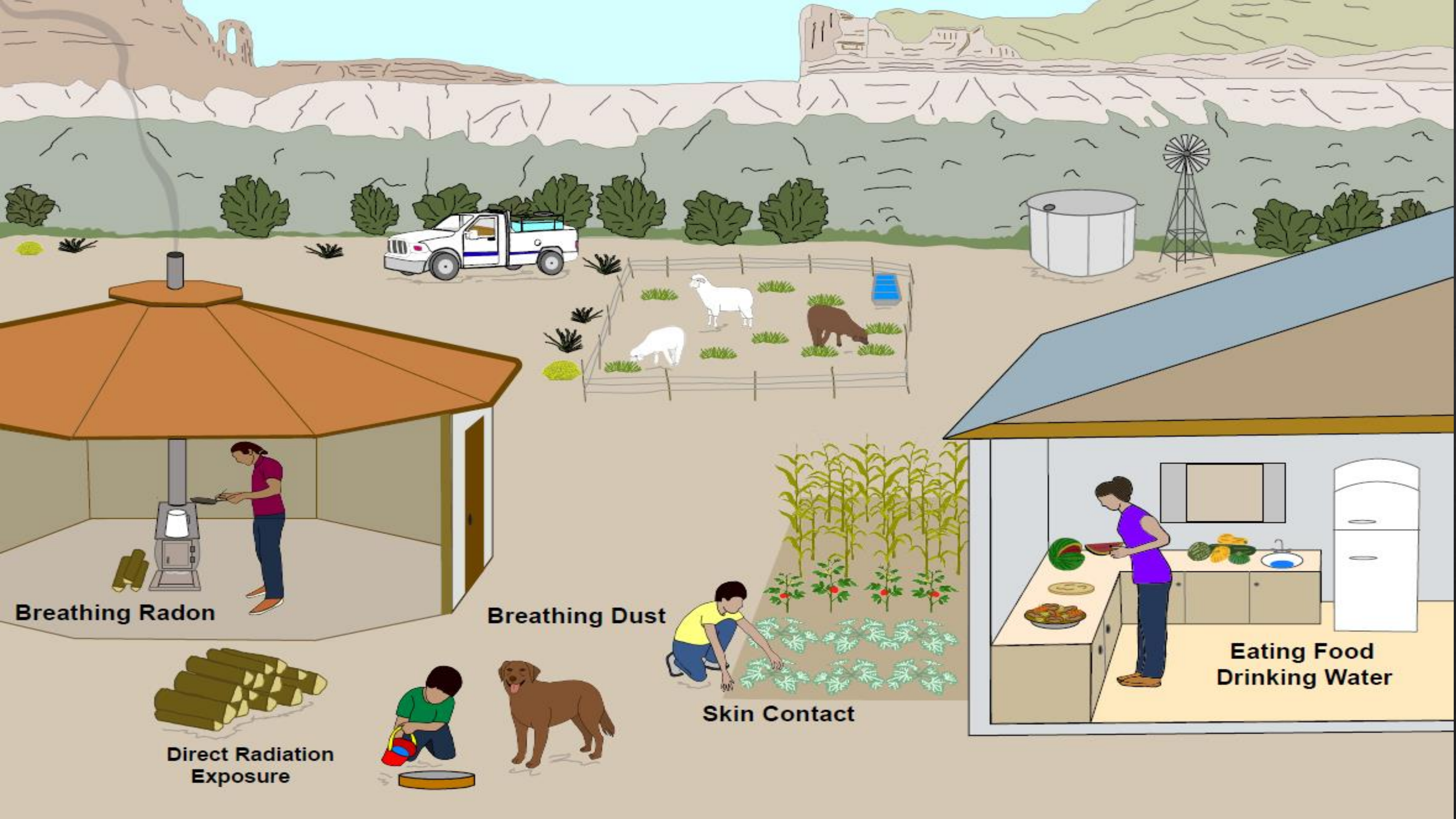
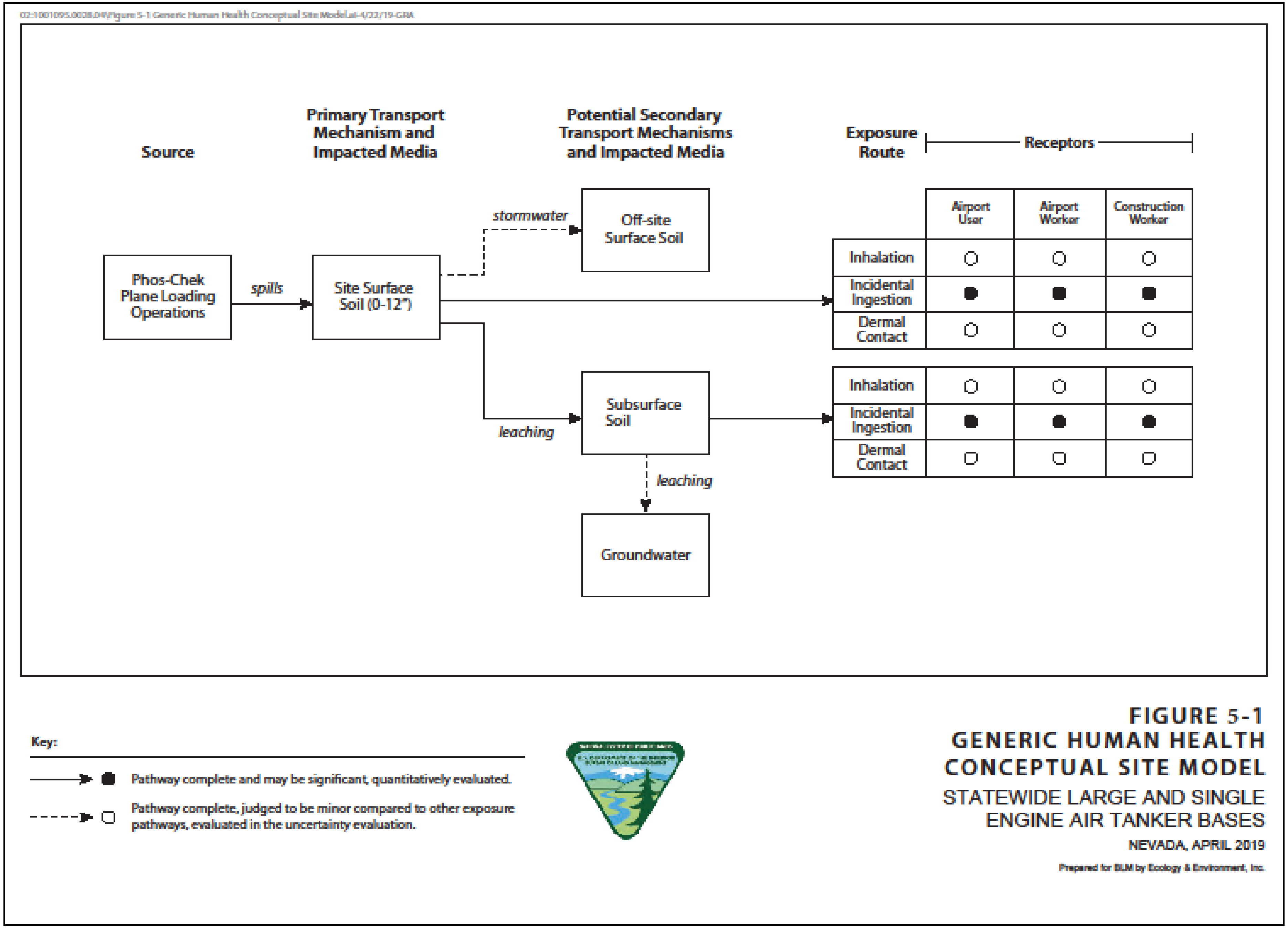
Qualitative Exposure Assessment Needs

Describe the site setting and uses sufficiently well to understand:

- The source of contamination
- How it moves through the environment
- How receptors contact the contamination
  - No exposure = no risk

Conceptual Site Models (CSMs) use influence diagrams to create a visual representation.


Breathing Radon
Breathing Dust
Skin Contact
Eating Food
Drinking Water
Direct Radiation
Exposure



- Winnemucca Municipal Airport
- Phos-Chek® fire retardants dropped by BLM aircraft contain cadmium and chromium.
- Historic fire retardants may have contained cyanide.
- Storage tanks and spills during plane refilling.
- Storm drainage, but no hydraulic connection to perennial waters.
- Depth to groundwater unknown.

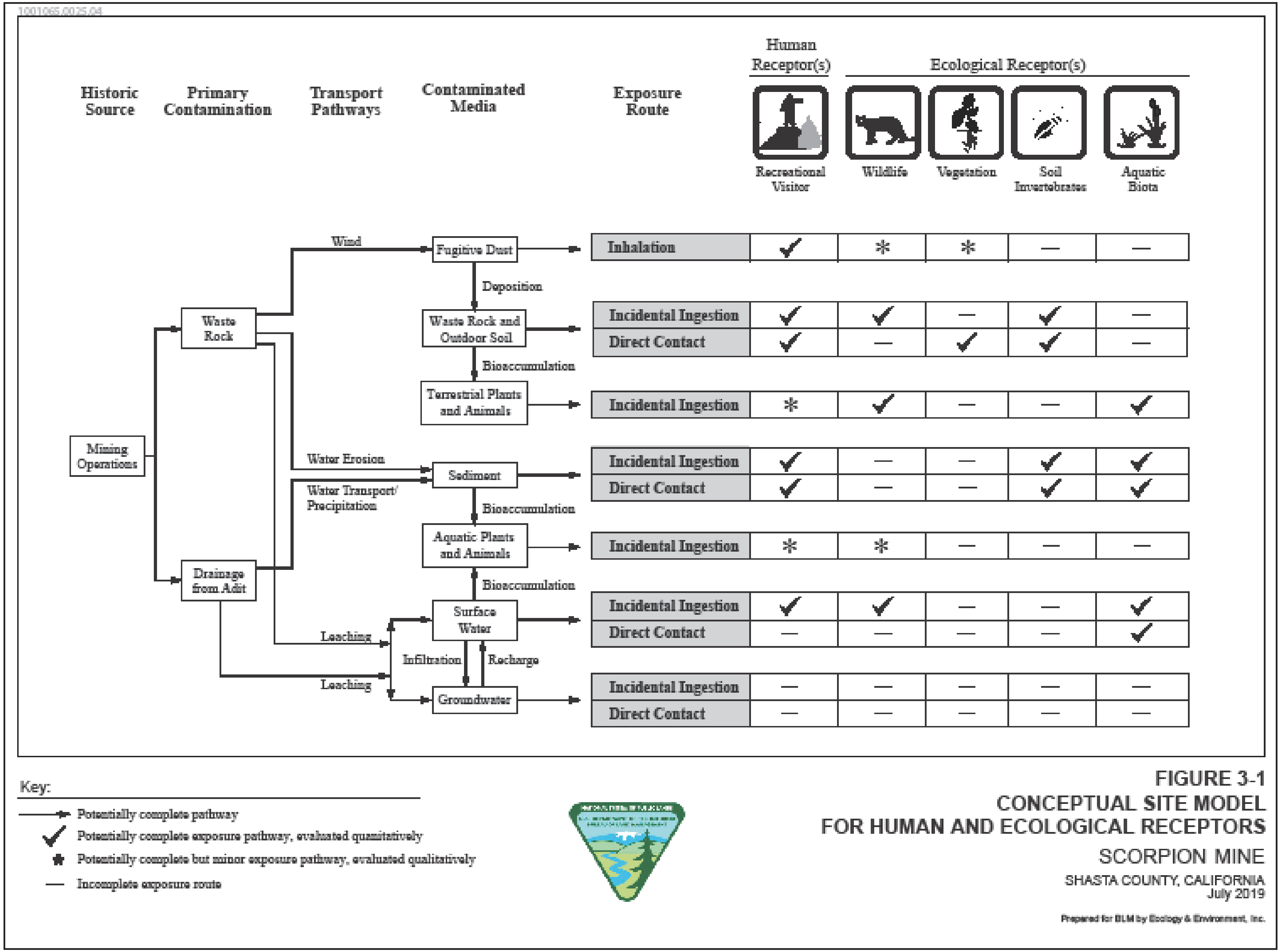
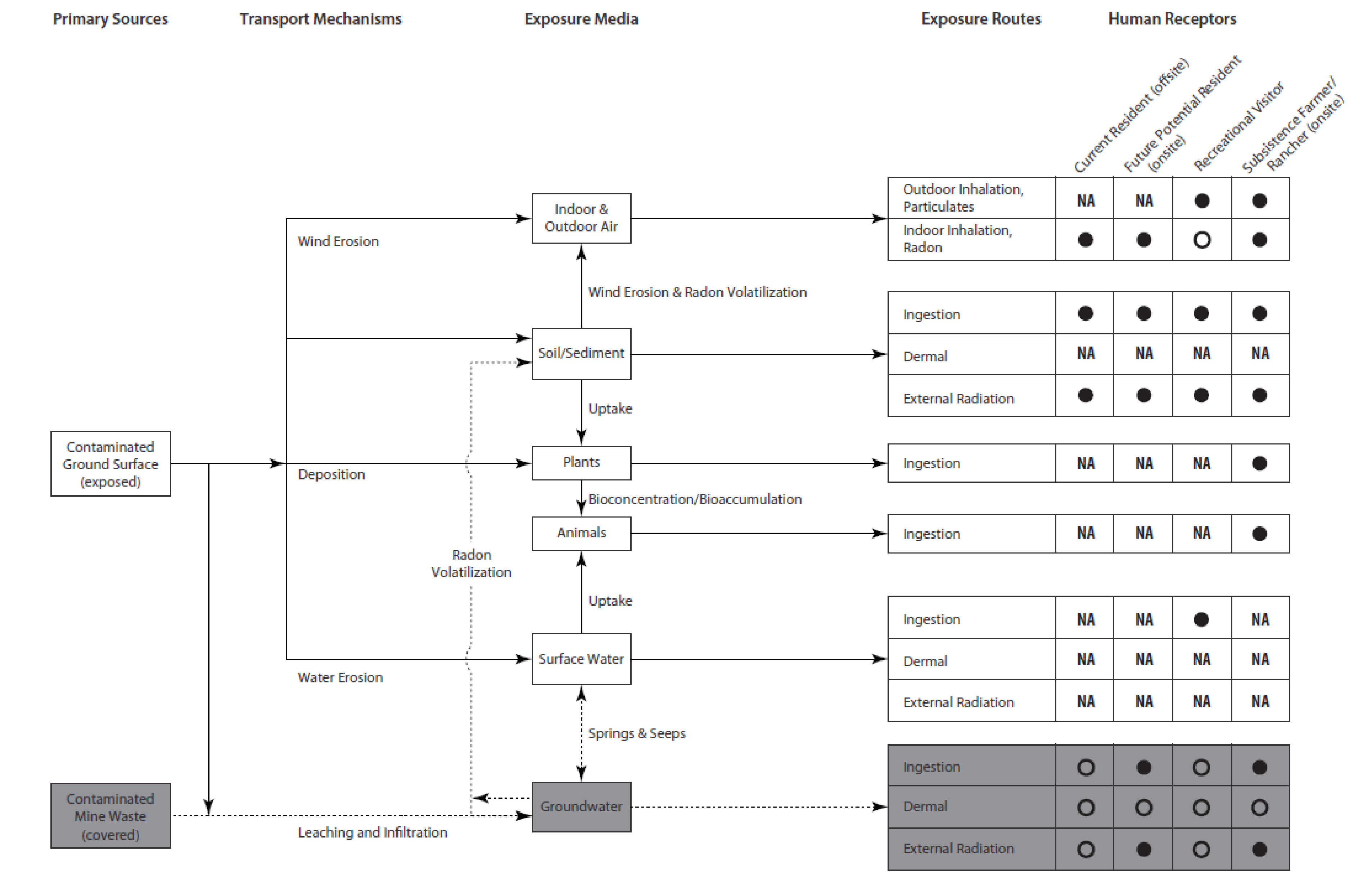


FIGURE 3-1
CONCEPTUAL SITE MODEL
FOR HUMAN AND ECOLOGICAL RECEPTORS
SCORPION MINE
SHASTA COUNTY, CALIFORNIA
July 2019

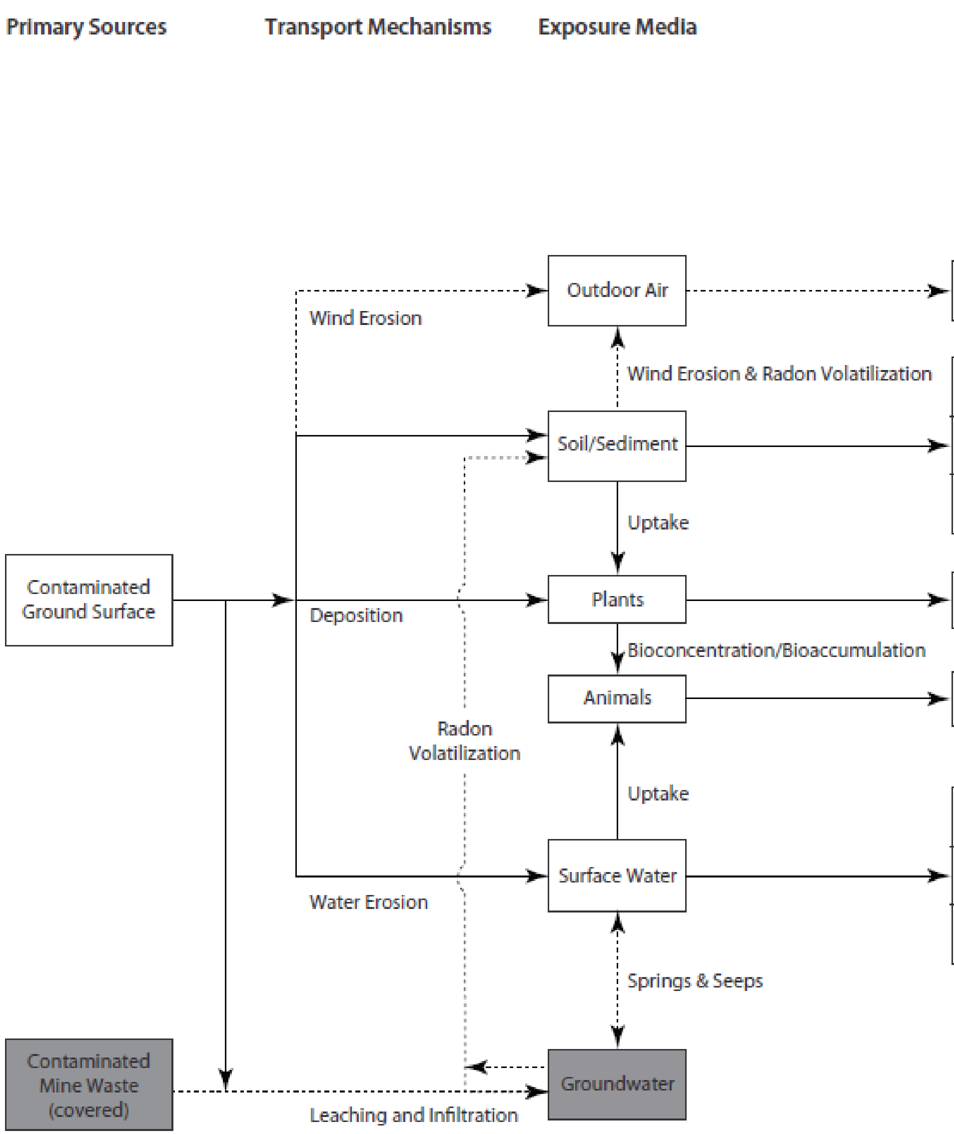
- French Gulch in Shasta County, California
- Historic underground lode gold mine with draining, collapsed, AMD adit portal 20 feet from receiving intermittent stream.
- Stream flows around a waste rock pile.
- ATV accessible, eroding access road.
- Gaining stream.



Key:
- ● Potentially complete exposure pathway, evaluated quantitatively
- ○ Potentially incomplete or not significant exposure pathway, evaluated qualitatively
- NA Pathway not applicable
- Not applicable at most RSE sites
- Potentially complete pathway
- Minor pathway; addressed qualitatively

FIGURE 4
GENERIC HUMAN HEALTH CONCEPTUAL SITE MODEL
RSE SITES
BLACK MESA CHAPTER,
NAVAJO NATION
APACHE COUNTY, AZ

- Navajo Nation, AZ.
- Many abandoned uranium mines.
- Large depth to groundwater with groundwater recharge from distant mountains.
- Subsistence living and ranching.



Exposure Routes	Receptors							
	Terrestrial				Aquatic (?)			
	Plants	Soil Invertebrates	Birds & Mammals (including livestock)	Reptiles	Aquatic Plants	Amphibians	Benthic Invertebrates	Fish & Aquatic Dependent Wildlife
Inhalation	NA	NA	○	○	NA	NA	NA	○ *
Ingestion	NA	○	●	○	NA	○	○	○ *
Direct Contact/ Absorption	●	●	NA	NA	●	○	●	NA *
External Radiation	●	●	●	○	●	○	○	●
Ingestion/Food Chain	NA	○	●	○	NA	○	NA	● *
Ingestion/Food Chain	NA	○	●	○	NA	○	○	● *
Ingestion	NA	NA	●	○	NA	○	○	●
Direct Contact/ Absorption	NA	NA	○	○	○	○	○	○
External Radiation	NA	NA	○	○	○	○	○	●

Key:

● Potentially complete exposure pathway, evaluated quantitatively

○ Potentially incomplete or not significant exposure pathway, or limited toxicity data, evaluated qualitatively

NA Pathway not applicable

- - -> Minor pathway; addressed qualitatively

——> Potentially complete pathway

? Pathways to be determined depending on water availability at the seep, stock pond, and persistent pools downstream

* Wildlife only

FIGURE 5

GENERIC ECOLOGICAL CONCEPTUAL SITE MODEL

RSE SITES
BLACK MESA CHAPTER,
NAVAJO NATION
APACHE COUNTY, AZ

Chemical & Physical Properties Information Sources

- ATSDR Toxicological Profiles: https://www.atsdr.cdc.gov/toxprofiledocs/index.html
- The Risk Information System
  - Chemical Profiles: https://rais.ornl.gov/tools/profile.php
  - Toxicity Values and Physical Parameters Search: https://rais.ornl.gov/cgi-bin/tools/TOX_search?select=chemspef
- Safety Data Sheets (beware of quality)
- Other Internet searches.

Ecological Food Web Models

Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Chapter 4; while now provided as an archive file, chapter 4 still provides many good example food web models: https://archive.epa.gov/epawaste/hazard/tsd/td/web/pdf/chap4.pdf

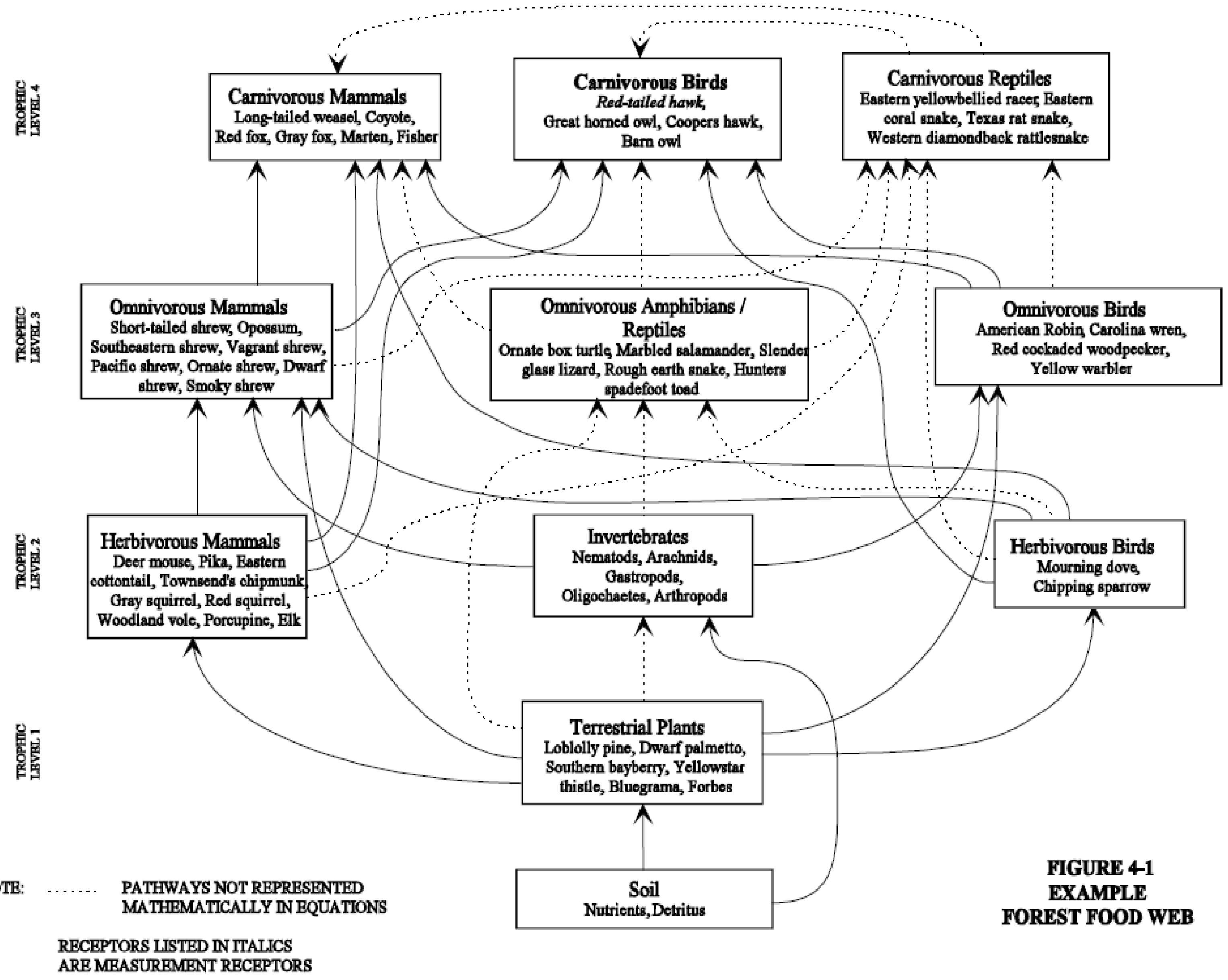


FIGURE 4-1
EXAMPLE
FOREST FOOD WEB

Food Modeling Terms

A **food chain** is a series of organisms that sequentially feed on one another. Food chains show the relationships between producers, consumers, and decomposers—what eats what.

Trophic level is a functional classification of taxa within a community that is based on relative positions occupied in a food chain: producers, primary consumers (eat plants), and secondary producers (eat meat).

Indicator species are receptor species selected to represent the various trophic levels evaluated in a risk assessment. Indicator species are thought to be representative of the status and reproductive success of other species in a particular habitat, or valued (e.g. T& E species).

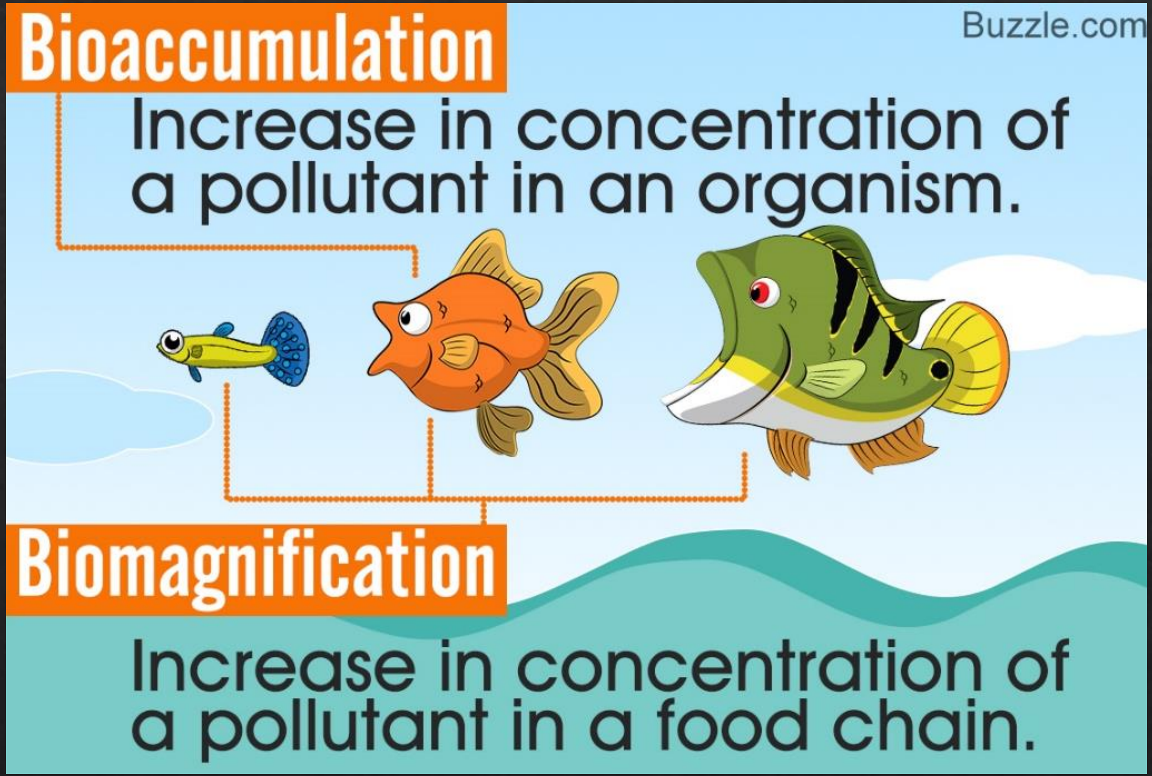
A **food web** is made up of interconnected food chains. Food webs were developed to assess the feeding strategies and trophic level interactions that characterize representative habitats.

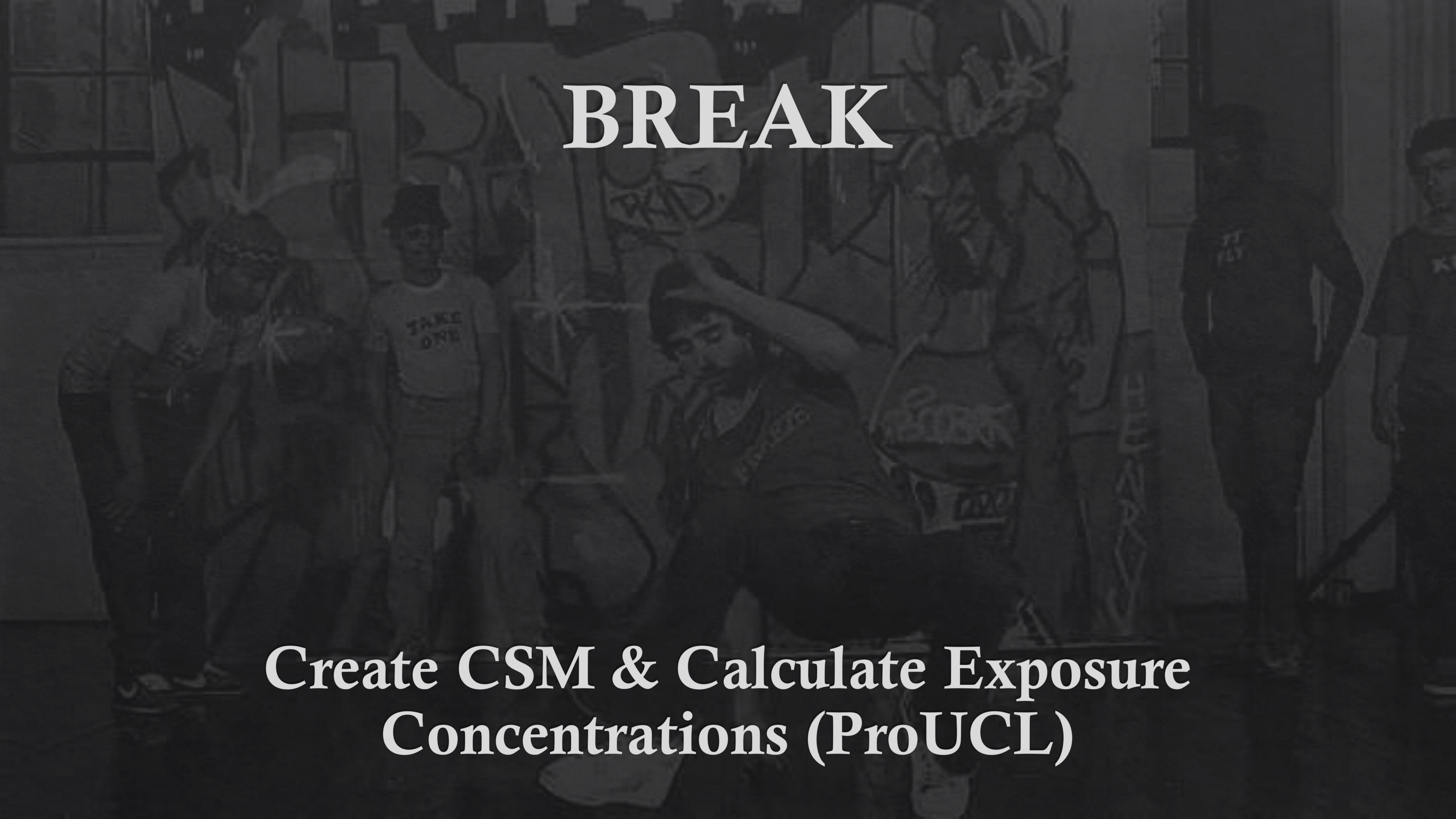
Bioconcentration vs Bioaccumulation

- **Bioconcentration Factor** (BCF) or **Bioaccumulation Factor** (BAF): the ratio of the chemical concentration in an animal to the chemical concentration in its environment; generally at lower trophic levels.
  - Fish tissue vs water concentrations.
- **Biomagnification**: the potential for the BCF to increase at higher trophic levels.

See EPA list of Persistent, Bioaccumulative and Toxic (PBT) chemicals.

See EPA EcoBox Tools for guidance and values:
https://www.epa.gov/node/149563/view





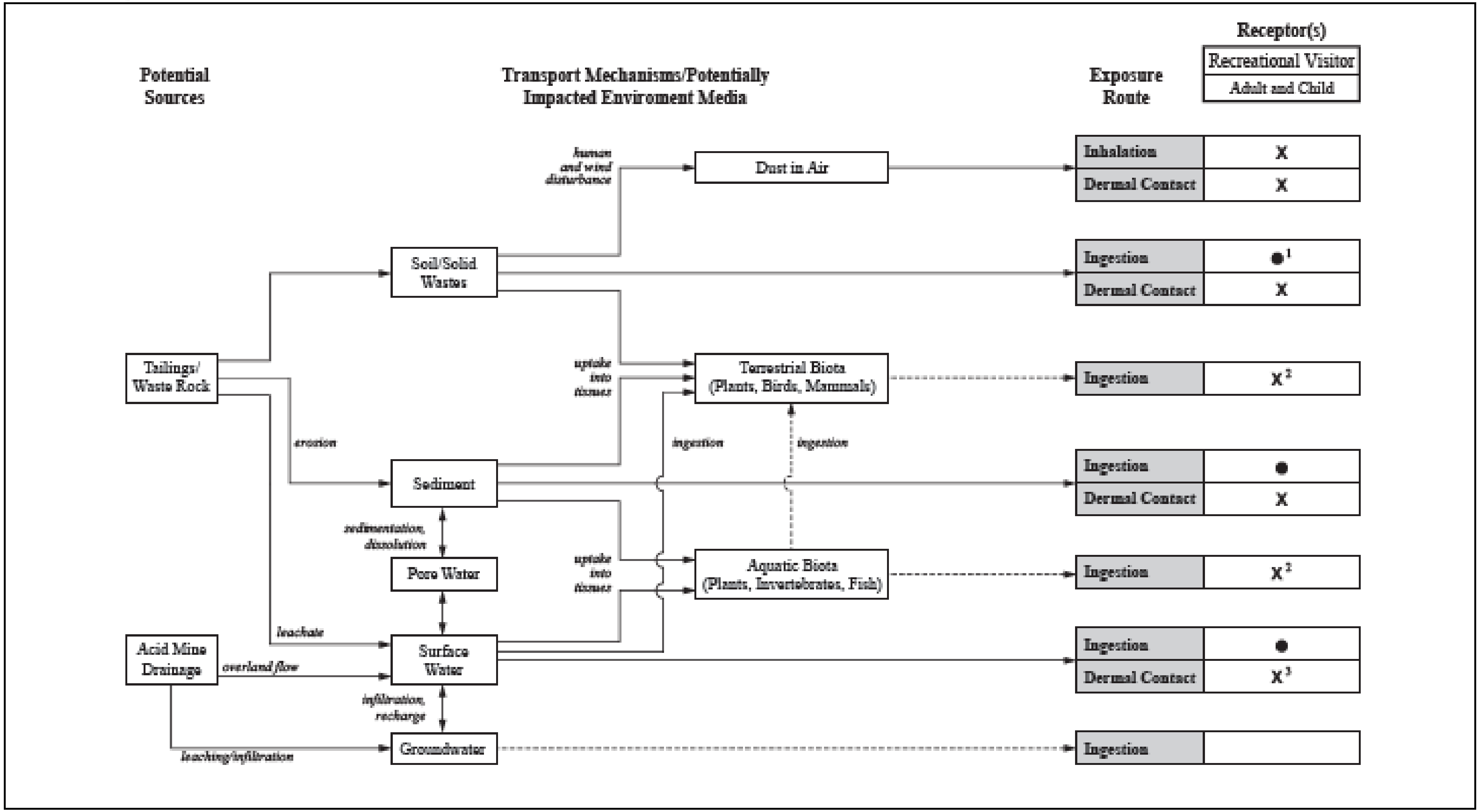
BREAK

Create CSM & Calculate Exposure Concentrations (ProUCL)

Your Turn

CSM Exercise

Create a CSM for the Lewis Lake site.



Key:

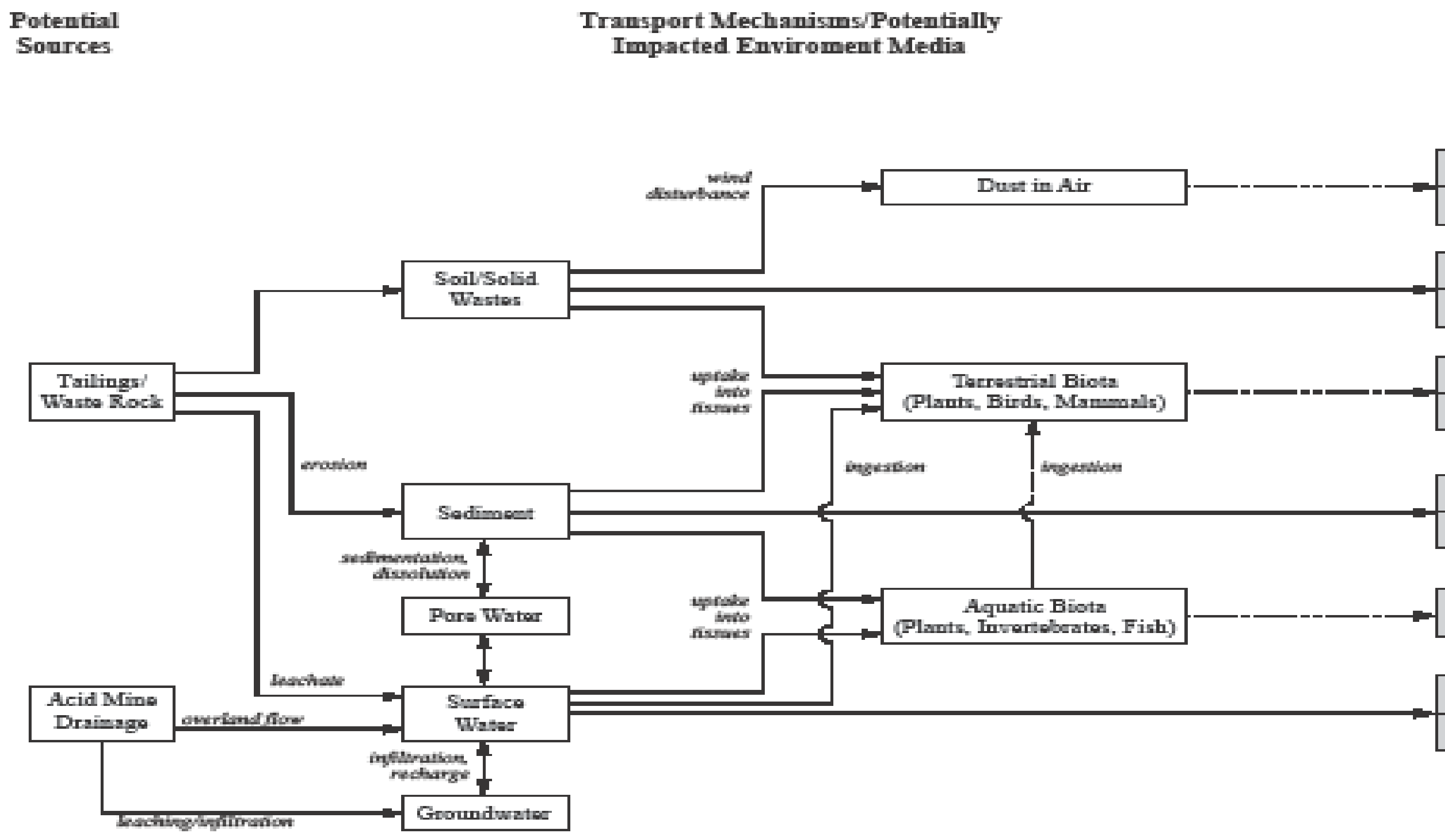
- → ● Pathway complete and may be significant, quantitatively evaluated.
- - - → X Pathway complete, judged to be minor compared to other exposure pathways, evaluated in the uncertainty evaluation.
- blank Pathway not complete.

FIGURE 2-1
GENERIC HUMAN HEALTH CONCEPTUAL SITE MODEL
BONITA PEAK MINING DISTRICT
SAN JUAN COUNTY, COLORADO
December 2018

Prepared for BLM by Ecology & Environment, Inc.

Notes:
1. Pathway will not be evaluated using the Adult Lead Model because the minimum exposure frequency and duration is not met for intermittent exposure.
2. May be quantitatively considered for persistent, bioaccumulative and toxic chemicals in a mine-specific baseline risk assessment.
3. Acute toxicity (e.g. irritation, eye damage, etc.) evaluated quantitatively where applicable.

- Above Silverton, CO at 10,000+ ft elevation.
- Many historic mines in the watershed.
- History of natural ARD.
- Heavy recreational use for 4-wheeling, camping, fishing, etc.
- Draining adits and waste rock piles and mill tailings.



Exposure Route	Aquatic: Benthic Macroinvertebrates	Aquatic: Fish	Semi-Aquatic: Plants	Semi-Aquatic: Birds and Mammals	Terrestrial: Invertebrates	Terrestrial: Plants	Terrestrial: Birds and Mammals
Inhalation				X	X		X
Direct Contact			X			X	
Ingestion				●	●		●
Direct Contact			●	X	X	●	X
Ingestion				X[1]	X[1]		X[1]
Direct Contact			X[1]			X[1]	
Ingestion	●			X			X
Direct Contact	●		X				
Ingestion	X	X		X[1]			
Ingestion	●	●		X	X		X
Direct Contact	●	●	X			X	

Key:

→ ● Pathway complete and may be significant, quantitatively evaluated.

→ X Pathway complete, judged to be minor compared to other exposure pathways, evaluated in the uncertainty evaluation.

blank Pathway not complete.

FIGURE 2-2
GENERIC ECOLOGICAL CONCEPTUAL SITE MODEL
BONITA PEAK MINING DISTRICT
SAN JUAN COUNTY, COLORADO
December 2018

Prepared for BLM by Ecology & Environment, Inc.

Notes: 1. May be quantitatively considered for persistent, bioaccumulative and toxic chemicals in a mine-specific baseline risk assessment.

Course Organization

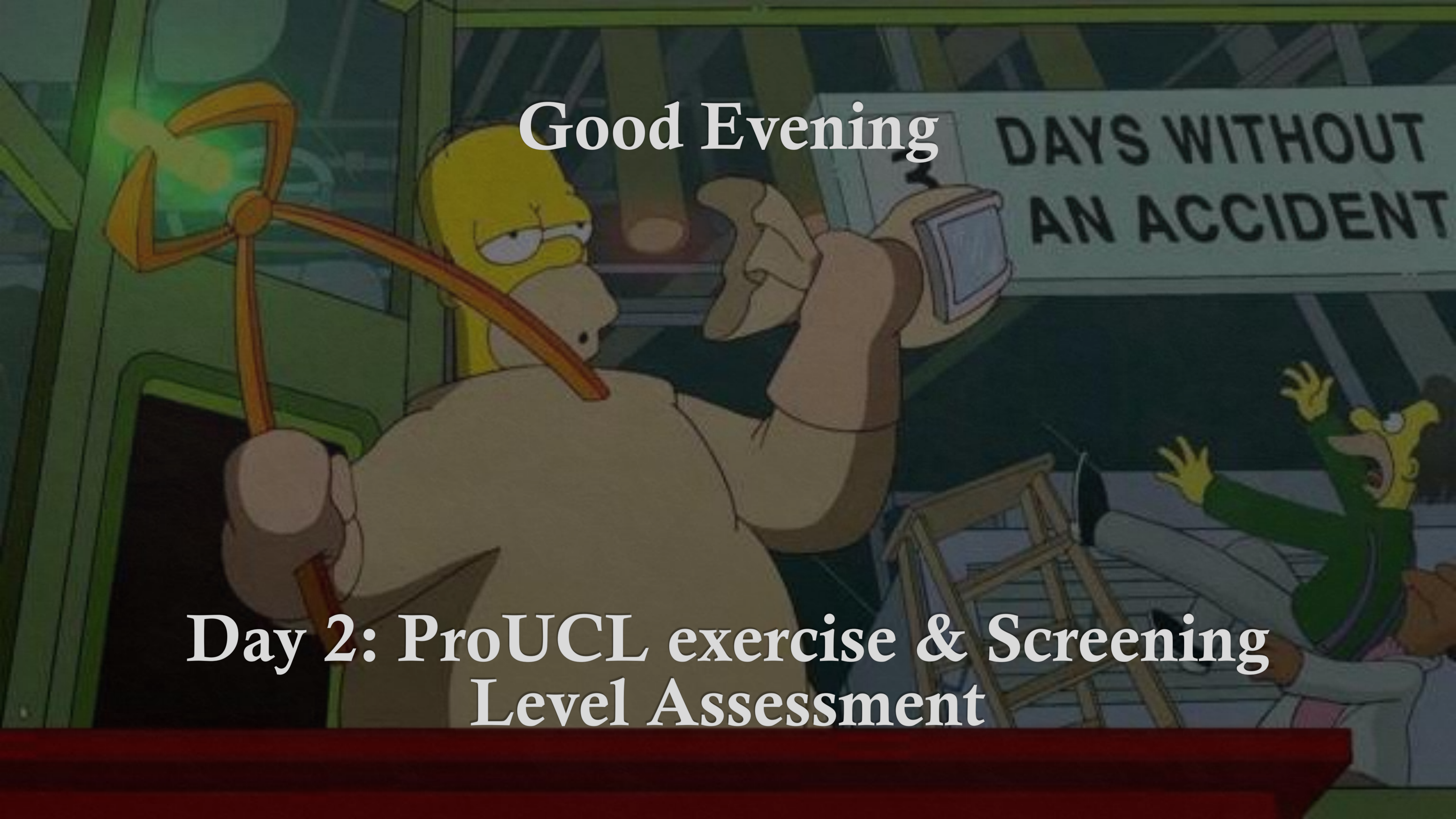
- Overview
- Site Characterization
- Exposure Assessment
  - Qualitative
  - Quantitative
- Screening Level Assessment
- Toxicity Assessment
  - Human
  - Ecological
- Risk Characterization
- Uncertainty Assessment
- Lead
- Acute Arsenic & Lead
- Radionuclides

Calculating Exposure Concentration

EPA ProUCL Software: https://www.epa.gov/land-research/proucl-software

- Used extensively to calculate the 95% Upper Confidence Limit (95 UCL)
  - Has greatly standardized and simplified industry application of complex statistics.
  - Focused on statistical needs of Superfund type site investigations.
  - Many descriptive statistics to help inform proper 95 UCL selection.
    - Sample size requirements.
- Other functions:
  - Hypothesis testing
  - Upper Tolerance Limits
  - More…
- Users Guide and Technical Guide available
- https://clu-in.org/training/ ProUCL Utilization 2020 Part 1 to 3.
  - Used as source material for portions of this presentation.

Good Evening



Day 2: ProUCL exercise & Screening Level Assessment

Typical Workflow for UCL Calculation

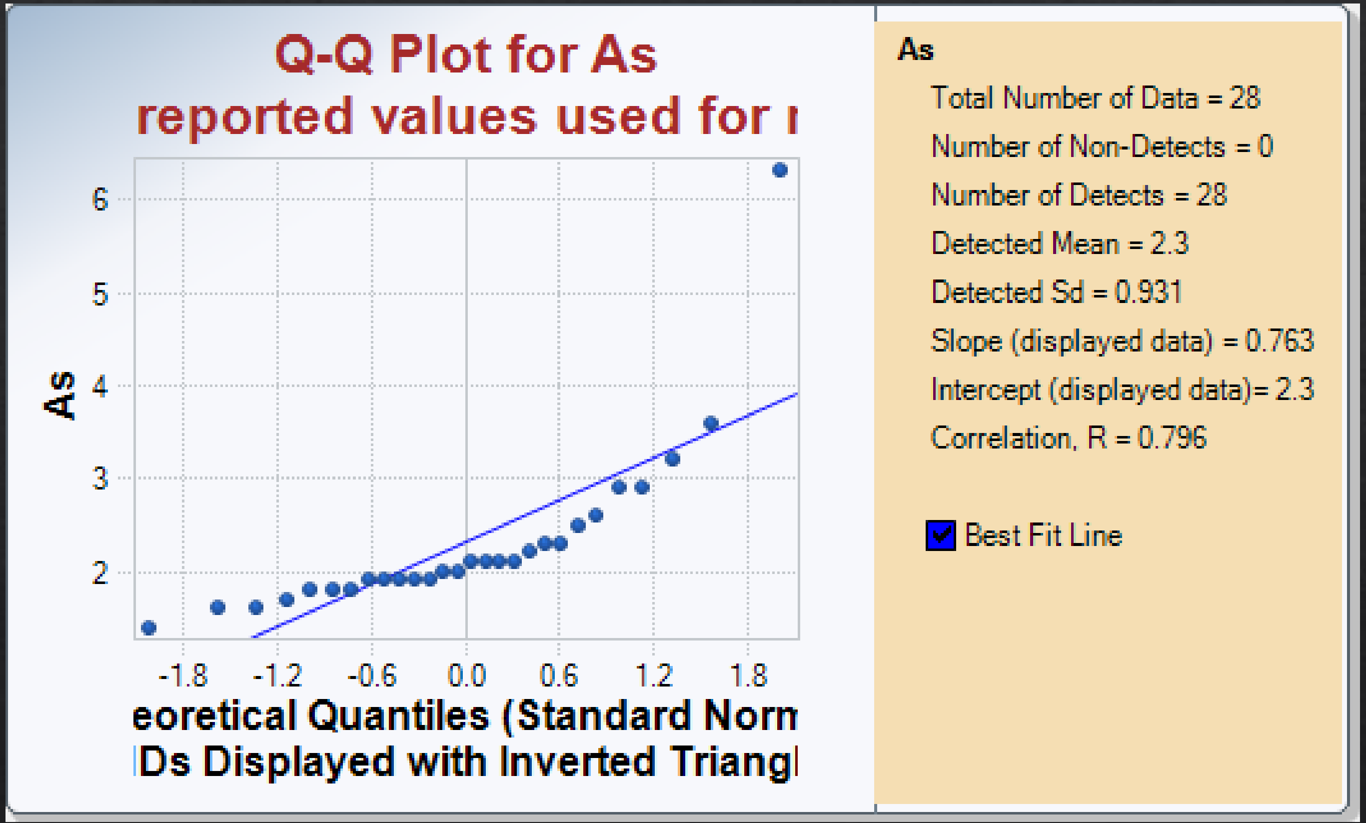
1. Develop the ProUCL input file
   - Data in columns
   - Detection field (e.g. D_As) uses 0 for ND, 1 for detected values.

As	D_As	Mo	D_Mo
2.1	1	0.18	1
2	1	0.18	1
1.8	1	0.13	1
1.8	1	0.11	0
2	1	0.12	0
2.1	1	0.11	0

Typical Workflow for UCL Calculation

2. Run UCL for all methods (see coursebook)

3. Deeper dive into issues for non-normal data
   - Normality Tests
   - Outlier Tests (see coursebook)
     - Dixon and Rosner (n=25+tests) in ProUCL
     - Both require assumption of normality of the data set without outliers (rarely true!)
     - Limited options for NDs?
       - Exclude NDs
       - Replace NDs by DL/2 values



Thoughts on Outliers

Reference: *EPA guidance QA/G-9S Data Quality Assessment: Statistical Methods for Practitioners*

Outliers can distort statistics

Assess with and without outliers to understand the magnitude of the potential error.

Robust outlier detection involves a mix of statistics and real-world information.

Statistics is only an aid to decision-making!

Statistics identifies "suspects".

"Not removing true outliers or removing false outliers both lead to distorted estimates of population parameters" (QA/G-9S)

May result from errors:

Transcription, unit, etc. errors

Laboratory measurement errors (inherent or mistakes).

May indicate more variability than expected, e.g.

Extreme population values

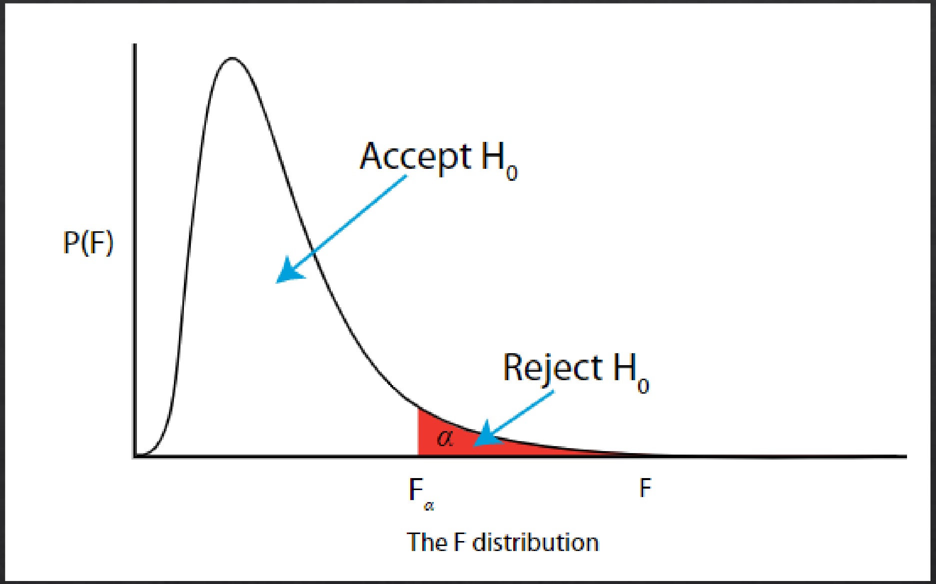
On-site hot spots

Multiple soil types in background area

If outliers are critical and you are uncertain – get help!

Hypothesis Testing

- Single-sample hypothesis test
  - To compare site data with prespecified level of concern
- Two-sample hypothesis testing
  - To compare two populations, i.e. background vs "site"
- Parametric and non-parametric test options are available in ProUCL



Ho = null hypothesis

Single Sample Hypothesis Testing

One Sample t-test

Assumes normality of data set
Can't be used for censored data (i.e. NDs)
Large data set required depending on the data skewness

One-Sample Sign Test or Wilcoxon Signed Rank (WSR) Test

- Can handle NDs
- Requires ND < Cleanup Standard

Percentile Test to compare exceedances to the actionable level

- Can handle NDs
- Requires ND < Cleanup Standard

Two Sample Hypothesis Testing

Without NDs

- **Student's t and Satterthwaite tests**: to compare the means of two populations (e.g. Background versus AOC).
- **F-test**: to the check the equality of dispersions of two populations.
- **Two-sample nonparametric Wilcoxon-Mann-Whitney test**: equivalent to Wilcoxon Rank Sum test

With NDs

- **Wilcoxon-Mann-Whitney test**: All observations (including detected values) below the highest detection limit are treated as ND (less than the highest DL) values
- **Gehan's test and Tarone-Ware test**: useful when multiple detection limits may be present

Determine the exposure concentration

- Run ProUCL: https://www.epa.gov/land-research/proucl-software
- Use Navajo Background Study Area 1 chemistry data. Use project report Table 1 for data inputs (As, Se, Ra), and follow bullets 1-4 on page 3.
- Review memo time permitting to support post exercise discussion.

Your Turn

Screening Level Assessment

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What's Needed for Screening Level Risk Assessment?

Environmental Concentration

Maximum or alternative statistical representation of exposure such as an 95% UCL (upper confidence limit)

Applicable Media Standard

Basis for the standard should reflect site conditions

Media Standards in Screening Level Risk Assessment

$$Hazard\ Quotient = \frac{Environmental\ Concentration}{Media\ Standard}$$

Where,

- Environmental Concentration is related to exposure through many assumptions, and
- Media Standard reflects a no or low observed adverse effect or a risk level for carcinogens.
- HQ < 1 = (acceptably) low risk, not no risk.

HI & HQ Interpretation

- Hazard Quotient is not a linear function
  - Linearity applies to single chemical, single endpoint.
  - Other endpoints become a concern as exposure increases.
- Agency for Toxic Substance Disease Registry (ATSDR) Toxicological Profiles: https://www.atsdr.cdc.gov/toxprofiledocs/index.html
  - Excellent reference for general information.
  - Public Health Statement
  - Understanding quality of information underlying toxicity assessments - identifies available studies in effective graphics

Multiple Chemical Exposures

Hazard Index = $\sum$ Hazard Quotient.

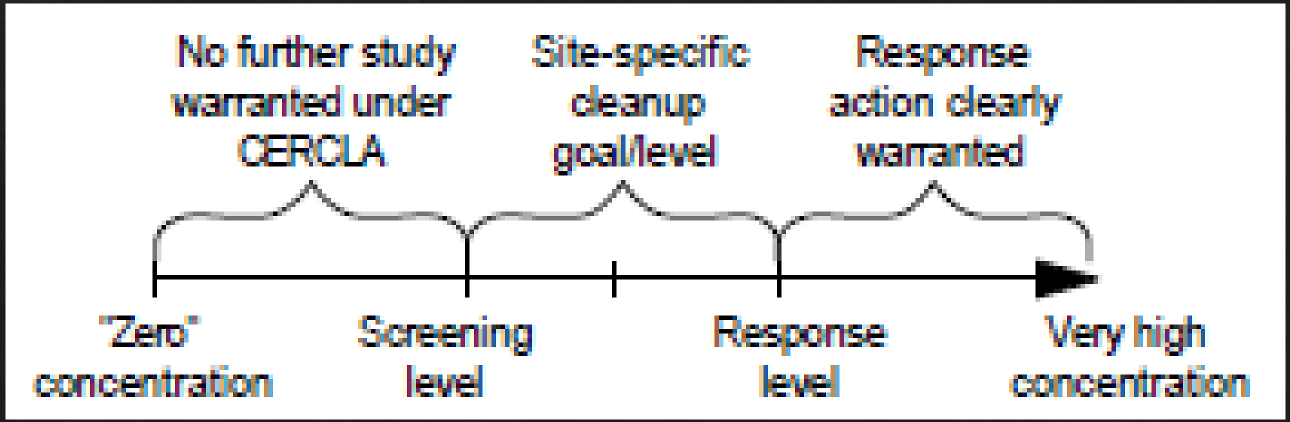
Hazard Quotients (HQ) vs. Hazard Index (HI)

HQ applies if there is a similar toxic effect.

Additivity (rather than synergistic or antagonistic) is nearly always an assumption due to limited knowledge.

Opportunities and Challenges

- Relatively simple.
- Higher levels of conservatism.
- Recognize complexity behind a seemingly simple task – many common errors leading to increased project cost!
- Know when to make site-specific adjustments or move into site-specific risk assessment.



Types & Primary Sources of Screening Level Values for Human Health

Risk-based

- EPA Regional Screening Levels: https://www.epa.gov/risk/regional-screening-levels-rsls
- EPA RSL Calculator: https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search
- BLM Recreational: see course book and next page.
- Nevada Guidelines for Discovery Events: https://ndep.nv.gov/environmental-cleanup/site-cleanup-program/site-cleanup-guidance
- TCEQ, TRRP Human Sediment (contact) PCLs: https://www.tceq.texas.gov/remediation/trrp/guidance.html

Technology-based:

- Maximum Contaminant Levels (MCLs) & Secondary MCLs per the Safe Drinking Water Act: https://www.epa.gov/dwstandardsregulations
- OSHA workplace standards and TSCA 2016 renewal

Human Health Screening Levels (SLs) for Chemicals in Soil at BLM HazMat/AML Sites (mg/kg)

[A] The recreational SL for lead is based on EPA's industrial SL, which assumes regular and chronic exposure to soil, although not as frequently or extensively as the residential SL.

[B] Mercury is the only metal on the list whose SL is based on the inhalation pathway. EPA made some minor changes in their volatilization modeling in 2015 and the SL increased slightly. SLs for all populations may exceed the soil saturation concentration (Csat), an estimate of the concentration at which the soil pore water, pore air, and surface sorption sites are saturated. Above this theoretical threshold concentration, mercury may be present in free-phase within the soil matrix.

[C] Uranium screening values updated per changes in EPA's oral toxicity value.

Chemical	BLM Recreational SL	EPA Residential SL	EPA Industrial SL
Aluminum (Al)	>1,000,000	77,000	>1,000,000
Antimony (Sb)	782	31	470
Arsenic (As)	30.6	0.68	3
Barium (Ba)	390,000	15,000	220,000
Beryllium (Be)	3,910	160	2,300
Cadmium (Cd)	1,780	71	980
Chromium (III) (Cr)	>1,000,000	120,000	>1,000,000
Cobalt (Co)	586	23	350
Copper (Cu)	78,200	3,100	47,000
Iron (Fe)	>1,000,000	55,000	820,000
Lead (Pb)	800[a]	400	800
Manganese (Mn)	46,700	1,800	26,000
Mercury (elemental) (Hg)[b]	271	11	46
Molybdenum (Mo)	9,780	390	5,800
Nickel (Ni)	39,000	1,500	22,000
Selenium (Se)	9,780	390	5,800
Silver (Ag)	9,780	390	5,800
Thallium (Tl)	19.6	0.78	12
Uranium (U)[c]	391	16	230
Vanadium (V)	9,850	390	5,800
Zinc (Zn)	587,000	23,000	350,000
Primary Exposure Assumptions	14 days/year, 26 years, adult/child	350 days/year, 26 years, adult/child	225 days/year, 25 years, adult

Human vs Ecological Assessment

Human

- One Species
- Cancer risk & Noncancer hazard
- RME Individual
- Food chain less common

Ecological

- Multiple Species
- Noncancer hazard
- Population (typically)
- Food chain common

Problem Formulation in Ecological Risk Assessment

Assessment Endpoints: What you care about, what's regulated.

- Habitat Integrity: sustainability, resilience
- Valued species
- Food chain bioaccumulation
- Threatened & Endangered Species

Measurement Endpoints: What you can measure or monitor.

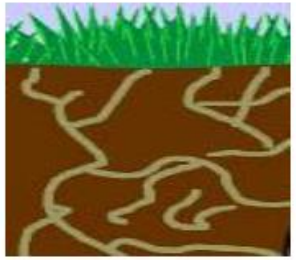
- Media concentrations
- Biota concentrations in representative species
- Species diversity and abundance

Important for the soil fertility

They eat dead organic material

- Increases the bioavailability of nutrients for other organisms

They make burrows in the soil



- Increase the aeration and water drainage
- Mixing organic and inorganic components of the soil

Important role in the food web

Who cares about worms?

KJM360: Assessing Risk to Humans and the Environment, Debra Oughton, Norwegian Universtity of Life Sciences.

Problem Formulation in Ecological Risk Assessment

Table 2-1 Assessment Endpoints, Risk Questions, and Measures for the Screening Level Ecological Risk Assessment, Olean Wellfield Superfund Site, Operable Unit 4, Cattaraugus County, New York

Assessment Endpoint (Attribute)	Level of Organization	Representative Species	Risk Question	Measure	Analysis Approach
TERRESTRIAL RECEPTORS					
Terrestrial Plants					
Terrestrial vegetation (S, G, R)	Local Community	All plants that obtain nutrients primarily from soil	Are contaminant concentrations in surface soil (0 to 2 feet bgs) greater than screening levels for effects on survival, growth, or reproduction of plants?	Contaminant levels in surface soil.	Compare surface-soil contaminant concentrations with literature-based soil screening levels for effects on plants.
Terrestrial Invertebrates					
Terrestrial invertebrates (S, G, R)	Local Community	All soil invertebrates (e.g., earthworms)	Are contaminant concentrations in surface soil greater than screening levels for effects on survival, growth, or reproduction of soil invertebrates?	Contaminant levels in surface soil.	Compare surface-soil contaminant concentrations with literature-based soil screening levels for effects on soil invertebrates.
Terrestrial Mammals (Herbivorous, Insectivorous, and Carnivorous)					
Terrestrial mammals (S,G,R)	Local Populations	Vole, shrew, weasel	Are contaminant concentrations in surface soil greater than screening levels for effects on survival, growth, or reproduction of mammals?	Contaminant levels in surface soil.	Compare surface-soil contaminant concentrations with literature-based soil screening levels for effects on mammals.
Terrestrial Birds (Herbivorous, Insectivorous, and Carnivorous)					
Terrestrial birds (S,G,R)	Local Populations	Dove, robin, hawk	Are contaminant concentrations in surface soil greater than screening levels for effects on survival, growth, or reproduction of birds?	Contaminant levels in surface soil.	Compare surface-soil contaminant concentrations with literature-based soil screening levels for effects on birds.

Problem Formulation in Ecological Risk Assessment

Assessment Endpoint (Attribute)	Level of Organization	Representative Species	Risk Question	Measure	Analysis Approach
AQUATIC RECEPTORS					
Benthic Macroinvertebrates					
Benthic macroinvertebrates (S,G)	Local Community	Species present in habitat	Are contaminant concentrations in sediment greater than screening levels for effects on survival, growth, or reproduction of benthos?	Contaminant concentrations in sediment.	Compare sediment contaminant concentrations with literature-based sediment screening levels for effects on benthic macroinvertebrates.
			Are survival and growth of laboratory-reared benthic organisms in OU4 sediment less than in control sediment?	Sediment toxicity testing results.	Compare survival and growth in OU4 sediment with same endpoints in control sediment.
Aquatic Biota Exposed to Surface Water (Fish, Amphibians, Plankton, Macrophytes)					
Aquatic organisms exposed to surface water (S,G,R)	Local Communities	Species present in habitat	Are contaminant concentrations in surface water greater than water quality criteria for protection of aquatic organisms?	Surface-water contaminant levels.	Compare surface-water contaminant concentrations with water quality criteria and standards.
Aquatic-Dependent Mammals (Herbivorous, Insectivorous, and Carnivorous)					
Aquatic-dependent mammals (survival, growth, reproduction [S,G,R])	Local Populations	Muskrat, Mink, Bat	Are contaminant levels in sediment greater than screening levels for effects on survival, growth, or reproduction of aquatic-dependent mammals?	Contaminant levels in sediment.	None. Sediment screening levels for protection of aquatic-dependent mammals are not available for most contaminants.
Aquatic-Dependent Birds (Herbivorous, Insectivorous, and Carnivorous)					
Aquatic-dependent birds (S,G,R)	Local Populations	Mallard, Swallow, Heron	Are contaminant levels in sediment greater than screening levels for effects on survival, growth, or reproduction of aquatic-dependent birds?	Contaminant levels in sediment.	None. Sediment screening levels for protection of aquatic-dependent birds are not available for most contaminants.

Some Key Sources of Screening Values for Ecological Risk

- Aquatic Life Criteria: https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table
- Interim Ecological Soil Screening Level Documents: https://www.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents
- NOAA SQuiRT: https://response.restoration.noaa.gov/environmental-restoration/environmental-assessment-tools/squirt-cards.html
- The Risk Information System, Ecological Benchmark Tool: https://rais.ornl.gov/tools/eco_search.php
- USGS Contaminant Hazard Reviews for Wildlife: https://www.pwrc.usgs.gov/eisler/reviews.cfm
- Risk Management Criteria for Metals at BLM Mining Sites: https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1021&context=usblmpub
- Reptiles: http://publications.gc.ca/collections/Collection/CW69-5-357E.pdf

More Key Sources of Screening Values for Ecological Risk

- Los Alamos National Laboratory EcoRisk Database
  - LANL Site down until Oct-Nov 2020. The R4.1 Database is available at https://www.intellusnm.com/. To download the database and user guides, go to the Documents section in the Intellus header bar, navigate to LANL Files >> Ecorisk Database, and download both .zip files in that directory. See:
    - Access database: ECORISK Database
    - file: ESL_PRG_HistorySummary2.pdf.
    - Use PRGs for screening
- California Ecotox Database: https://oehha.ca.gov/ecotoxicology/general-info/calecotox-database

But Wait, There's Even More Key Sources of Screening Values for Ecological Risk!

- National Park Service: NPS Protocol for the Selection and Use of Ecological Screening Values for non-radiological analytes.
- Navy Amphibians: https://clu-in.org/download/contaminantfocus/sediments/Seds-eco-TR-2245-ENV.pdf
- Reference to references: https://www.tceq.texas.gov/remediation/eco/eco_links.html
- Ecological toxicity based on International Atomic Energy Agency radionuclide dose limit of 0.1 rad/d for the protection of ecological receptors at the population level (LANL, TRV Development Methods, 2014).

Ecological Screening Values for Metals Used by EPA

Analyte	Plants		Invertebrates		Birds		Mammals	
Aluminum	50	a	--		--		--	
Antimony	11	b	78	a	--		0.27	a
Arsenic	18	a	6.8	b	43	a	46	a
Barium	110	b	330	a	820	b	2000	a
Beryllium	2.5	b	40	a	--		21	a
Cadmium	32	a	140	a	0.77	a	0.36	a
Calcium	--		--		--		--	
Chromium*	--		0.4	d	26	a	34	a
Cobalt	13	a	--		120	a	230	a
Copper	70	a	80	a	28	a	49	a
Iron	pH	a	pH	a	--		--	
Lead	120	a	1700	a	11	a	56	a
Magnesium	--		--		--		--	
Manganese	220	a	450	a	4300	a	4000	a
Mercury**	34	b	0.05	b	0.013	b	1.7	b
Nickel	38	a	280	a	210	a	130	a
Potassium	--		--		--		--	
Selenium	0.52	a	4.1	a	1.2	a	0.63	a
Silver	560	b	--		4.2	a	14	a
Sodium	--		--		--		--	
Thallium	0.05	b	--		6.3	b	0.22	b
Vanadium	60	b	--		7.8	a	280	a
Zinc	160	a	120	a	46	a	79	a

US EPA, 2018. *Final Terrestrial Screening-Level Ecological Risk Assessment, Bonita Peak Mining District NPL Site*, prepared by TechLaw, Inc., January.

References	
a	EPA's Ecological Soil Screening Levels (EcoSSLs): https://www.epa.gov/risk/ecological-soil-screening-level-eco-ssl-guidance-and-documents. Aluminum for plants is pH-dependent, pH must be less than 5.5. Iron plant toxicity depends on pH and eH. https://www.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents.
b	Los Alamos National Laboratory (LANL) no-effect ecological screening levels: https://lanl.gov/environment/protection/eco-risk-assessment.php.
c	EPA Region 4 soil screening values for hazardous waste sites (Table 4): https://www.epa.gov/risk/region-4-ecological-risk-assessment-supplemental-guidance
d	Oak Ridge National Laboratory (ORNL), Preliminary remediation goals for ecological endpoints. ES/ER/TM-162/R2: https://rais.ornl.gov/guidance/tm.html
*	Chromium values are for Chromium-III or Total.
**	Mercury values are for Inorganic or Total.

Interpretation of Ecological Screening Values

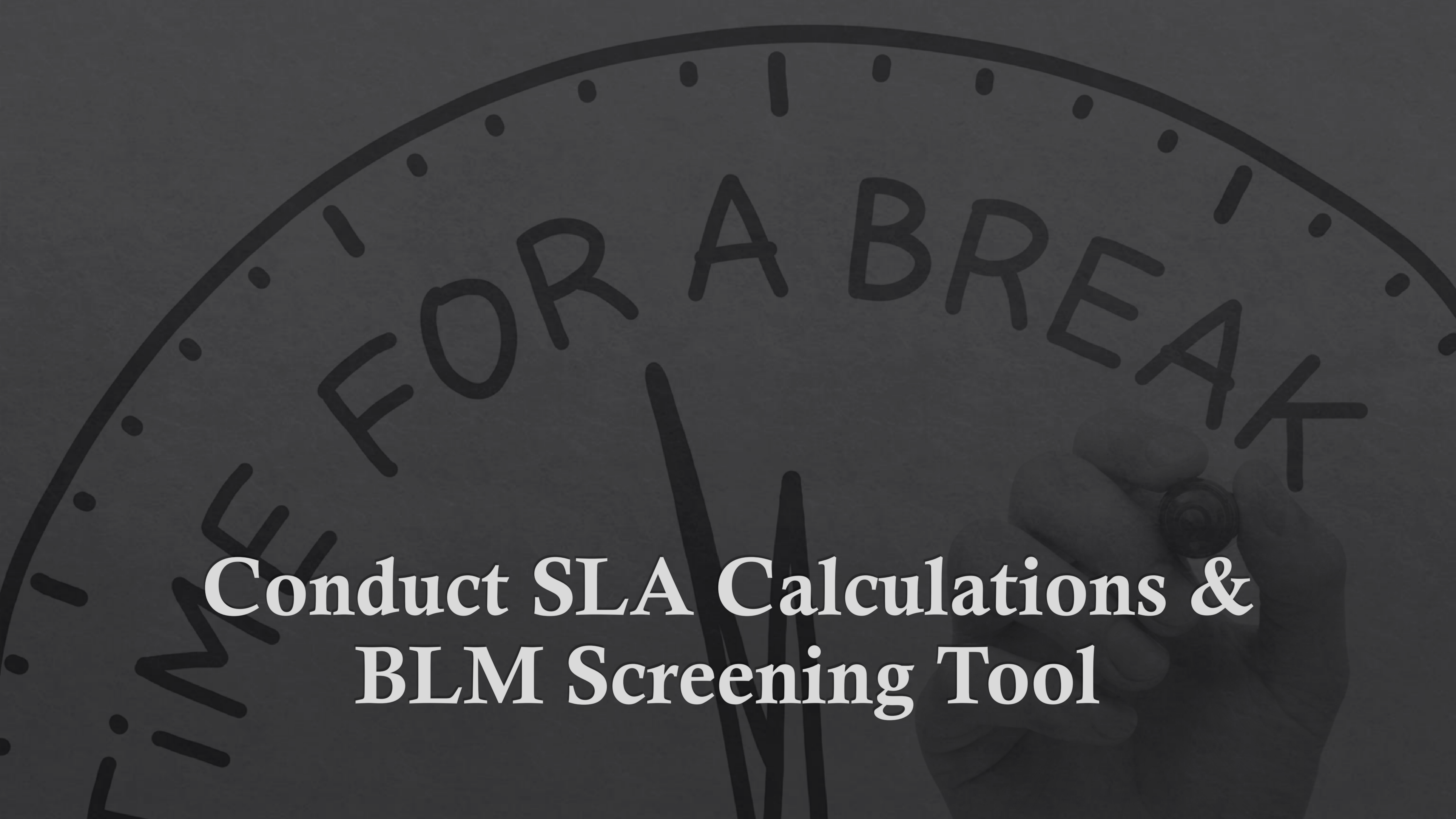
Standards may not address bioaccumulation and biomagnification.

Species variability to toxicity.

Quality of data and variability across agencies.

Water hardness applies to some metals.

Organic levels, grain size, and redox are among the variables that influence bioavailability and toxicity in sediment.



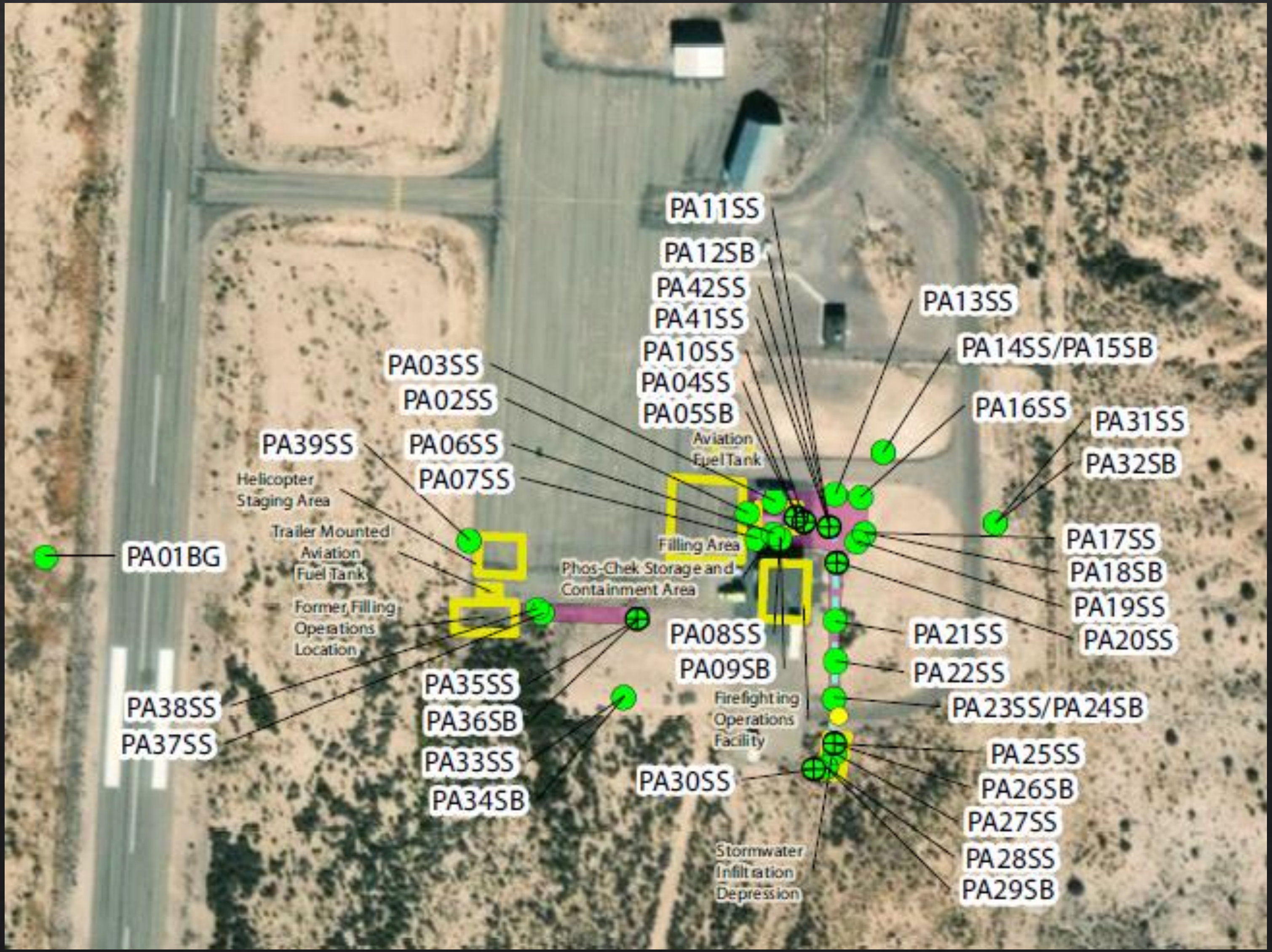
Conduct SLA Calculations & BLM Screening Tool

Conduct a Screening Level Risk assessment

- Conduct a screening level assessment for a NV SEAT site.
  1. Consider data quantity and quality
  2. Use CSM to identify screening values
  3. Perform HQ calculations
  4. Assess uncertainty
  5. Develop informed conclusions

Your Turn

Panaca Site


PA11SS
PA12SB
PA42SS
PA41SS
PA10SS
PA04SS
PA05SB
PA13SS
PA14SS/PA15SB
PA16SS
PA31SS
PA32SB
PA03SS
PA02SS
PA39SS
PA06SS
PA07SS
Aviation Fuel Tank
Helicopter Staging Area
Trailer Mounted Aviation Fuel Tank
Filling Area
Phos-Chek Storage and Containment Area
PA01BG
Former Filling Operations Location
PA17SS
PA18SB
PA19SS
PA20SS
PA08SS
PA09SB
PA21SS
PA22SS
PA23SS/PA24SB
PA35SS
PA36SB
PA38SS
PA37SS
Firefighting Operations Facility
PA33SS
PA34SB
PA30SS
PA25SS
PA26SB
PA27SS
PA28SS
PA29SB
Stormwater Infiltration Depression


Date & Time: Mon. Jun 17. 2019. 13:46:13 PDT
Position: 037°47.4637'N / 114°25.1111'W
Altitude: 4826ft
Datum: WGS-84
Azimuth/Bearing: 279° N81W 4960mils (True)
Elevation Angle: -20.2°
Horizon Angle: +00.8°
Zoom: 1X
PA38SS


Date & Time: Mon. Jun 17. 2019. 14:18:11 PDT
Position: 037°47.4770'N / 114°25.0534'W
Altitude: 4823ft
Datum: WGS-84
Azimuth/Bearing: 298° N62W 5298mils (True)
Elevation Angle: -17.0°
Horizon Angle: -00.4°
Zoom: 1X
PA17SS/PA18SB

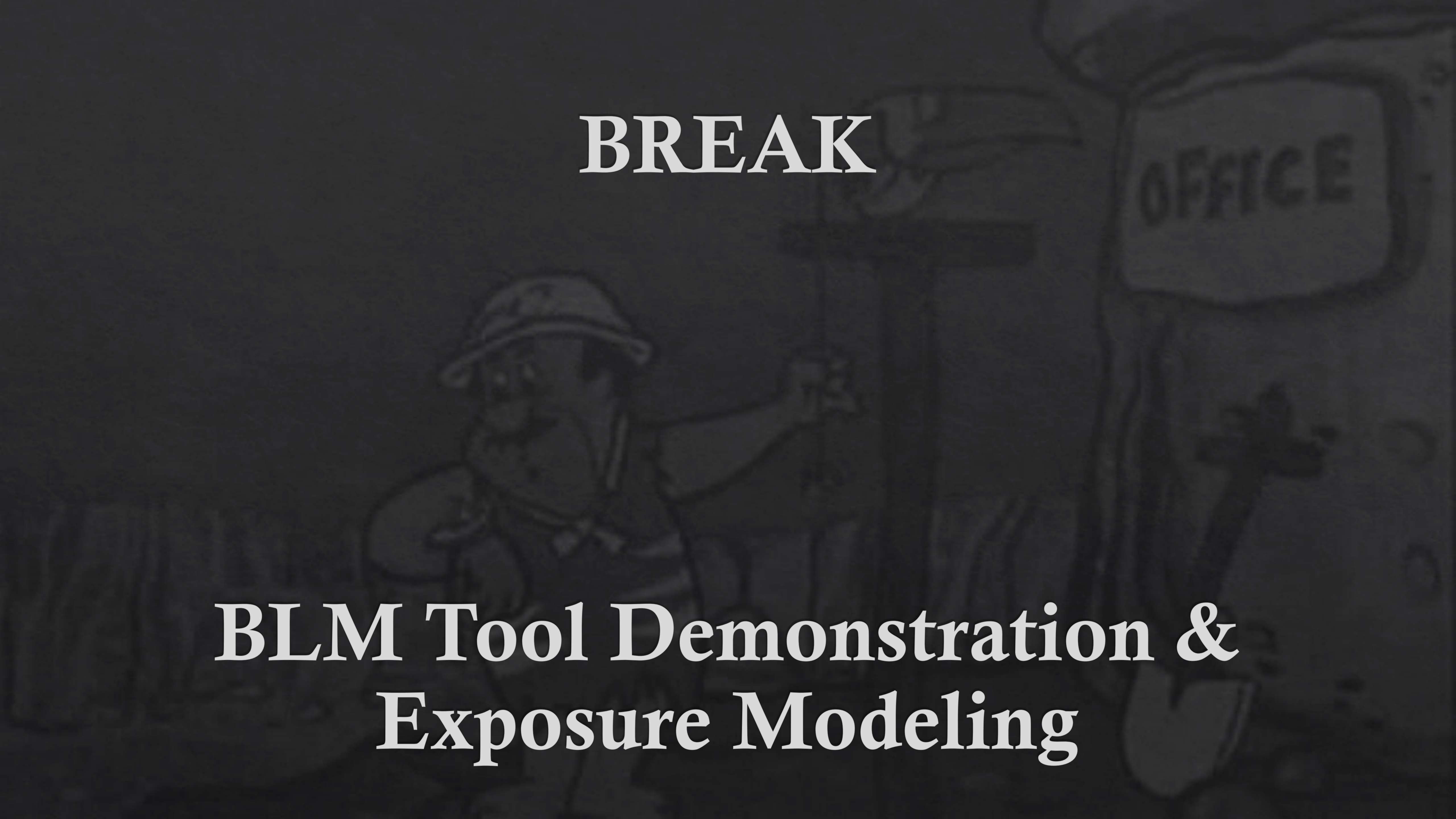
Table 4-1. Panaca SEAT Base Laboratory and XRF Results and Risk-based Screening Values

Sample ID	Sample Date, Time	SW846 6010C						Percent Moisture (%)
		Cadmium (mg/kg)			Total Chromium (mg/kg)			
		Lab		XRF	Lab		XRF	
Surface Soil								
PA10SS	6/17/2019 11:56	**4.4**		ND	**35**		68.5	6.8
PA20SS	6/17/2019 13:11	0.22	J	ND	13		ND	11.8
PA25SS	6/17/2019 12:41	**4.5**		ND	**38**		ND	11.6
PA30SS	6/17/2019 13:00	**7**		ND	**37**		ND	4.5
PA35SS	6/17/2019 13:16	0.15		ND	14		ND	11
PA41SS	6/17/2019 13:42	0.25	J	ND	15		ND	2.6
PA42SS	6/17/2019 13:40	--		--	--		--	
Subsurface Soil								
PA05SB	6/17/2019 11:54	0.27	J	ND	12		ND	9.5
PA15SB	6/17/2019 12:12	0.066	J	ND	13		ND	12.3
PA40SB	6/17/2019 13:30	0.061	J	ND	15		ND	17.6
Risk-based Screening Values								
Natural Background, US		0.3; 76.8		--	36-4,120		--	--
NV Groundwater Protection		8		--	38		--	--
NV Residential Soil		--		--	--		--	--
NV Soil Action Level (TPH)		--		--	--		--	--
EPA Groundwater Protection		8		--	180,000		--	--
EPA Residential RSL		71		--	120,000		--	--
EPA Industrial RSL		980		--	1,800,000		--	--

Panaca Results

BREAK

BLM Tool Demonstration & Exposure Modeling



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Development of a Risk Management Strategy for Prioritizing Response Actions at Abandoned Mine Sites

Erin Lynch (E&E), Cynthia Newman (SCG), Carl Stineman, Teresa Snyder (BLM), Douglas Cox (BLM), Manique Talaia-Murray (E&E), Steve Ackerlund (E&E)

NATIONAL SYSTEM OF PUBLIC LANDS
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
Utah

SCG Strike Consulting Group
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Global Environmental Specialists

Overview

- Purpose and Need
- Step 1: Evaluate Existing Data
- Step 2: Field Visit
- Step 3: Screening Level Risk Assessment/ Multiple Lines of Evidence Matrix (MLOE)
- Step 4: Decision Criteria
- Step 5: Action Determination
- Key Considerations
- Steps Forward

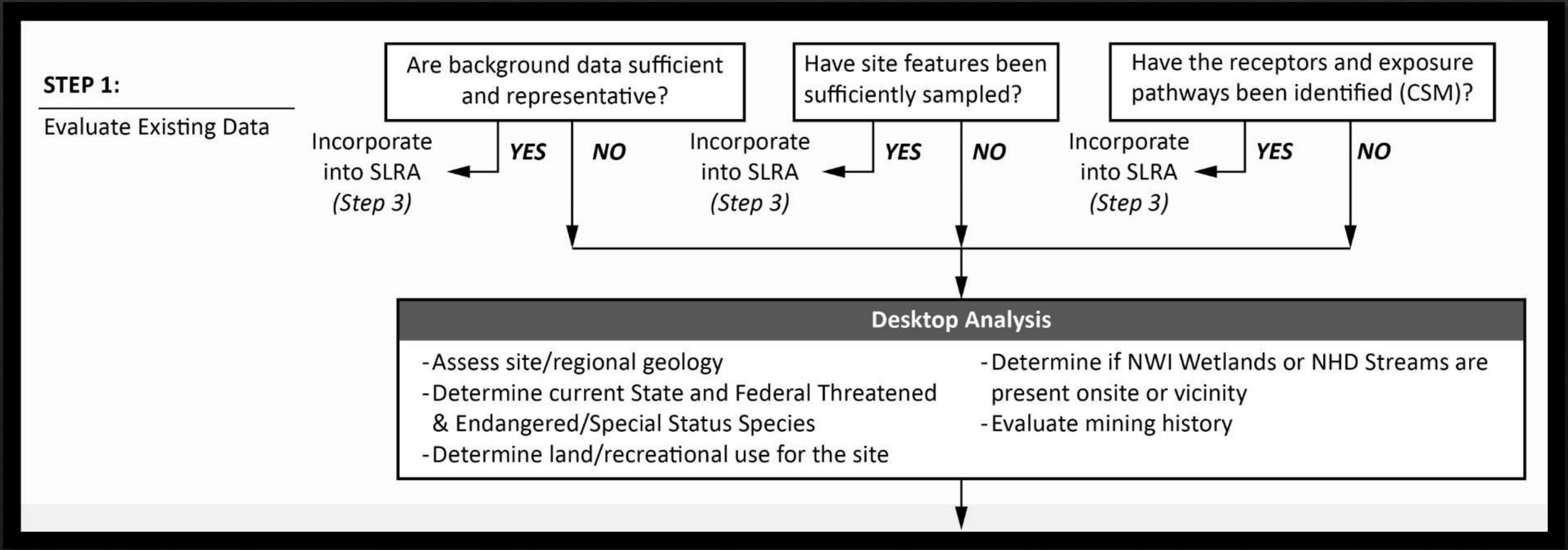
Purpose & Need

- 174 mining districts & 20,000 abandoned mines on BLM/DOE-managed land in Utah.
- Prioritize resources based on:
  1. Human/environmental risk assessment
  2. Physical safety hazard assessment

Spor Mountain Mining District
Juab County, UT

92 mine sites: including 84 adits, shafts, and inclined openings, and pits, equipment, structures and waste piles

Step 1: Evaluate Existing Data



Step 2: Field Visit: Evaluation of Site Conditions (Qualitative)

- Dump Size
- Surface Water & Other Contaminant Migration Potential
- Site Accessibility & Signs of Human Use
- Qualitative Bioassessment
- T&E/SSS Observations

Step 2: Field Data Collection (Quantitative)

- XRF Instrument Screening
- Gamma Screening
- Soil/Mine Waste Sampling
- Sediment Sampling
- Surface Water Sampling
- Background Sampling

Step 3: Screening Level Risk Assessment

Summary Table of Exceedances for Carcinogens by Background Area						
Gold Hill Mining District Screening Level Risk Assessment						
Chemical	**Project Specific Background**	**BLM Recreational SL**	**Conc. (mg/kg)**	**Risk Ratio**	**Conc. (mg/kg)**	**Risk Ratio**
Background Area 1						
			10HO1		10HO2 &HO3	
Arsenic	34.94	30.6	551	18	337	11.01
Mine Waste Dump Risk Ratio			--	18	--	11.01

$$Risk\ Ratio = C_{dump}/SL$$

Risk Ratio	=	Cancer/Non-cancer Risk Ratio
C_{dump}	=	Concentration of a COPC in a Waste Dump sample
SL	=	BLM Recreational Screening Level

Step 3: Multiple Lines of Evidence Matrix

Summary of MLOE Matrix for Mine Waste Dumps

Gold Hill Mining District Screening Level Risk Assessment

Site	RML Ratio	Main Risk Driver	Overall Site Conditions Risk		
			Human	Ecological	Total
10HO4 &HO5	26.21	Lead	Low	High	High
14VO1	24.50	Lead	High	Moderate	High
11IO2 & VO2	20.29	Lead	Low	Low	Low

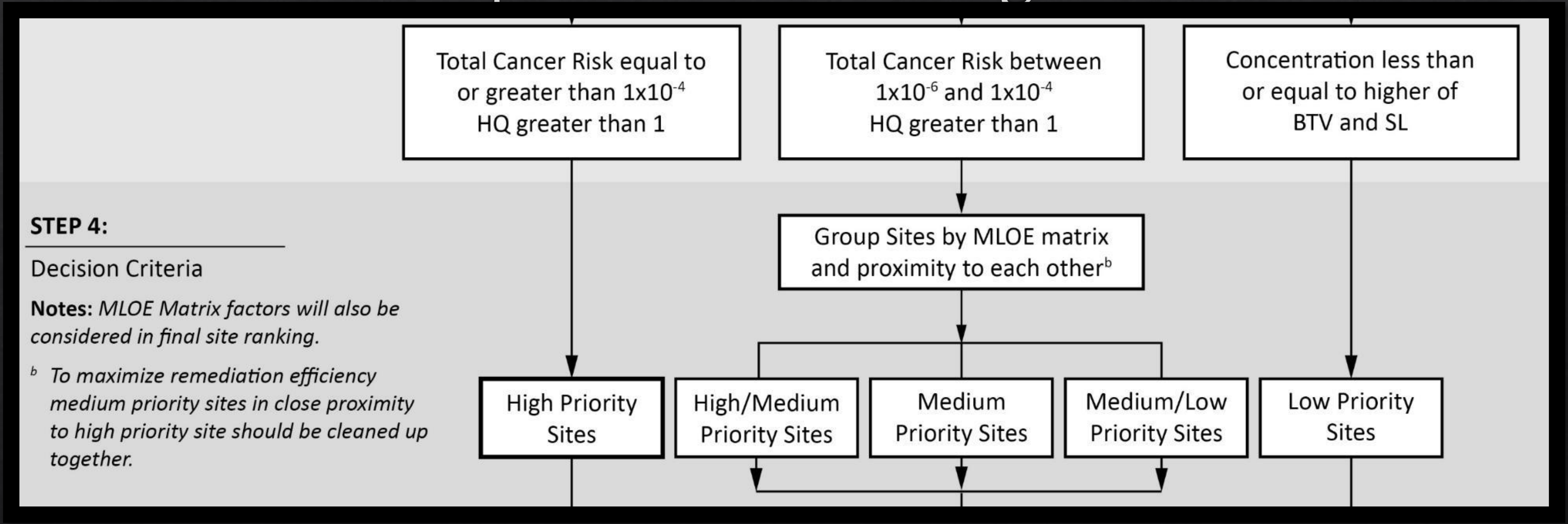
Heat Map Y-Axis

- site accessibility
- signs of use
- dump size

- surface water
- COPC migration
- habitat quality
- T&E presence
- dump size

Heat Map X-Axis

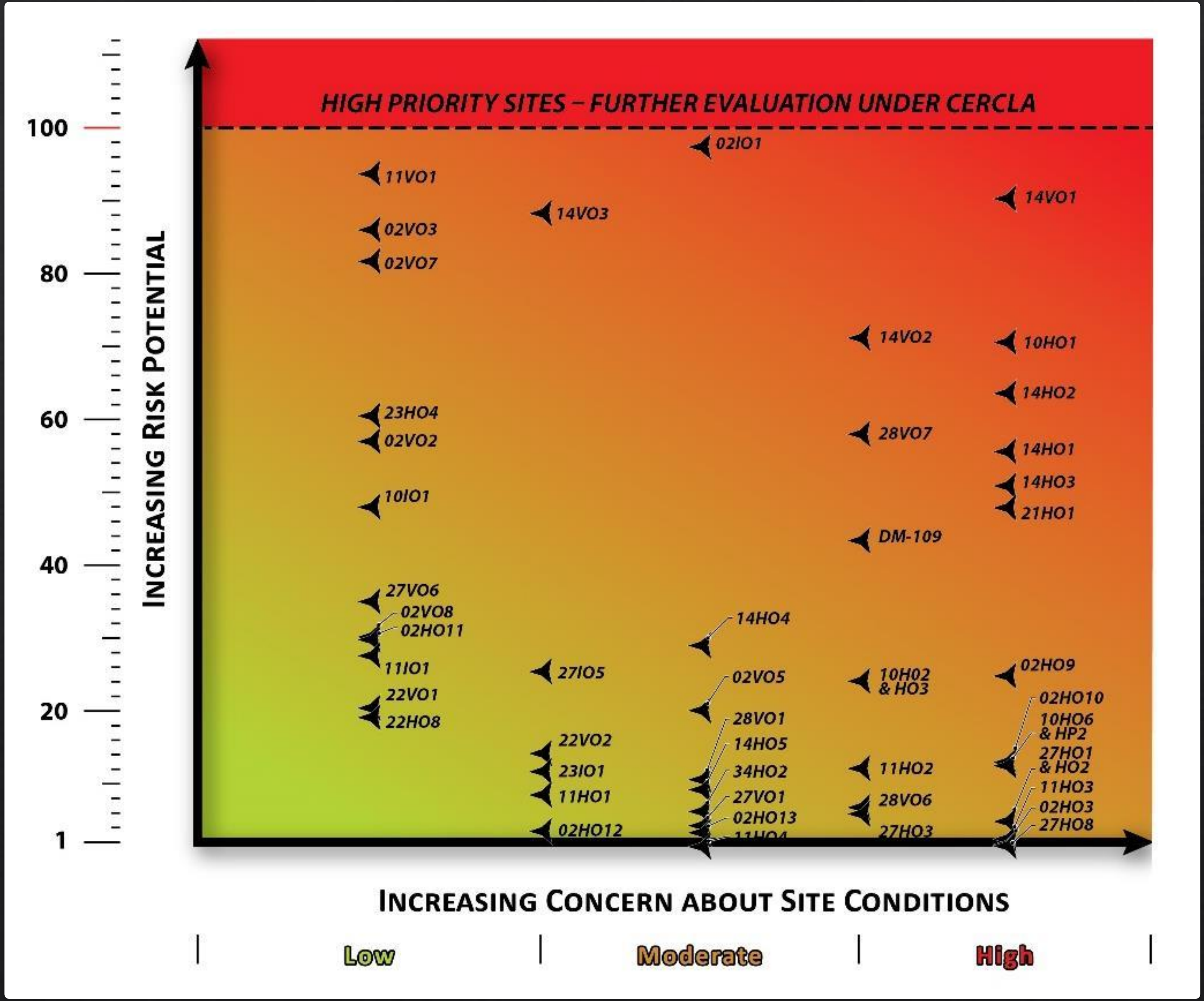
Step 4: Decision Categories



Step 5: Action Determination

	Site Conditions				
	High	Moderate - High	Moderate	Low-Moderate	Low
Risk Ratio based on the Recreational RML	Red	Red	Red	Orange	Orange
	Red	Red	Orange	Orange	Yellow
	Red	Orange	Orange	Yellow	Yellow
	Orange	Orange	Yellow	Yellow	Green
	Green	Green	Green	Green	Green

Heat Mapping



Key Considerations

- Risk level of concern for radionuclides vs. chemicals
- Lead for short-term exposures
- HI vs. HQ and prioritization scale for non-cancer hazard
- Unified Y-axis and decision criteria for risk and hazard
- Chemical exposure vs. safety hazard
- Natural background concentrations

Benefits Summary

- Integrates risk screening with site-specific conditions!
- Hazard Analysis & Risk-based Ranking
  - Prioritizes further investigation, not site cleanup
  - Limited data collection and conservative screening
- Complexity & transparency considerations
  - Emphasizes human health risk (y-axis)
  - Many "Site Consideration" factors (x-axis)

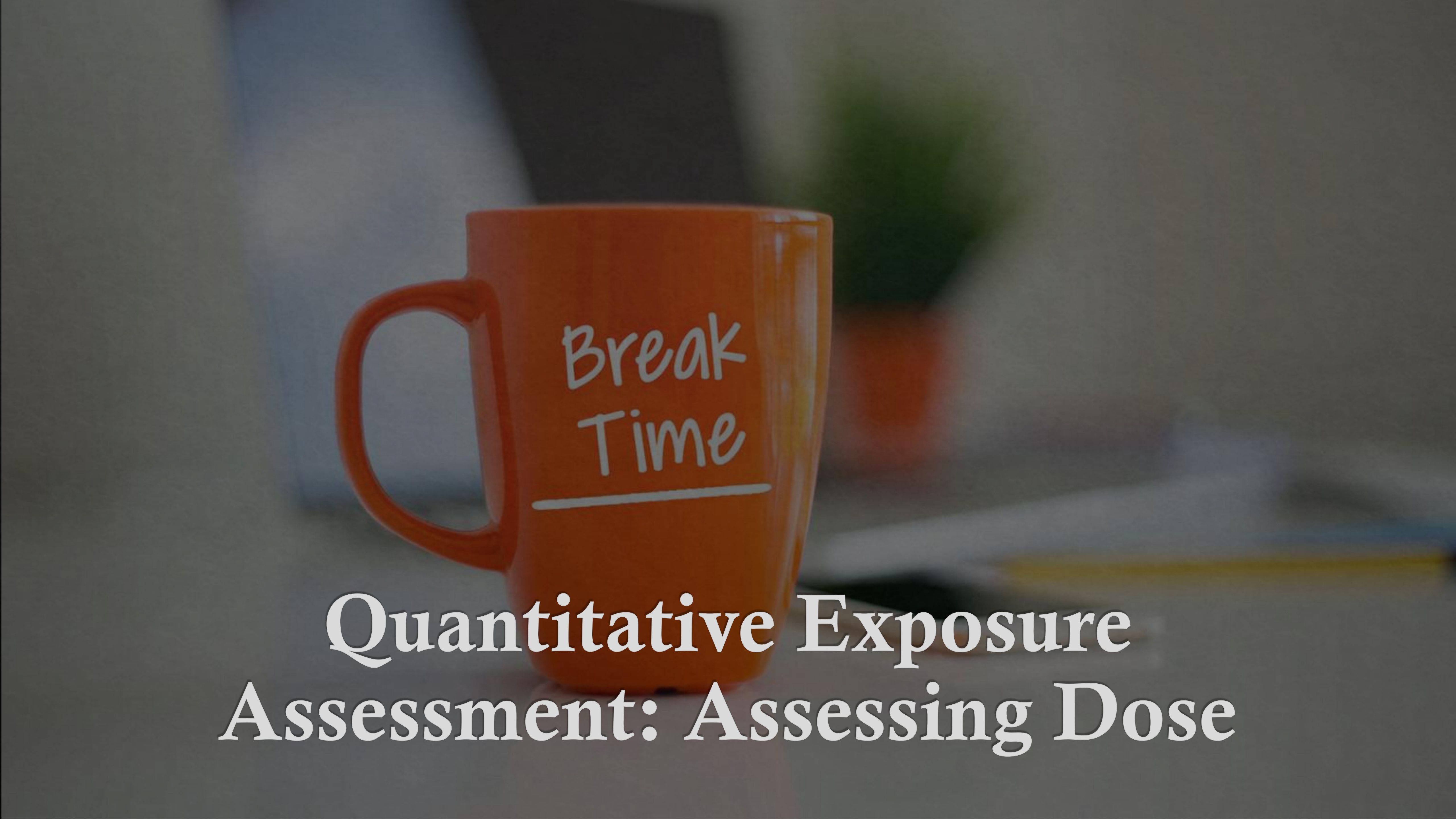
Steps Forward

- Field trials
  - Validation and refinement
  - User tools (e.g., database for easy comparison of 20,000+ sites)
- Expansion into other states?
- Applications beyond BLM & DOE?

BLM Screening tool Demonstration

- Walk through Gold Hill model.

Your Turn



Quantitative Exposure Assessment: Assessing Dose

Course Organization

- Overview
- Site Characterization
- Exposure Assessment
  - Qualitative
  - Quantitative
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- Toxicity Assessment
  - Human
  - Ecological
- Risk Characterization
- Uncertainty Assessment
- Lead
- Acute Arsenic & Lead
- Radionuclides

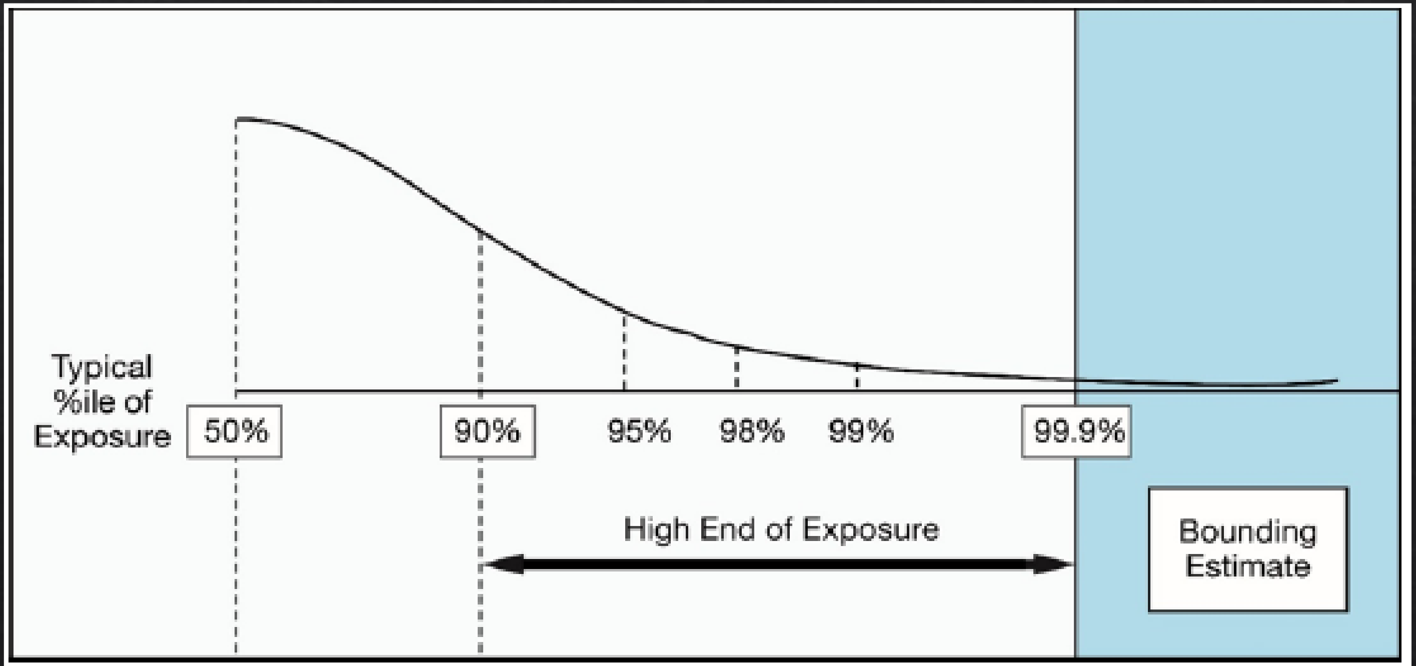
Quantitative Exposure Modeling: assessing dose

Primary Models Used by Risk Assessors

Dose/exposure:

- Exposure equations, RAGs Chapter 6: https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part
- Current exposure assumptions, Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors: https://www.epa.gov/sites/production/files/2015-11/documents/oswer_directive_9200.1-120_exposurefactors_corrected2.pdf

Average and Reasonable Maximum Exposure



EPA, 2019. Guidelines for Human Exposure Assessment: https://www.epa.gov/sites/production/files/2020-01/documents/guidelines_for_human_exposure_assessment_final2019.pdf

Primary Models Used by Risk Assessors

- ❖ Environmental Transport: https://www.epa.gov/risk/regional-screening-levels-rsls
  - Soil to groundwater infiltration
    - Dilution Attenuation Factors (DAFs): 20 for less than 0.5 acre EPA and NV DEP.
    - EPA RSL methodology: partition coefficient methods
  - Air dust dispersion: wind Particulate Emission Factor (PEF)
  - Vapor intrusion: volatile organics, radon gas, etc.
- ❖ Ecological Food Web
  - Wildlife Exposure Factors Handbook: https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=2799
  - Attachment 4-1 of Guidance for Developing Ecological Soil Screening Levels:
  - https://www.epa.gov/sites/production/files/2015-09/documents/ecossl_attachment_4-1.pdf

Persistent, Bioaccumulative and Toxic (PBT) Chemicals

- EPA Toxic Release Inventory (TRI) list: https://www.epa.gov/toxics-release-inventory-tri-program/persistent-bioaccumulative-toxic-pbt-chemicals-covered-tri

  Includes lead and mercury compounds

  - Lead bioconcentrates but does not bioaccumulate.
  - Adheres strongly to soils
- Additional organic PBTs listed under TSCA.
- Uranium related isotopes can bioconcentrate at levels of potential concern.

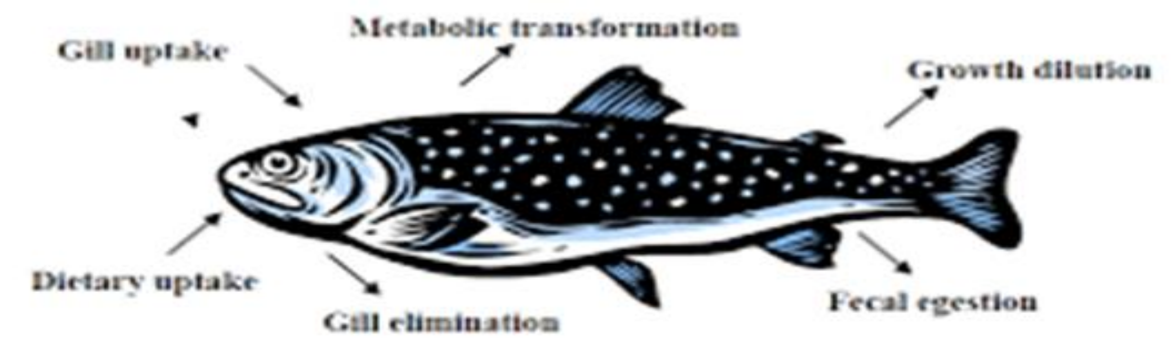


Figure H-1. Conceptual Diagram of the Major Routes of Contaminant Uptake and Depuration (Adapted from Arnot and Gobas, 2004).

Mercury

Its complicated!

- Three valence states:
  - Reduced metallic or elemental mercury (Hg^0) is volatile
  - In soils and surface waters, mercury can exist in the mercuric (Hg+2) and mercurous (Hg+1) states as a number of complex ions with varying water solubilities
- Organo-mercury compounds (e.g. methyl mercury) are:
  - Highly toxic
  - Bioaccumulate and bind to organic matter
  - More common in anoxic sediments
- Analytical detection may exceed applicable risk-based standards and require ultra-clean techniques which are not typically done.

Run RSL Calculator Models

- Go to RSL Calculator: https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search
  1. Determine the arsenic concentration in soil that will not cause a 1E-5 risk for consumption of groundwater assuming a dilution attenuation factor of 10.
  2. What are the protective soil concentrations for a teenager to adult aged individuals who camps 14 days/year near Winnemucca on a 5-acre, 20 m thick mine waste dump devoid of vegetation and containing arsenic, cadmium and cobalt.

Your Turn

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- Radionuclides

Toxicity is all about dose

- *What is there that is not a poison?*
- *All things are poison, and nothing is without poison.*
- *Solely the dose determines that a thing is not a poison.*

Paracelus, trans Deichmann

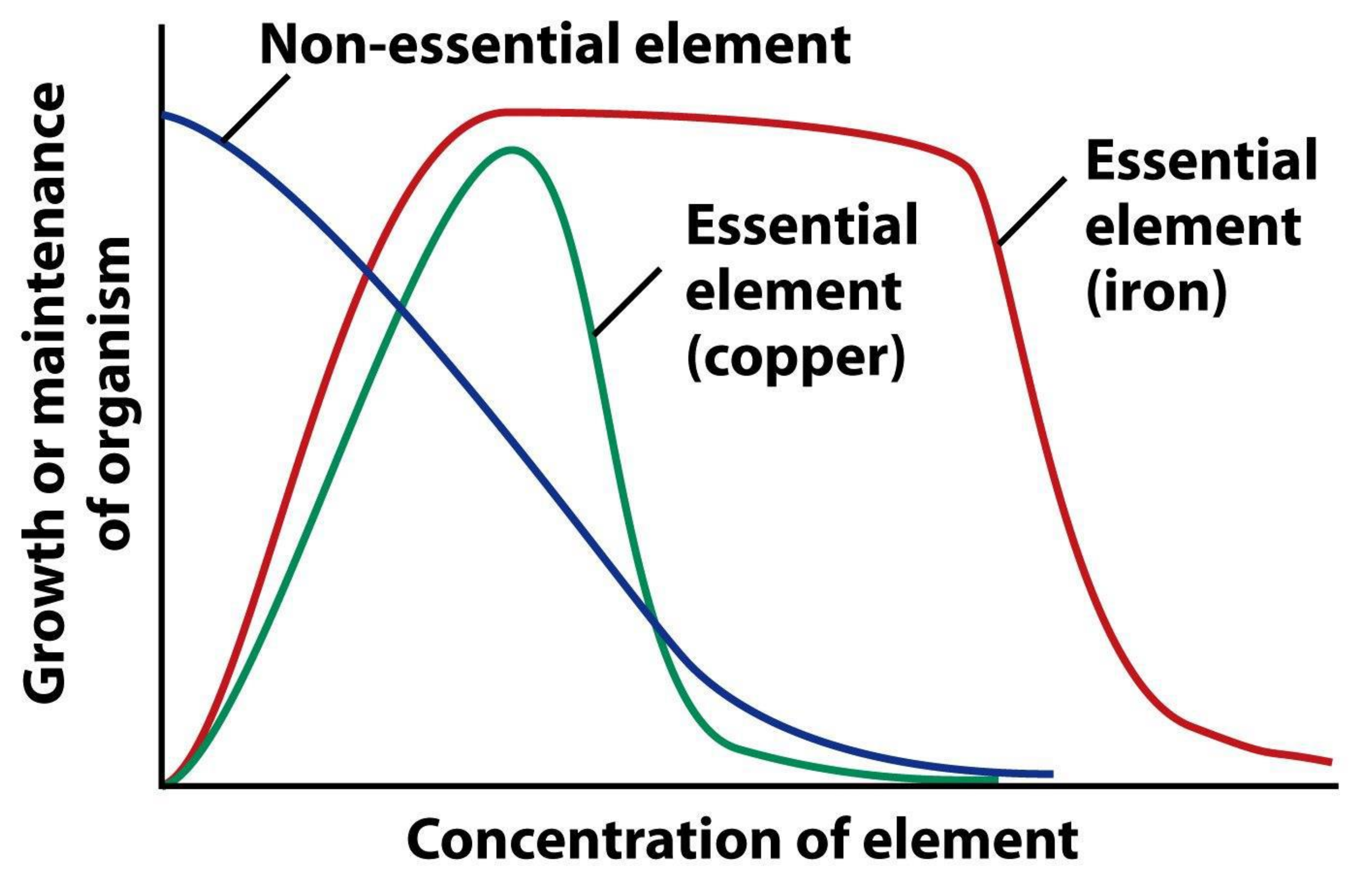


Figure B18-1
Shriver & Atkins Inorganic Chemistry, Fourth Edition

KJM360: Assessing Risk to Humans and the Environment, Debra Oughton, Norwegian University of Life Sciences.

Toxicity Assessment Terms

- **Reference Dose**: estimated (order of magnitude) daily exposure level that is likely to not cause adverse effects, considering sensitive populations. Invokes threshold. mg/kg/day = mg/kg-day
  - Acute: < 2 weeks (perhaps a concern for arsenic at some mining sites)
  - Subchronic: 2 weeks to 7 years
  - Chronic: 7 years to lifetime (70 years)
- **Slope Factor**: plausible upper bound estimate of the probability of a response (developing cancer) per unit intake over a lifetime. No threshold. 1/(mg/kg/day). Weight of evidence:
  - A: Human carcinogen based on human data
  - B: Probably human carcinogen. B1: limited human data. B2: sufficient animal data
  - C: Possible human carcinogen
  - D: Not classifiable
  - E: Evidence of noncarcinogenicity for humans
- **Toxicity Value**: numerical expression of toxicity.

Common Hierarchy of Human Toxicity Assessment Sources

1. IRIS: https://www.epa.gov/iris
   - Also in EPAs RSL calculator

2. Provisional Peer-Reviewed Toxicity Values (PPRTVs) used in U.S. EPA's Superfund Program: https://www.epa.gov/pprtv/provisional-peer-reviewed-toxicity-values-pprtvs-assessments

3. Other (peer-reviewed) toxicity values, including:
   - Minimal Risk Levels, Agency for Toxic Substances and Disease Registry (ATSDR): https://www.atsdr.cdc.gov/mrls/mrllist.asp
   - California Environmental Protection Agency (CalEPA) values: https://data.ca.gov/dataset/toxicity-criteria-database
   - HEAST : https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=2877
     - Especially for radionuclides: also see EPAs PRG calculator

Ecological Toxicity Assessment

- Aquatic Life: uses media standards, i.e. Aquatic Life Criteria and sediment screening values
  - o Benthic invertebrates may be evaluated by applying aquatic life criteria to pore water data.
  - o Not protective of plants or wildlife uses of water.
  - o Does not consider food chain bioconcentration or bioaccumulation.
- Terrestrial Life: uses **Toxicity Reference Values** (TRVs): term used to refer to ecological specific reference dose (mg/kg-bw/day)
  - o Plant and Terrestrial Invertebrate TRVs are soil media values.
  - o TRVs are based on NOAEL or LOAEL values.

TRV Sources

- Interim Ecological Soil Screening Level Documents: https://www.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents

- Los Alamos National Laboratory EcoRisk Database (https://www.intellusnm.com/, see prior slide in Screening Level Assessment for instructions).

- Older DOE sources:

  - Toxicological Benchmarks for Wildlife: 1996 Revision https://rais.ornl.gov/documents/tm86r3.pdf

  - Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision https://rais.ornl.gov/documents/tm85r3.pdf

  - Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision https://info.ornl.gov/sites/publications/Files/Pub57854.pdf

Presenting Toxicity Factors

RAGS Part D: Standardized Planning, Reporting, and Review of Superfund Risk Assessments: https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part-d.

RfD

- Value
- Confidence level & uncertainty factors: for uncertainty assessment
- Critical effect/target organ: for HI calculations
- Source

Slope Factor

- Value
- Weight of evidence: for uncertainty assessment
- Type of Cancer: qualitative purposes
- Source

Oral to Dermal RfD Conversion

Oral reference doses or slope factors based on intake may not be protective of dermal exposures (which are calculated in terms of uptake or absorbed dose) when oral absorption of a chemical is low.

- For dermal risks, the oral RfD or SF should be adjusted to an absorbed dose whenever oral absorption is 50 percent or less.

Metals do not penetrate health skin:

- RAGS Part E, Supplemental Guidance for Dermal Risk Assessment: https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part-e
- Arsenic absorption is 3%, not typically enough to compete with assumed soil ingestion rates.

Oral Bioaccessibility & Bioavailability

Absolute bioavailability: the fraction of the dose of a chemical that is absorbed by the body.

- Absolute bioavailability of lead from water or diet averages 50 percent in children and 20 percent in adults
- Absolute bioavailability of lead from soil and dust ingested by young children is currently estimated by USEPA to average 30 percent
- Absolute bioavailability of water-soluble arsenic is greater than 95 percent. Less soluble forms of arsenic are reported to be one-tenth to one-half as bioavailable as the more soluble forms of arsenic.

Relative bioavailability: the ratio of the absorbed dose of a chemical in the environmental exposure medium (e.g., soil) to its absorbed dose in the dosing vehicle used in the critical study upon which its toxicity is estimated.

Bioaccessibility: the fraction of metal that is soluble and available for absorption

- *in vitro* tests are designed to measure the extent of metals solubilization in an extraction solvent that mimics physiological conditions in the human gastrointestinal tract (*in vivo*).
- Minerology studies can also be helpful in estimating bioaccessibility.

Lead: Relative Bioavailability = 0.878 x *in vitro* Bioaccessibility – 0.028 (Drexler and Brattin, 2007)

Arsenic: Relative Bioavailability = 0.65 x *in vitro* Bioaccessibility + 7.8 (Bradham et al., 2015)

Swine Bioavailability Studies

- 1989 – 1997, Juvenile Swine Model: developed by EPA to predict relative bioavailability of lead and arsenic.
- Preferred over other models (rats, monkeys) due to physiological similarities.
- Bioavailability determined was relative to that of a soluble salts: lead acetate trihydrate or sodium arsenate.
- Expensive, time consuming, etc.

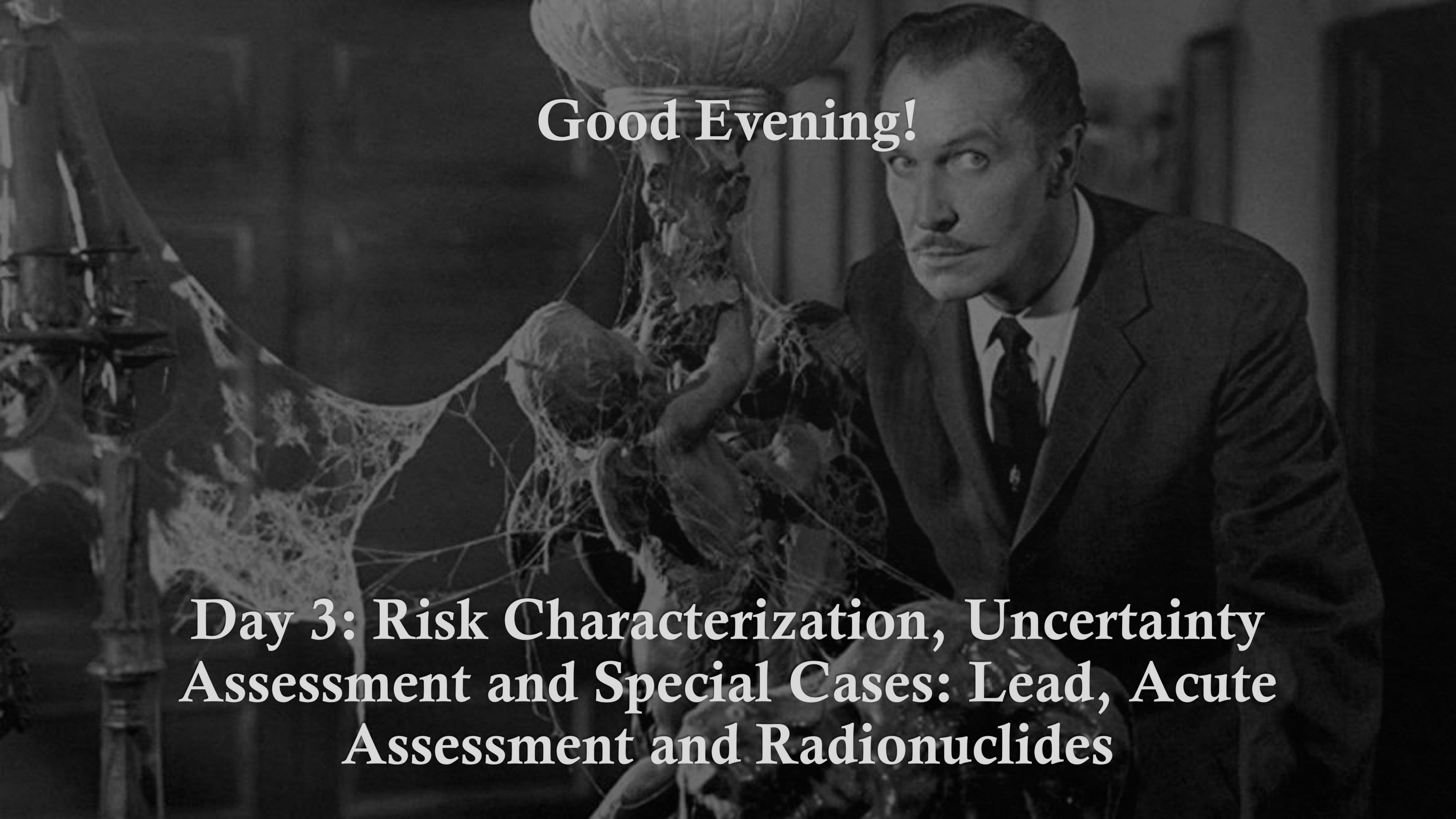
In Vitro RBA

In Vitro Bioaccessibility Assay for Metals in Soil (EPA 9200.1-86/1340): [lead and arsenic]

Tumble	Tumble a <250 um sieved size material in simulated gastric fluid consisting of Glycine and Hydrochloric acid, at 37 °C for one hour.
Filter	Filter (0.45 um) and test for lead and/or arsenic.
Compare	Compare the filter mass to the mass introduced to determine the bioaccessible fraction.

Site Specific Toxicity Testing and Biomonitoring

- Toxicity Testing
  - Water Effect Ratio
  - Aquatic toxicity tests (e.g. fathead minnow)
- Biological Surveys
  - Soil and Aquatic Benthic Invertebrates
  - Vegetation
  - Threatened and Endangered Species



Good Evening!

Day 3: Risk Characterization, Uncertainty Assessment and Special Cases: Lead, Acute Assessment and Radionuclides

Look up toxicity factors: Find the most applicable oral human health and ecological toxicity factors (ignore LANL) for: arsenic, cobalt and mercury.

Your Turn

Course Organization

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Non-Cancer Risk Characterization

Non-Cancer Hazard Index (HI) = Exposure/RfD

- Hazard is the potential for adverse effect
- Exposure is dose over an averaging period (mg/kg/day)
- RfD is the dose considered safe for sensitive populations (mg/kg/day)

Accurate to 1 significant figure

Not a statement of probability

EPA Policy: acceptable HI < 1

- A larger number suggest a larger concern, but its not a linear function. E.g. Other toxic effects beyond the most sensitive may be implicated.
- Other less sensitive populations may be implicated.
- Toxicity is not linear throughout the dose response range.
- Repeated short-term higher exposures may not produce the same response as ongoing lower exposures (even so its assumed).

Multiple Chemical Exposures

- Hazard Quotient (HQ) = sum of HIs for chemicals with similar target organ or effect.
  - **Synergistic**: a combined effect greater than the sum of individual effects.
  - **Additive**: the sum of individual effects.
  - **Antagonistic**: the combined effect of two or more compounds is less toxic than each individual compound.

Cancer Risk Characterization

Cancer Risk = CDI x SF

- Risk is a unitless probability of developing cancer
- CDI is Chronic Daily Intake averaged over 70 years (mg/kg/day)
- SF is the upper bound cancer Slope Factor $(mg/kg/day)^{-1}$

Sum cancer risk for all COPCs regardless of target organ.

Accurate to 1 significant figure.

EPA Policy: acceptable risk is less than 1E-4 to 1E-6

- Personal observation: Trend over time with EPA and states has moved from 1E-6 to 1E-4.
- Background rate of cancer in the US is about 1 in 3 (3E-1)

Superfund Decision Criteria

- Human & ecological health protection
- ARARs
- Long-term Effectiveness
- Short-term Effectiveness
- Reduced toxicity, mobility or volume
- Implementability
- Cost
- State and local acceptability

Risk management at BLM

- What is the policy and practice for acceptable risk at BLM?
- Application of Risk Management Levels at BLM?

Your Turn

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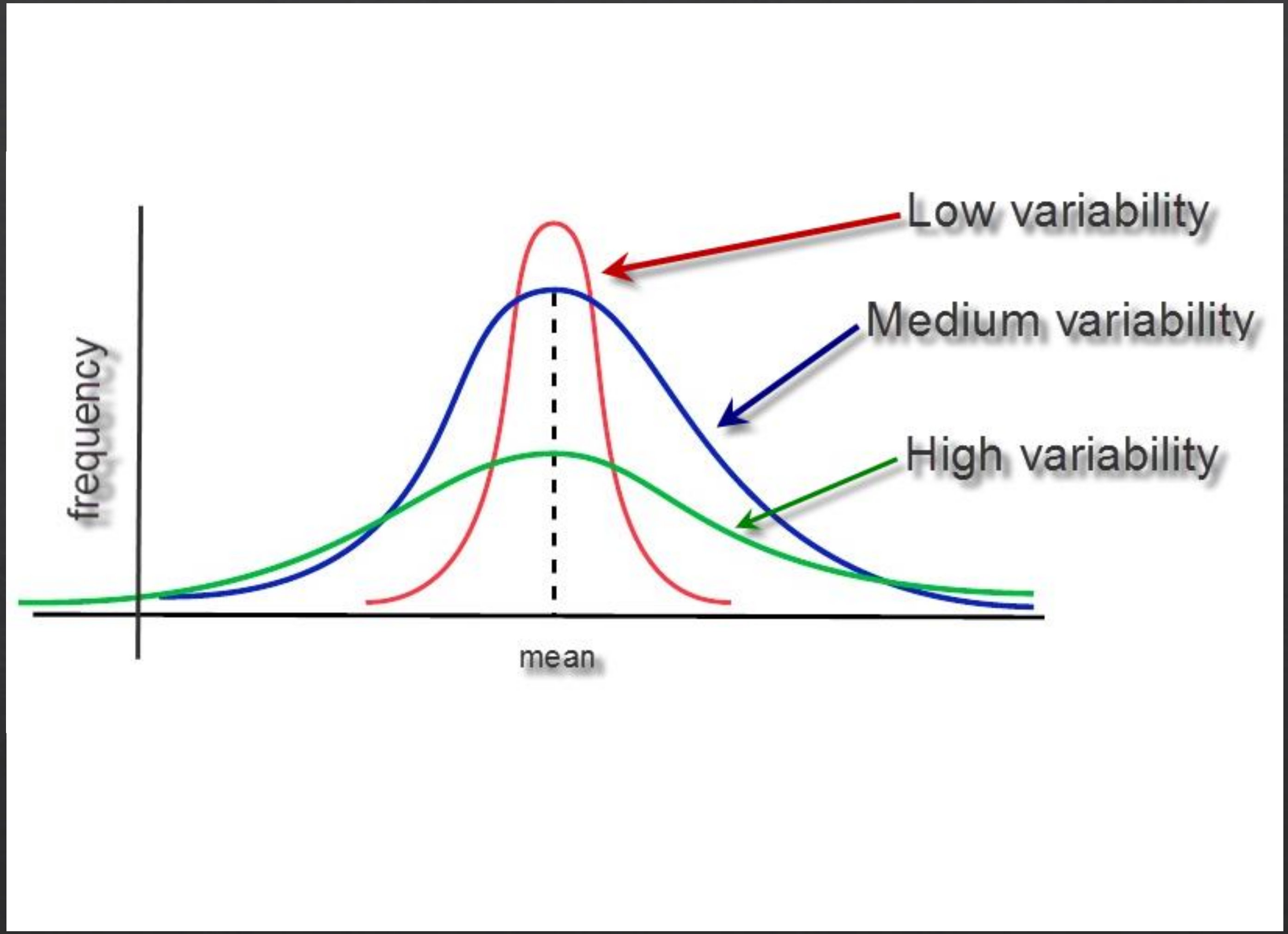
- Radionuclides

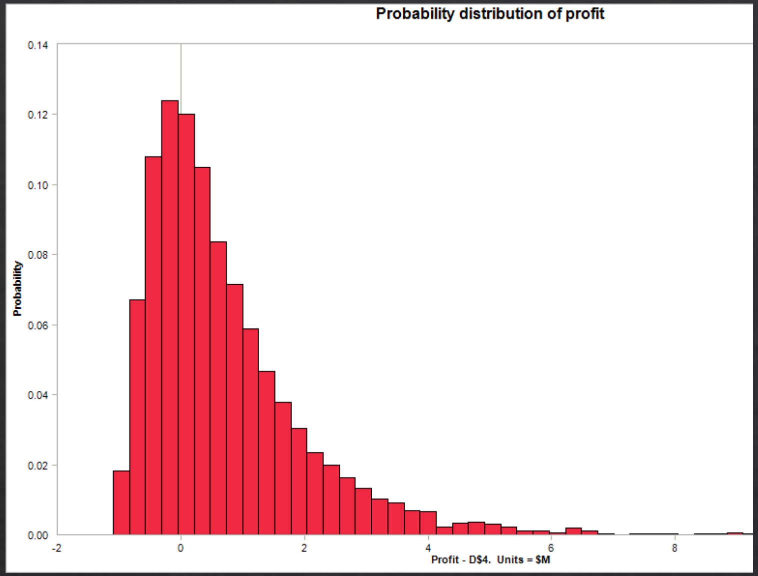
Uncertainty Assessment

Provides understanding on degree of conservatism and identifies major unknowns:

- **Variability**: normal range for quantitative input assumptions. Can be measured (e.g. body weight, chemical concentrations, etc.)
- **Uncertainty**: Input assumptions that can't be known (e.g. threshold for carcinogens) or where a variable is not measured.



Uncertainty Assessment



- Variability can be quantitatively assessed:
  - Monte Carlo probabilistic analysis.
  - Multiple deterministic model runs.

- Most useful points for decision-making are:
  - Identification of high or low bias, and qualitative magnitude.
  - Areas where uncertainty can be reduced with more data collection.

Major Areas of Uncertainty

- Representative exposure
  - Sample locations vs exposure area
  - Modeled concentrations (esp. soil to air or groundwater)
- Site-specific background
- Cumulative exposure to multiple chemicals
- Interspecies variability to toxicity.
- Systemic ecological impacts.

Possible Applications of Qualitative/Uncertainty Assessments

- Uncertainty assessments under appreciated and under used!
- How might BLM make better use of qualitative or uncertainty assessments?

Your Turn

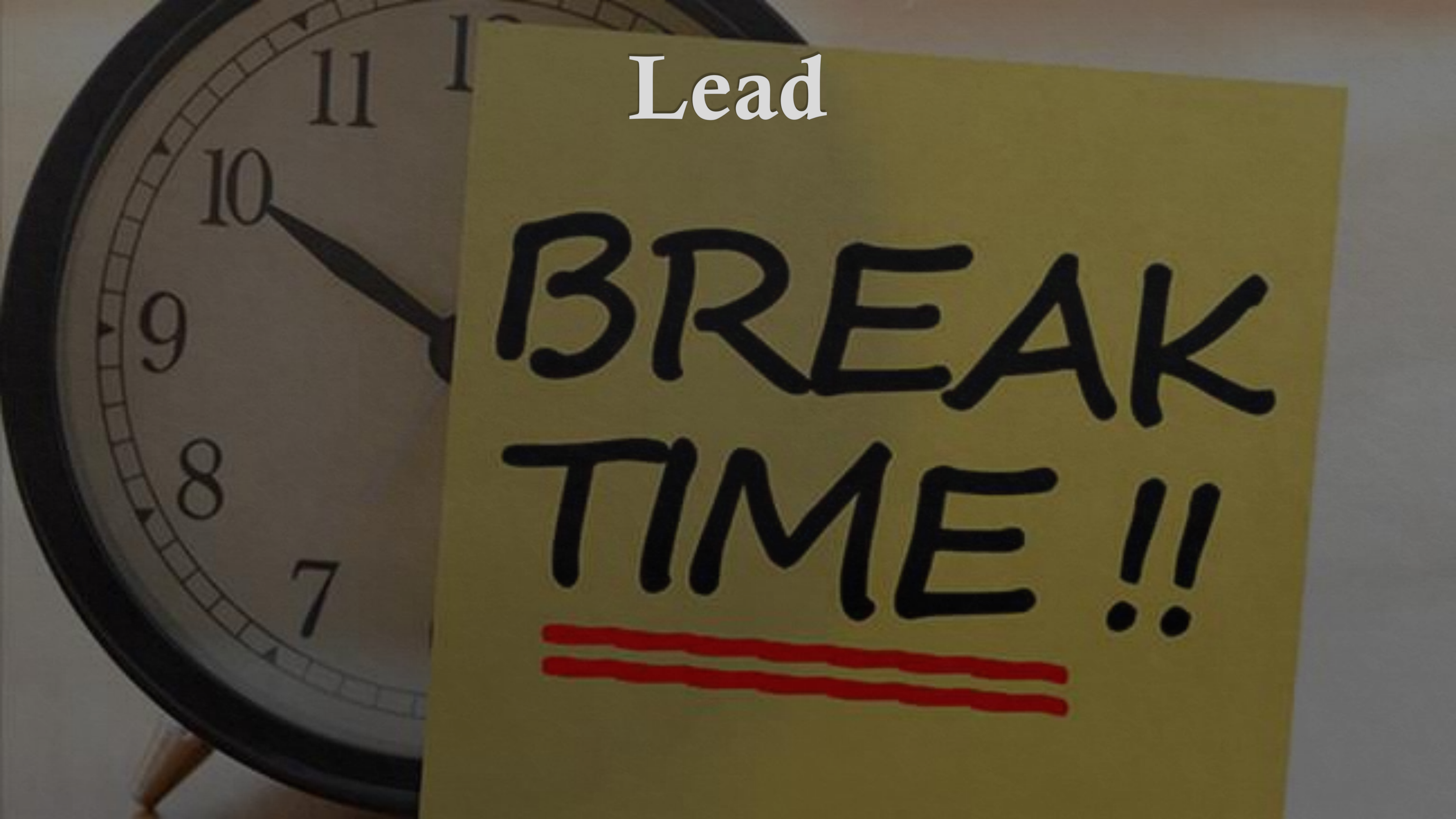
Complete a Risk Assessment!

Use NV SEAT data set to complete a dose-based human health and ecological risk assessment.

1. Calculate average and RME exposure concentrations using ProUCL.
2. Use RSL Calculator to compute hazard for airport worker.
3. Identify major uncertainties.
4. Compare conclusions to screening level assessment.
   a) What value is gained from doing the dose-based assessment?
   b) What level of effort is required to assess risk to future groundwater consumption?

Your Turn

Lead



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Lead

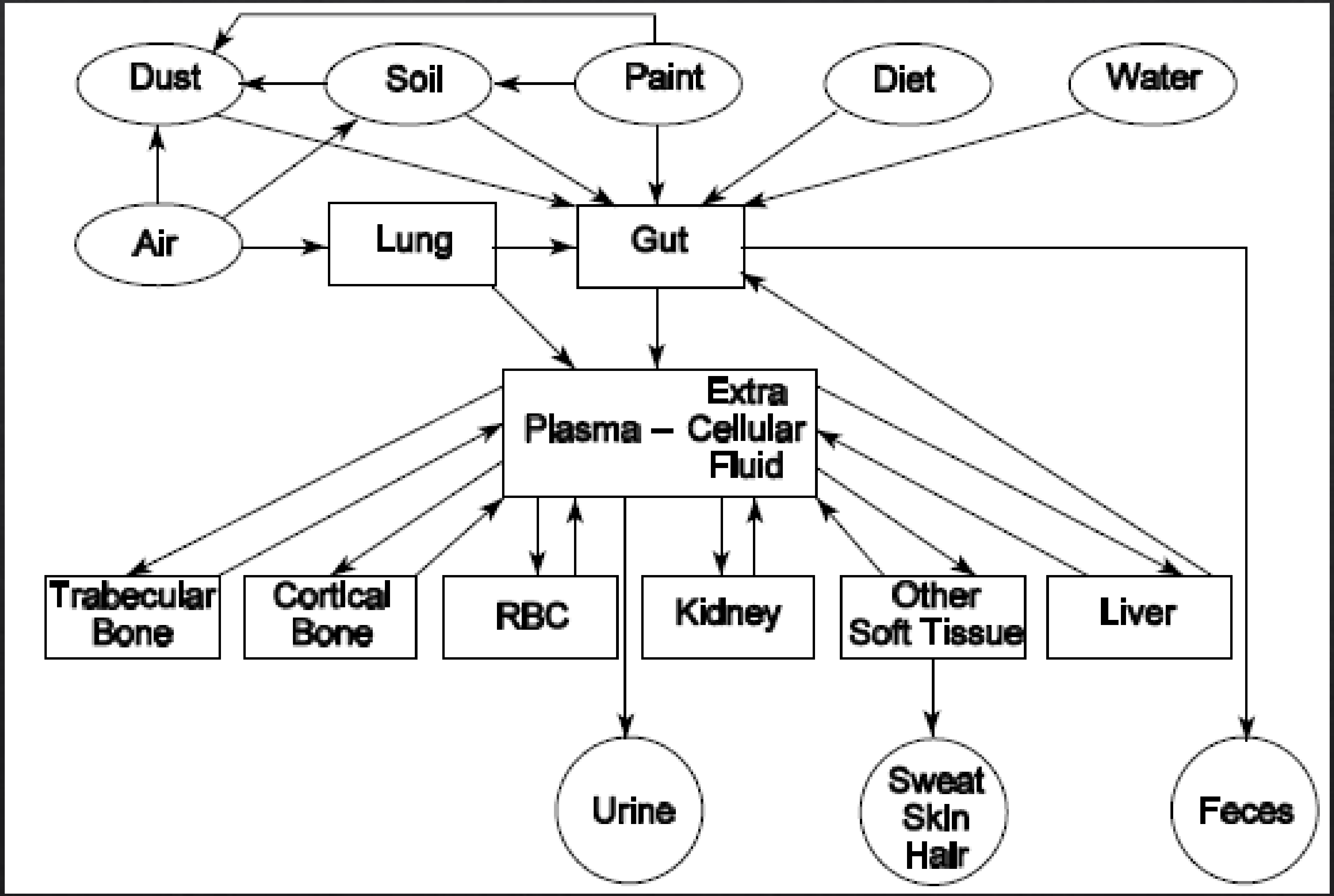
Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children

Continuous exposure: 1 day/week for > 3 months.

- IEUBK Model: for children <7 years of age
- Adult Lead Model

Why a different approach?

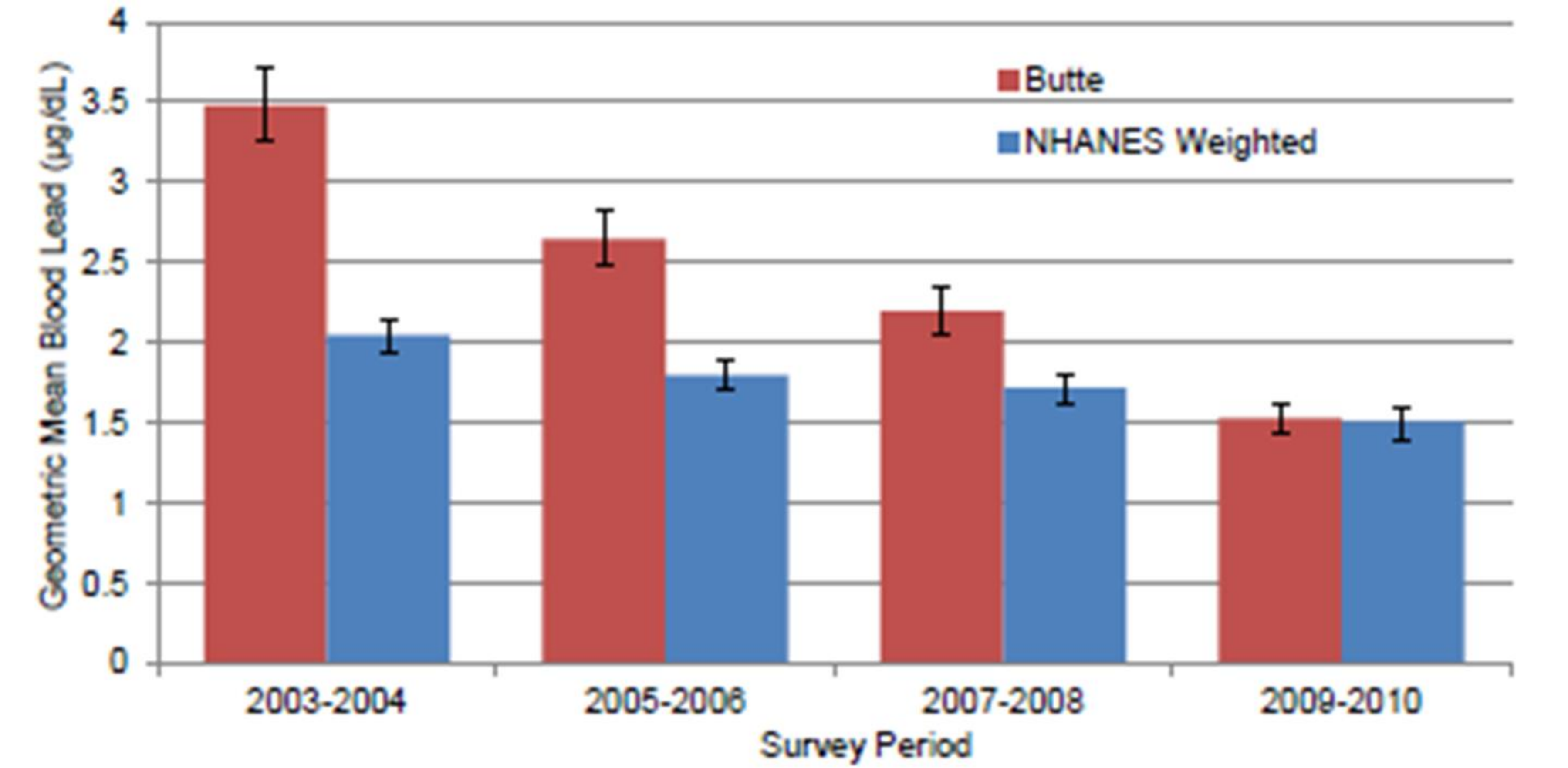
- Sensitive Populations: "Slope factors are a function of many factors: media ingestion rates; bioavailability and absorption of lead from the medium; and biological kinetics of lead retention and elimination in the child. Biological and physical differences between sites and study populations cannot be incorporated explicitly and quantitatively into regression slope factors from different studies."
- Multiple Sources of Exposure: "Slope factors for a single medium, such as lead in air or lead in soil, may provide only a very incomplete picture of total lead exposure from a particular source, even if the source is identified with the medium. A single medium such as household dust may contain lead from many sources, and lead from a single source such as exterior lead-based paint may contribute to several exposure media pathways to the child."



Lead PB-PK Model: physiological based pharmacokinetic

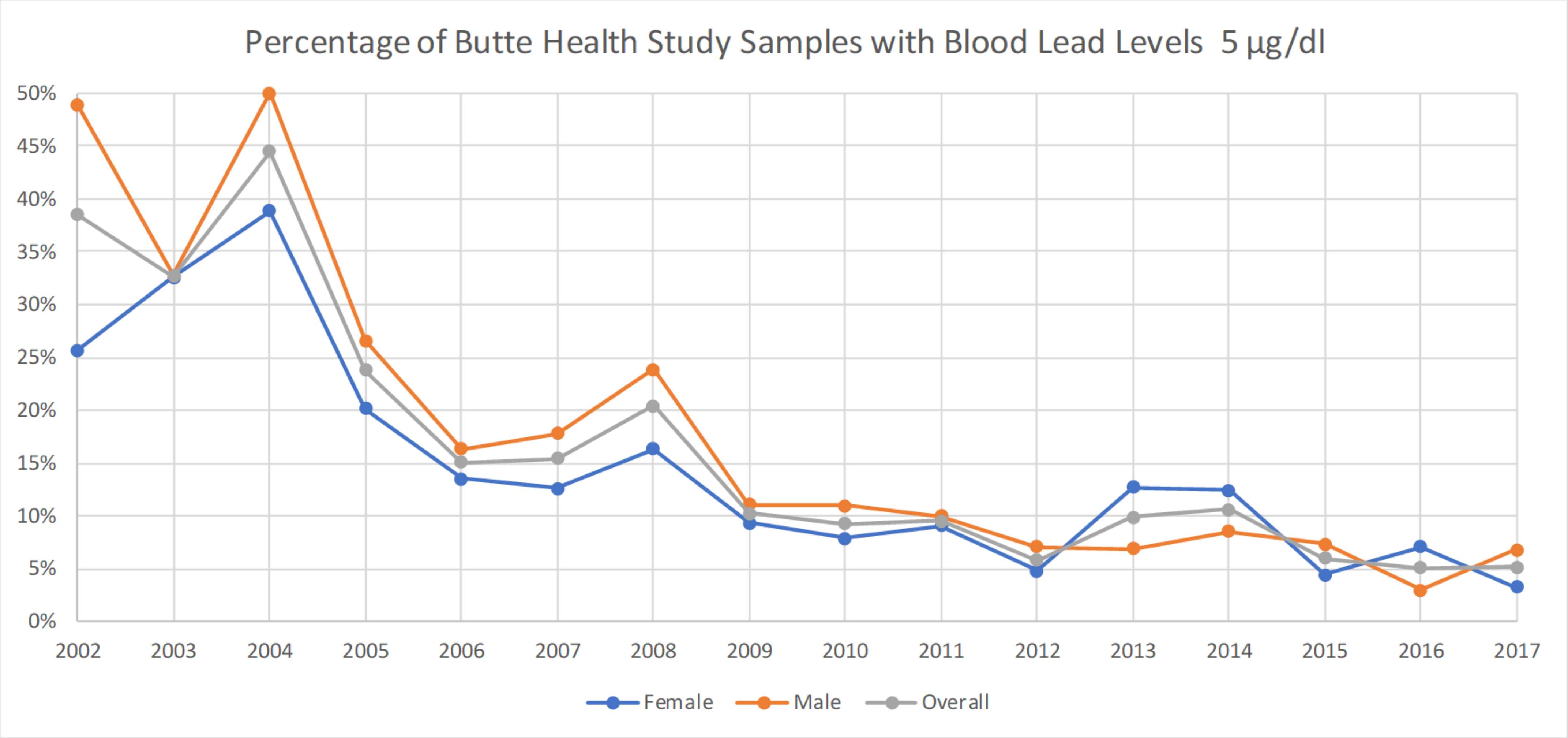
Butte Health Study 2014 (ENVIRON 2014)

- Blood lead levels in Butte have been dropping to levels approaching that of the rest of the country.
- Blood lead levels in Uptown are higher than the Flats
- No observed increase in cancer incidence in Butte vs. Montana attributable to mining wastes.



Modeled Geometric Mean Blood Lead Levels with 95% Confidence Levels

Butte Health Study 2019



Higher risk remains for: children, Uptown, older houses, summer season.

Adult Lead Model

For <u>adult only</u> exposure situations:

- Fetus protection model: Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil https://semspub.epa.gov/work/HQ/174559.pdf
  - BLM Risk Screening Tool uses 2,400 ppm lead.

All Ages Lead Model: EPA beta version

- Expands the IEUBK model to all ages, exposure periods as short as a few days, and expansion of multi-media sources.

Child Lead Model: Integrated Exposure Uptake Biokinetic Model

For child exposure situations:

- User's Guide for the Integrated Exposure Uptake Biokinetic Model for Lead in Children https://semspub.epa.gov/work/HQ/176289.pdf

- IEUBK walk through: https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals

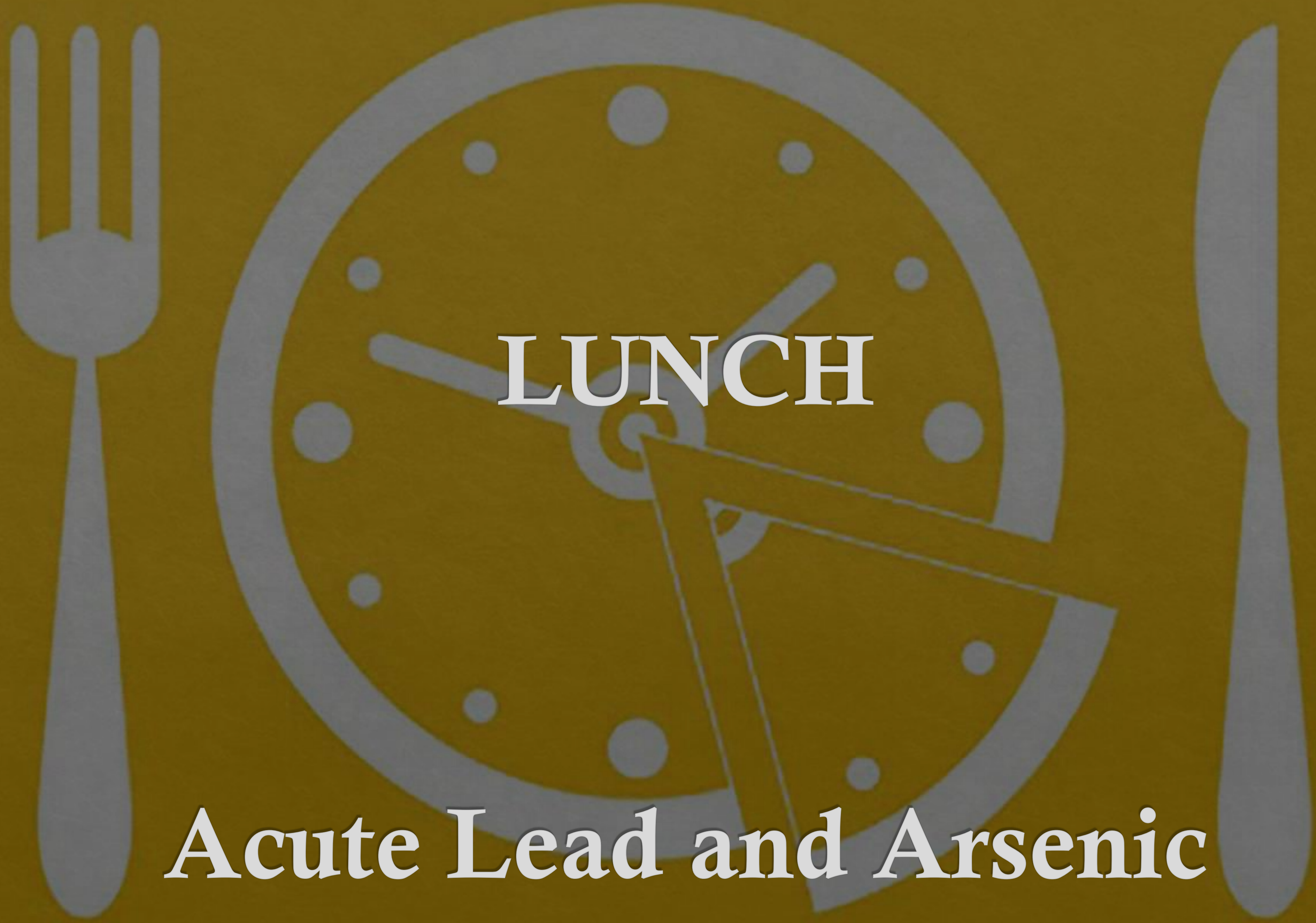
Adult Lead Model Exercise

Adult Lead Model: https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals#recommend

Does a lone mine dump covering 5 acres in a remote location pose excess risk to recreationalists?

- ISM Data: 3,000 ppm & RBA = 0.6; 2,500 ppm & RBA = 0.5; 2,000 ppm & RBA = 0.4
- Consider:
  1. Representative exposure
  2. BLM Recreational guidance exposure assumptions
  3. Lead biokinetics
  4. EPA Default AF: Based on an absorption factor for soluble lead of 0.20 and a relative bioavailability of 0.60 (soil/soluble).

Your Turn



LUNCH

Acute Lead and Arsenic

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Acute Arsenic Model

Why is evaluation of acute arsenic necessary?

- Arsenic exists naturally at levels exceeding 1E-6.
- At 1E-4 risk, the non-cancer endpoint can be more toxic.
- Many mine site cleanups are driven by arsenic (and lead).
- Many mine sites do not experience 14 days/year, lifetime exposure.
- No reliable method for evaluating hazard from acute or intermittent lead exposure.
- Acute toxicity for arsenic is well known.

Acute Arsenic Model

Arsenic background levels 5 – 20 mg/kg (average and RME).

For the BLM 14-day soil screening model?

- cancer risk:
  - 1E-6 = 30.6 mg/kg.
  - 1E-5 = 306 mg/kg
  - 1E-4 = 3060 mg/kg
- Noncancer hazard:
  - HQ of 1 = 2,620 mg/kg

Bonita Peak HHRA Acute Arsenic Assessment (CDMSmith)

Transient adverse health effects commonly occur when doses between 0.035 and 0.071 milligrams of arsenic per kilogram of body weight (mg/kg BW) are ingested.

The best estimate of an acute threshold for transient effects is 0.05 mg/kg BW.

Accessed 2 year old child, camping for 2 and 14 days on waste rock.

- Scenario 1: CTE soil ingestion rate 367 mg/day
- Scenario 2: RME soil ingestion rate 1,592 mg/day

Bonita Peak HHRA Acute Arsenic Assessment (CDMSmith)

Acute Arsenic Screening Levels (mg/kg)

	2 days		14 days	
Relative Biovailability	0.07	0.05	0.07	0.05
CTE Soil Ingestion	1216	1703	174	243
RME Soil Ingestion	280	393	40	56

2-year-old child camping scenario

Bonita Peak HHRA Lead Assessment (CDMSmith)

Acute Lead Screening Levels (mg/kg)

	2 days		14 days	
Relative Biovailability	0.54	0.23	0.54	0.23
CTE Soil Ingestion	2594	6090	1331	3125
RME Soil Ingestion	596	1400	306	719

2 year old child camping scenario
20 ug/dL level of concern

Your Turn

Application of acute levels for risk management?

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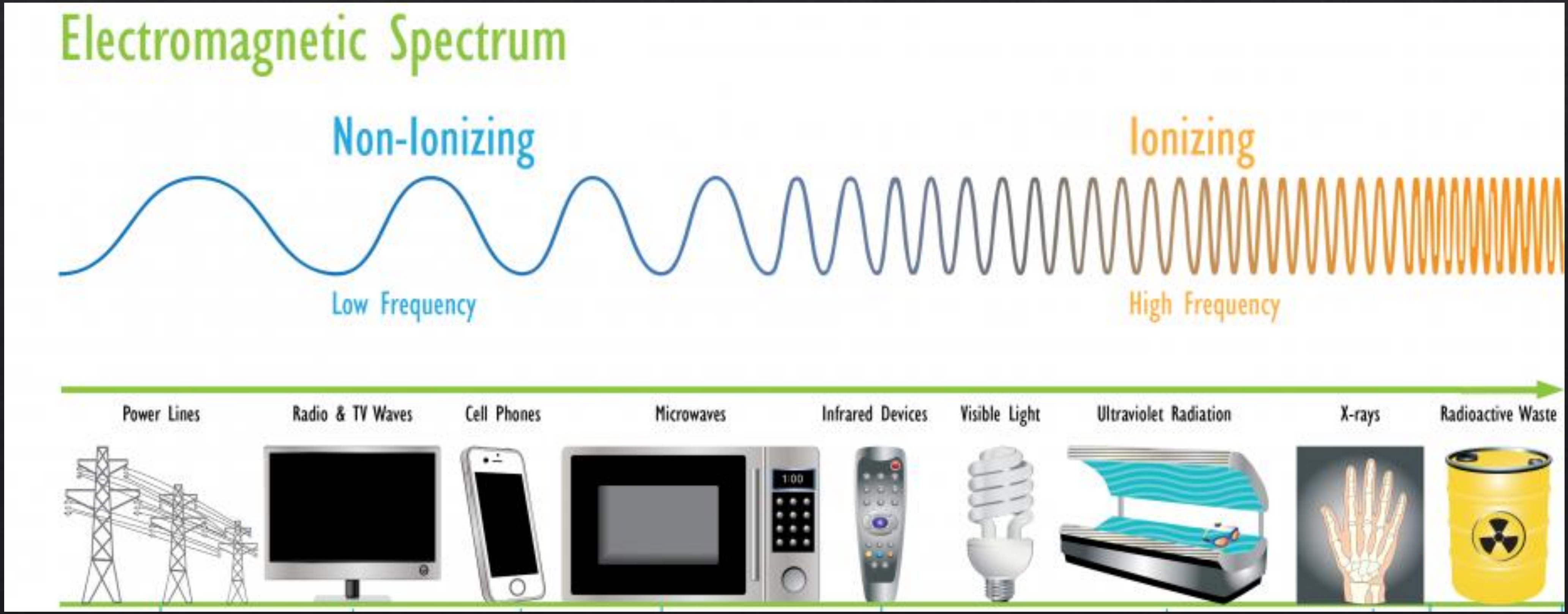
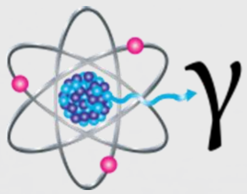
What is a radionuclide?

A **radionuclide** (radioactive nuclide, radioisotope or radioactive isotope) is an atom that emits excess nuclear energy in the form of ionizing (high frequency) radiation. Iron is the most stable atom.

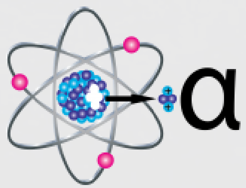


What is a radionuclide?

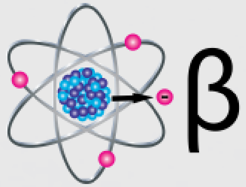
Ionizing radiation that is emitted from the nucleus can include:



- Gamma radiation/ray (photon)
  - Can pass through the human body; external threat
  - Does not lead to new element

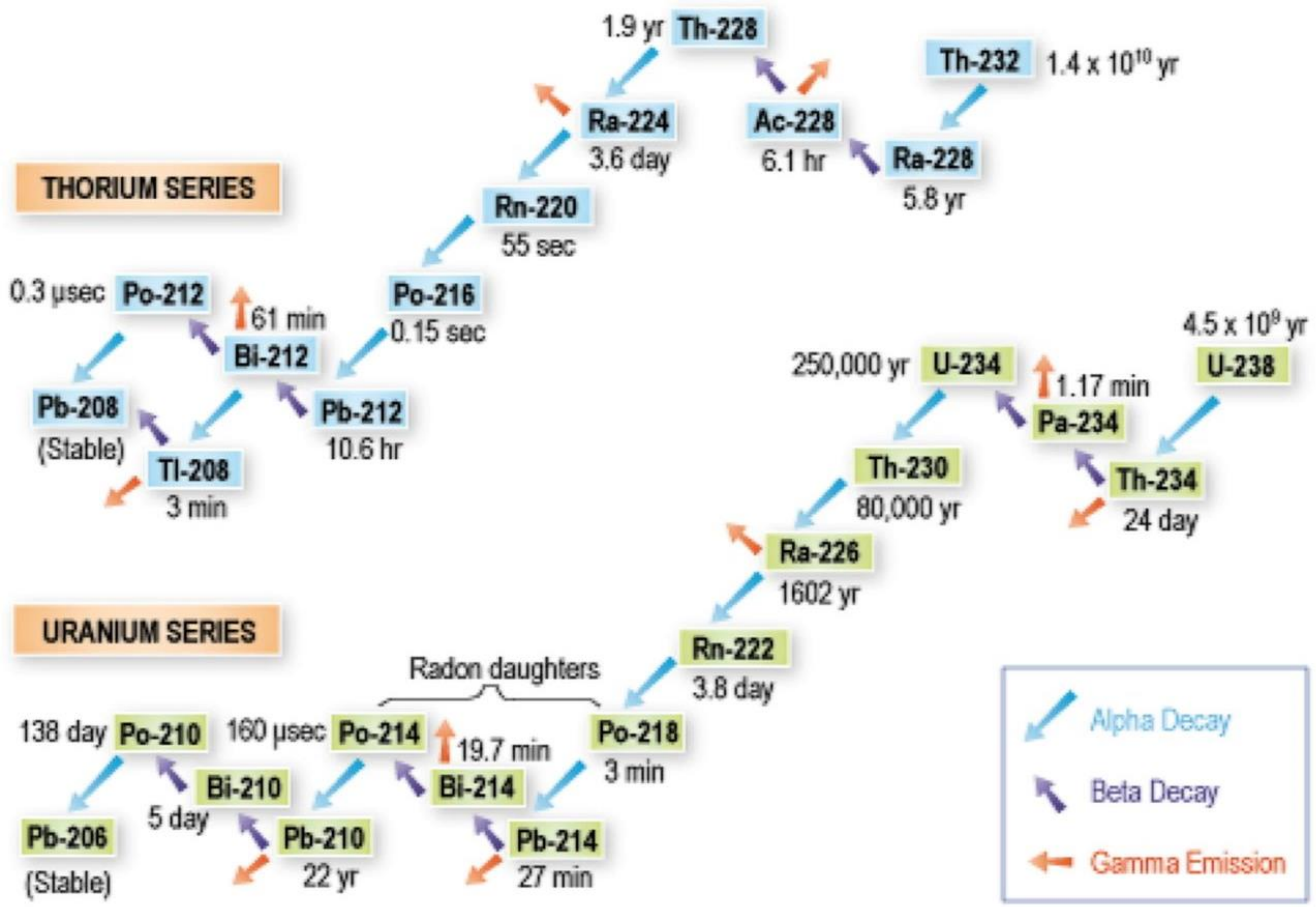


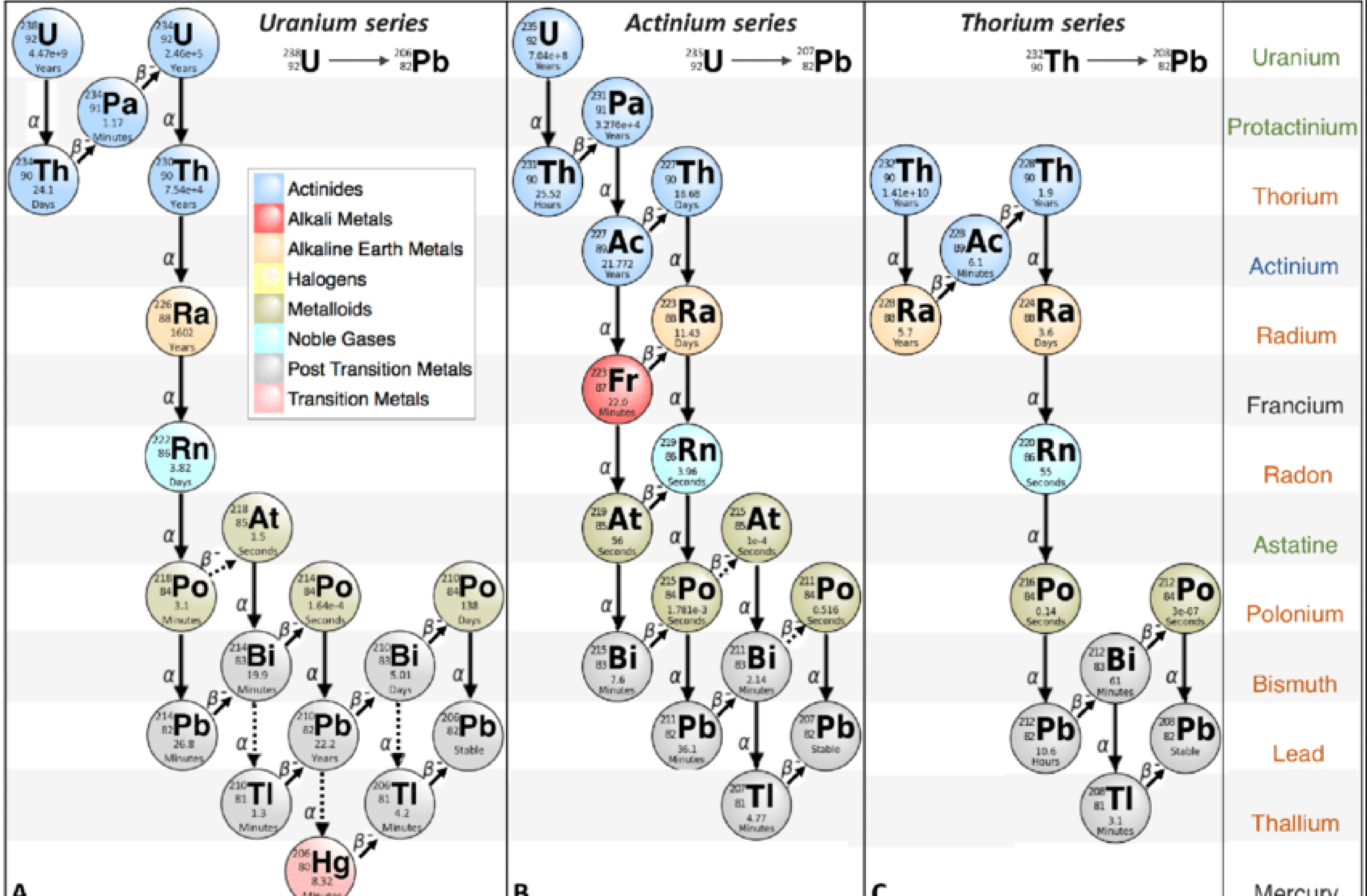
- Alpha particle (two neutrons and protons)
  - lowest penetrating and ionizing power
  - Ingestion and inhalation threat



- Beta particle (small, fast, negative particles)
  - beta particle: medium penetrating and highest ionizing power
  - Some can penetrate skin.
  - Ingestion and inhalation threat

Decay Chains





Decay Chains

Radiation Measurement Units

Radioactivity: How many atoms decay in a given time period.	• Becquerel: Bq, international • Curie: Ci, US
Exposure: How much radiation is in the air.	• coulomb/kilogram: C/kg, international • Roentgen: R, US
Absorbed dose: The amount of absorbed radiation.	• Gray: Gy, international • Rad: US - One gray = 100 rads.
Effective dose: The amount of radiation absorbed, adjusted to account for the type of radiation and the effect.	• Sievert: Sv, international • Rem: US - One sievert = 100 rems, millirem (mrem) = one thousandth of a rem

NORM and TENORM

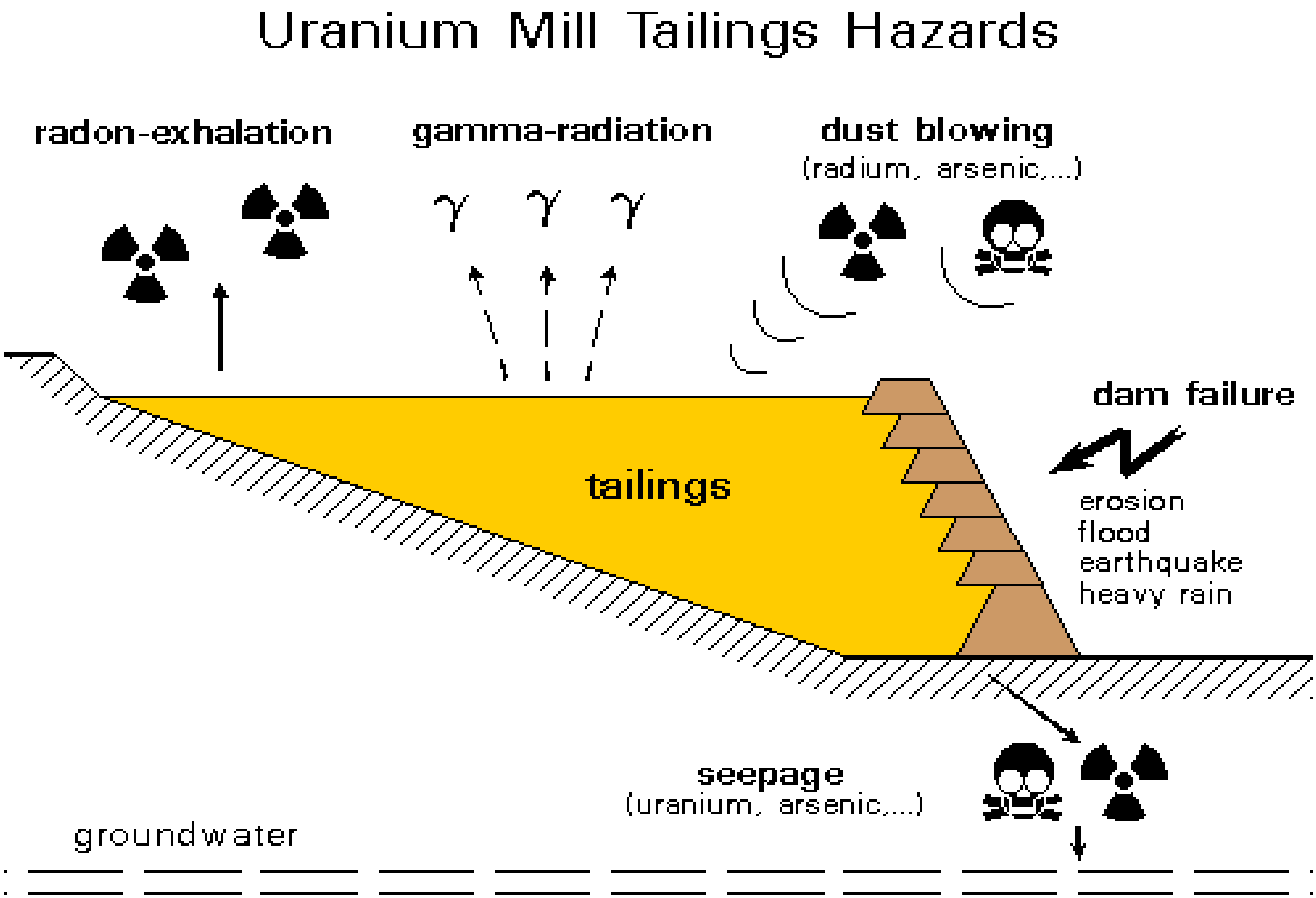
Naturally Occurring Radioactive Material (NORM): Materials which may contain any of the primordial radionuclides or radioactive elements as they occur in nature, such as radium, uranium, thorium, potassium, and their radioactive decay products, such as radium and radon, that are undisturbed as a result of human activities.

Technologically Enhanced Naturally Occurring Radioactive Material (TENORM): Naturally occurring radioactive materials that have been concentrated or exposed to the accessible environment as a result of human activities such as manufacturing, mineral extraction, or water processing (treatment residues).

Background Radiation Screening Benchmarks

Dose Standards	Soil Gamma (Ra-226)	Exposure Level	Benchmark Level: above natural background	Relative Priority Score	Action
12 mrem/yr [2] EPA (general public)	16 pCi/g	32 μR/hr	<32 μR/hr	0 (None)	Site does not pose a radiological risk. No further evaluation.
25 mrem/yr NRC (unrestricted use)	37 pCi/g	64 μR/hr	32–64 μR/hr	1 (Low)	Site poses minimal potential for radiological risk. No further evaluation, but exposure mitigation may occur in conjunction with other measures.
100 mrem/yr CFR Title 10 (public exposure)	147 pCi/g	256μR/hr	64–256 μR/hr	2 (Med.)	Site poses moderate potential for radiological risk. Potentially warrants further radiological hazard assessment, considering chemical and physical hazards.
--	--	--	>256 μR/hr	3 (High)	Site poses high potential for radiological risk. Warrants further radiological hazard assessment.

Source: Table adapted from Navarro (2019) and Brown (2017).



Source:
http://www.wise-uranium.org/uwai.html

Exhibit 1: Radioactive Decay Chains Included in HEAST Tables 4A and 4B*

Principal Decay Chain	Subchain[a]	Members[b]	Half-life[c]
Uranium-238	U-238+D	U-238 Th-234 Pa-234	4.468E+09 Y 2.410E+01 D 1.170E+00 M
	U-234	U-234	2.445E+05 Y
	Th-230	Th-230	7.700E+04 Y
	Ra-226+D	Ra-226 Rn-222[††] Po-218 Pb-214 Bi-214 Po-214	1.600E+03 Y 3.823E+00 D 3.050E+00 M 2.680E+01 M 1.990E+01 M 1.637E–04 S
	Pb-210+D	Pb-210 Bi-210 Po-210	2.226E+01 Y 5.013E+00 D 1.384E+02 D
	Pb-206	Pb-206	[Stable]
Uranium-235	U-235+D	U-235 Th-231	7.038E+08 Y 2.552E+01 H
	Pa-231	Pa-231	3.726E+04 Y
	Ac-227+D	Ac-227 Th-227 [99%] Ra-233 Rn-219 Po-215 Pb-211 Bi-211 Tl-207	2.177E+01 Y 1.872E+01 D 1.143E+01 D 3.960E+00 S 1.778E–03 S 3.610E+01 M 2.130E+00 M 4.770E+00 M
	Pb-207	Pb-207	[Stable]
Thorium-232	Th-232	Th-232	1.405E+10 Y
	Ra-228+D	Ra-228 Ac-228	5.750E+00 Y 6.130E+00 H
	Th-228+D	Th-228 Ra-224 Rn-220 Po-216 Pb-212 Bi-212 Po-212 [64%] Tl-208 [36%]	1.913E+00 Y 3.620E+00 D 5.561E+01 S 1.460E–01 S 1.064E+01 H 6.055E+01 M 2.980E–07 S 3.053E+00 M
	Pb-208	Pb-208	[Stable]

Exhibit 1: Radioactive Decay Chains Included in HEAST Tables 4A and 4B (Continued)*

Principal Decay Chain	Subchain[a]	Members[b]	Half-life[c]
Neptunium-237	Np-237+D	Np-237 Pa-233	2.140E+06 Y 2.700E+01 D
	U-233	U-233	1.592E+05 Y
	Th-229+D	Th-229 Ra-225 Ac-225 Fr-221 At-217 Bi-213 Po-213 [98%] Tl-209 [2%] Pd-209	7.340E+03 Y 1.480E+01 D 1.000E+01 D 4.800E+00 M 3.230E–02 S 4.565E+01 M 4.200E–06 S 2.200E+00 M 3.253E+00 H
	Bi-209	Bi-209	[Stable]
Americium-243	Am-243+D	Am-243 Np-239	7.380E+03 Y 2.355E+00 D
Cesium-137	Cs-137+D	Cs-137 Ba-137m	3.017E+01 Y 2.552E+00 M
Strontium-90	Sr-90+D	Sr-90 Y-90	2.860E+01 Y 6.410E+01 H

* See the discussion on radioactive decay chains in the User's Guide.
[a] Radioactive decay chains included in HEAST Tables 4A and 4B. Radionuclides marked with the suffix "+D" include risks from decay chain members, assuming secular equilibrium (i.e., equal activity concentrations) in the environment.
[b] The chain of decay products of a parent radionuclide extends to (but does not include) members of the next subchain (e.g., U-238+D includes U-238, Th-234 and Pa-234, but not U-234). Note that there may be circumstances when it may be necessary to combine the risks for a parent radionuclide over several contiguous subchains, depending on the conditions of equilibrium. Branches in the decay chain are indicated in square brackets with branching percentages in parentheses.
[††] A radon-222 decay subchain, Rn-222+D, is also included in the HEAST tables, comprised of ingestion, inhalation and external exposure slope factors for Rn-222 plus the corresponding slope factors for each of its decay products (Po-218, Pb-214, Bi-214 and Po-214). For the ingestion and external exposure slope factors for Rn-222+D, decay products are assumed to be in secular equilibrium. For the inhalation slope factor, decay products are assumed to be in 50% equilibrium.
[c] Radioactive half-life in years (Y), days (D), hours (H), minutes (M) or seconds (S).

HEAST, 1993 (superseded)

Chemical of Potential Concern (COPCs)

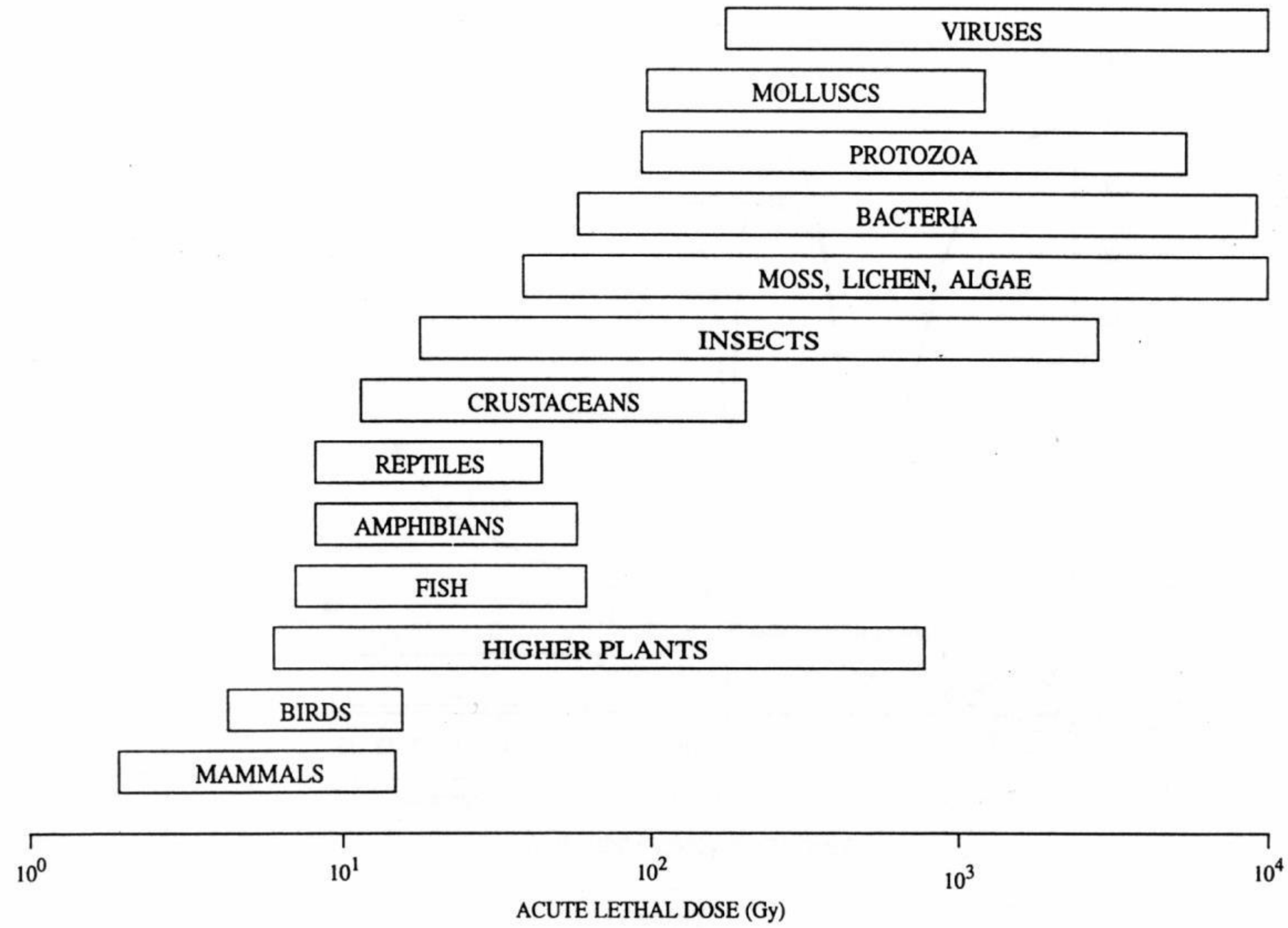
Possible Analytes for Uranium Mine Sites			
Analyte Group	Analytes	Media	Purpose
Radionuclides	Ra-226	SL, GW, SW, SD	Comparison to ARARs/ILs
	Ra-228	SL, GW, SW	Comparison to ARARs/ILs
	Isotopic U & Th, K-40, and Pb-210	SL, GW, SW, SD	Characterize rads, secular equil
	Gross alpha, gross beta	GW, SW	Characterize rads
Metals (total & diss)	TAL Metals + boron, lithium, molybdenum, phosphorus, strontium, thorium, & uranium. Soil pH.	SL, GW, SW, SD	Comparison to ARARs/ILs
Water quality/ions	Orthophosphate, sulfate, chloride, nitrate/nitrite, alkalinity, hardness, TDS	GW, SW	Characterize hydrogeochemistry
Field parameters	Temp, pH, conductivity, DO, ORP, turbidity	GW, SW	Characterize hydrogeochemistry
Physical properties	Moisture content (part of metals analysis)	SD	Characterize physical properties
	Grainsize distribution	SD	Characterize physical properties
	Total organic carbon	SD	Characterize physical properties
SPLP metals/rads	TAL Metals + boron, lithium, molybdenum, phosphorus, strontium, thorium, uranium & Ra-226	SD	Evaluate leachability
Sulfur & ABA	Total sulfur & sulfides, NNP, ABA	SL/SD	Acid base accounting

Acute Lethal Dose Sensitivity

Comparative radiosensitivity of different organisms demonstrated as the acute lethal dose ranges (reproduced from UNSCEAR 1996).

ERICA exposure screening values:

- 0.9 Gy marine acute
- 0.3 Gy terrestrial and freshwater acute
- 10 uGy/h for all ecosystems, chronic



Human Toxicity and Slope Factors

Radionuclides are Group A carcinogens, mutagens (genetic material impacts) and teratogens (embryo/fetus effects).

- Carcinogenic effects are most sensitive.
- Slope Factors and more in EPA's PRG Calculator: https://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search
- HEAST tables, Users Guide, Exhibit 1 explains D+ slope factors: https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=2877
- Slope factors are based on central estimates, unlike 95 UCL estimates for metals.

Uranium also has a potentially significant non-cancer RfD.

Ecological Screening Levels (DOE)

- No observable population changes:
  - Aquatic animals: 1 rad/day (10mGy/day)
  - Terrestrial Plants: 1 rad/day (10 mGy/day)
  - Terrestrial Animals: 0.1 rad/day (1 mGy/day): ERICA value is 0.024 rad/day
- Media-specific Biota Concentration Guides (BCGs): in RESRAD-biota

Aquatic System Evaluation

$$\left[\frac{C_A}{BCG_A}+\frac{C_B}{BCG_B}+\cdots+\frac{C_N}{BCG_N}\right]_{\text{water}}+\left[\frac{C_A}{BCG_A}+\frac{C_B}{BCG_B}+\cdots+\frac{C_N}{BCG_N}\right]_{\text{sediment}}<1.0$$

Terrestrial System Evaluation

$$\left[\frac{C_A}{BCG_A}+\frac{C_B}{BCG_B}+\cdots+\frac{C_N}{BCG_N}\right]_{\text{water}}+\left[\frac{C_A}{BCG_A}+\frac{C_B}{BCG_B}+\cdots+\frac{C_N}{BCG_N}\right]_{\text{soil}}<1.0$$

BCGs in DOE Standard 1153, Table G-2: https://resrad.evs.anl.gov/docs/technicalStandard.pdf

Ecological Screening Levels (ESLs): Sediment

Radionuclides	Value	Source
Lead 210 (pCi/g)	9,000	LANL 2017, 1/10th low effect ESL multiple aquatic community
Radium 226 (pCi/g)	1,400	LANL 2017, 1/10th low effect ESL multiple aquatic community
Radium 228 (pCi/g)	2,800	LANL 2017, 1/10th low effect ESL multiple aquatic community
Radon 222 (pCi/g)	2,800	LANL 2017, 1/10th low effect ESL multiple aquatic community
Thorium 228 (pCi/g)	1,600	LANL 2017, 1/10th low effect ESL multiple aquatic community
Thorium 230 (pCi/g)	270,000	LANL 2017, 1/10th low effect ESL multiple aquatic community
Thorium 232 (pCi/g)	320,000	LANL 2017, 1/10th low effect ESL multiple aquatic community
Uranium 234 (pCi/g)	300,000	LANL 2017, 1/10th low effect ESL multiple aquatic community
Uranium 235 (pCi/g)	10,000	LANL 2017, 1/10th low effect ESL multiple aquatic community
Uranium 238 (pCi/g)	4,300	LANL 2017, 1/10th low effect ESL aquatic community

LANL (Los Alamos National Laboratory). September 2017. ECORISK Database (Release 4.1). LA-UR-17-26376, Los Alamos National Laboratory, Los Alamos New Mexico.

Ecological Screening Levels (ESLs): Surface Water

Analyte	Acute Screening Level	Chronic Screening Level	Source	Live-stock	Source	Ag Water Supply	Source
Lead 210 (pCi/g) h	2500	250	LANL (2017)				
Radium 226 +228 (pCi/L)				5	NNEPA (2015)	5	NNEPA (2015)
Radium 226 (pCi/L) g	32	3.2	LANL (2017)				
Radium 228 (pCi/L) g	27	2.7	LANL (2017)				
Radon 222 (pCi/L)							
Thorium 228 (pCi/L) g	1,700	170	LANL (2017)				
Thorium 230 (pCi/L) g	2,000	200	LANL (2017)				
Thorium 232 (pCi/L) g	240	24	LANL (2017)				
Uranium 234 (pCi/L) h	390	39	LANL (2017)				
Uranium 235 (pCi/L) h	430	43	LANL (2017)				
Uranium 238 (pCi/L) h	440	44	LANL (2017)				
Gross Alpha (pCi/L) f				15	NNEPA (2015)		

Notes:

f NNEPA livestock value. For values above 15 pCi/L subtract the radon and uranium activity (in pCi/L) from the gross alpha value to determine the reported gross alpha value. If radon gas is removed during the gross alpha analytical method, only subtract the uranium activity value. Uranium activity in pCi/L is determined from the uranium concentration in (ug/L) according to the following formula: Uranium (pCi/L) = (uranium (ug/L)) X 0.67

g aquatic community no effect ESL and low effectESL

h fish carnivore no effect ESL and low effect ESL

LANL (Los Alamos National Laboratory). September 2017. ECORISK Database (Release 4.1). LA-UR-17-26376, Los Alamos National Laboratory.
Navajo Nation Environmental Protection Agency (NNEPA). 2008. Navajo Nation Surface Water Quality Standards. May 13, 2008.

Ecological Screening Levels (ESLs): Soil

Parameter	Plants	Invert's	Wildlife	Source
Lead 210 (pCi/g)	3,400	1,200	4,400	LANL, no effect level
Radium 226 (pCi/g)	54	1.5	8.2	LANL, no effect level
Radium 228 (pCi/g)	48	1.2	11	LANL, no effect level
Radon 222 (pCi/g)	48	1.2	11	LANL, no effect level
Thorium 228 (pCi/g)	140	43	800	LANL, no effect level
Thorium 230 (pCi/g)	200	52	1200	LANL, no effect level
Thorium 232 (pCi/g)	24	6.2	150	LANL, no effect level
Uranium 234 (pCi/g)	440	2200	14,000	LANL, no effect level
Uranium 235 (pCi/g)	440	1600	4,700	LANL, no effect level
Uranium 238 (pCi/g)	400	1100	2,000	LANL, no effect level

LANL (Los Alamos National Laboratory). September 2017. ECORISK Database (Release 4.1). LA-UR-17-26376, Los Alamos National Laboratory.

Navajo Nation Environmental Protection Agency (NNEPA). 2008. Navajo Nation Surface Water Quality Standards. May 13, 2008.

Exposure Calculator and Course Evaluations

Your Turn

Calculate your baseline exposure

Use EPA Dose Calculator:
https://www.epa.gov/radiation/calculate-your-radiation-dose

Discussion:

How do your results compare to the national average?

What most influenced your results?

What was most surprising?

Good Bye!

You're a risk assessor!

Course Evaluations…

Got questions?

Steve Ackerlund, PhD

Environmental Scientist and Risk Assessor

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