Low-Level Waste Performance Assessment and CERCLA Risk Assessment at the Idaho National Laboratory

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Idaho National Laboratory

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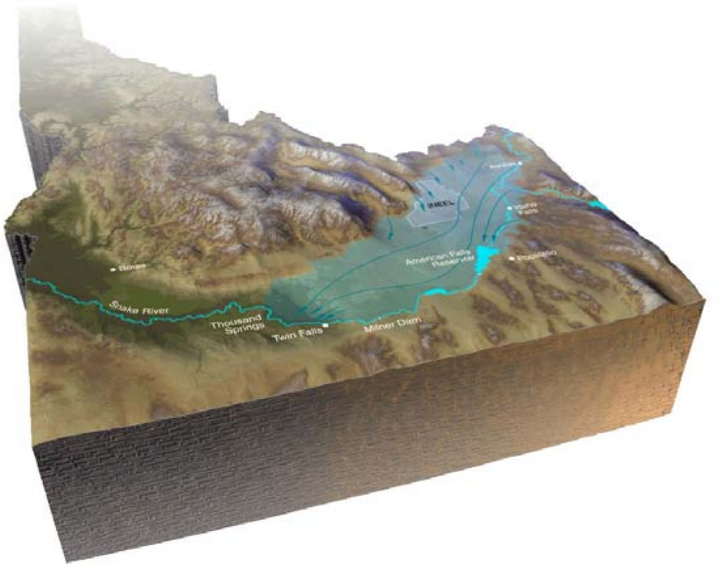

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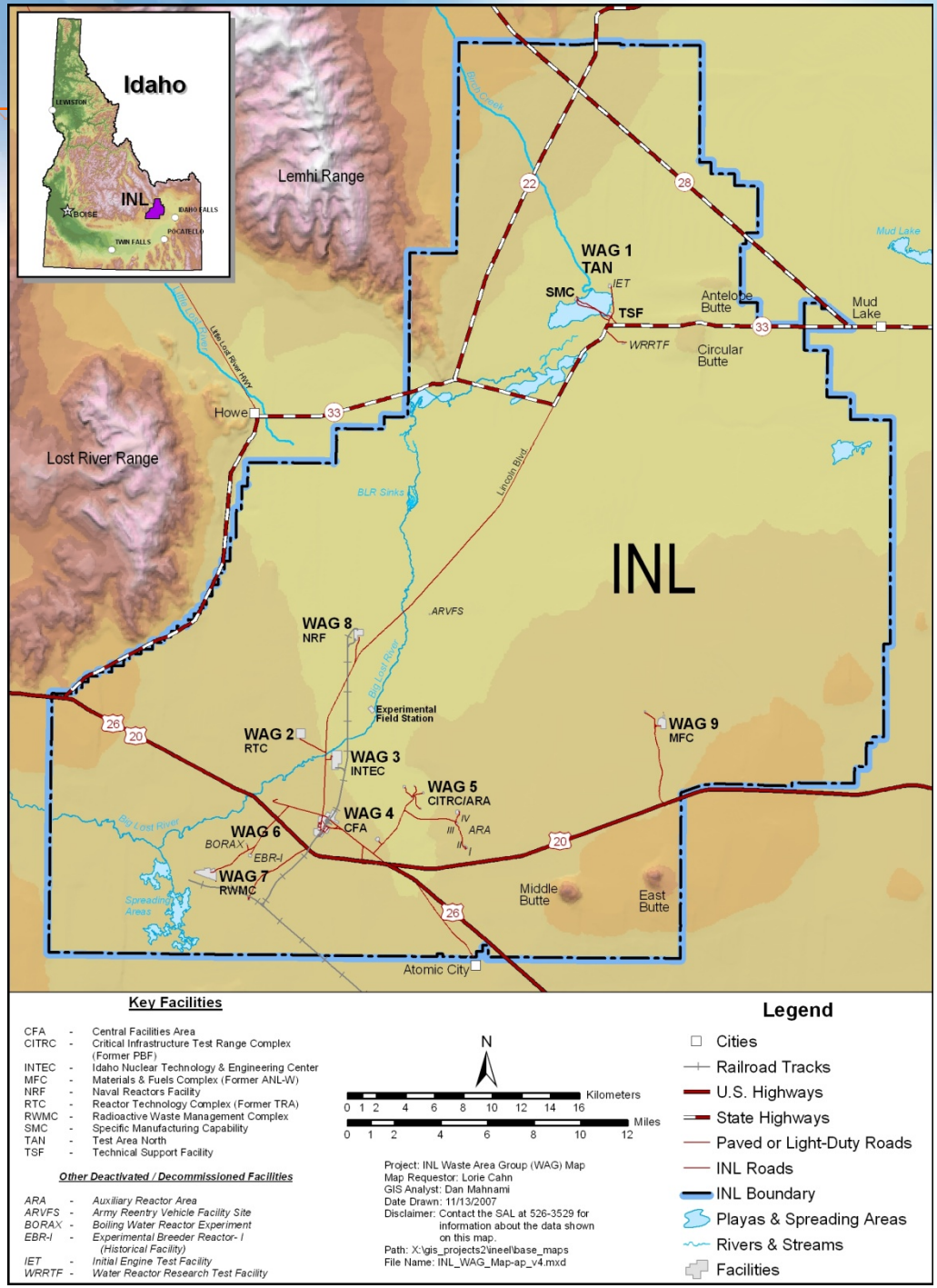
Outline

- Introduction and Background
- Current Modeling Approach
  - General Approach
  - Track 1 and 2 Process
  - Differences between PA process and CERCLA RIFS process
  - Case Studies
    - RWMC PA and WAG 7 RIFS
    - ICDF PA and WAG 3 RIFS
    - Composite Analysis and WAG 10 RIFS
- Summary and Conclusions

Introduction and Background: CERCLA

- November 1989 the INL placed on the NPL and subject to the provisions of CERCLA
- Agencies (DOE, EPA, and State) sign FFA/CO and action plan for CERCLA cleanup and RCRA corrective actions (~1991)
- Risk assessments performed on nine Waste Area Groups (WAG) that roughly correspond to INL facilities.
- A tenth WAG was identified that includes miscellaneous sites and the Snake River Plain Aquifer
- A Record of Decision (ROD) has been completed for all WAGs

CERCLA Waste Area Groups (WAGs)



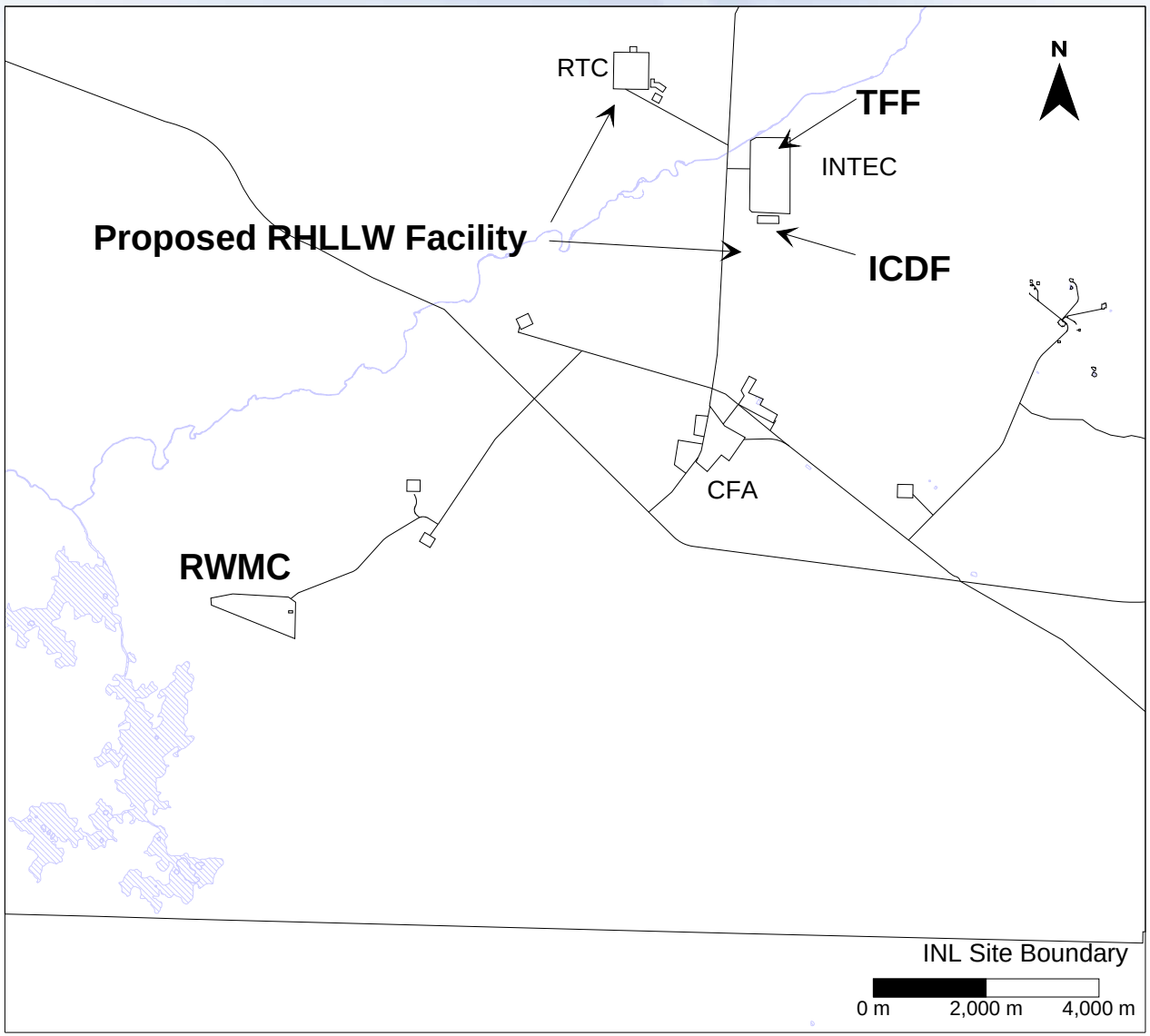
Introduction and Background: Performance Assessment

- Performance Assessment (PA) and Composite Analysis (CA) per DOE O 435.1 performed for three facilities
  - Radioactive Waste Management Complex (RWMC) LLW PA (May 1994)
    - Technical Revision to the PA and Composite Analysis (September 2000)
    - Revision to the PA/CA completed in 2007/2008
  - Idaho CERCLA Disposal Facility (ICDF) Landfill PA/CA (August, 2003)
  - Tank Farm Facility (TFF) PA (April 2003) and CA (May 2006)

Introduction and Background: Performance Assessment

- The active LLW disposal site (RWMC) is being closed and a new facility to dispose of Remote-Handled LLW is being evaluated as an on-site disposal option
  - A PA/CA is currently being prepared for this option
- A revision to the ICDF PA has been completed and is currently under DOE-ID review.

Low-Level Waste Facilities



General Approach to PA/CA and CERCLA Risk Assessment Modeling

- Top-down Approach
  - Simple models with conservative assumptions are used first to identify important radionuclides (i.e., screening or the Track 1 and 2 process).
    - If all radionuclides/chemicals are screened, then no further action is taken
  - Conceptual model of facility/site is developed
  - More complex models are developed and used to understand system behavior and identify important processes
  - Final model used for compliance demonstration/risk assessment may represent a melding of a simple and complex model (i.e., model abstraction)

Track 1 and 2 Process

- The Track 1 and 2 process was established in 1994 to provide a consistent methodology to assess probable low-hazard risk sites at the INL under CERCLA
- Developed in coordination with the State of Idaho and EPA Region 10
- Methodology included models, computer codes, and site-specific parameter values used in preliminary risk assessment
- Track 1 and 2 process used to arrive at a Record of Decision for many of the Waste Area Groups

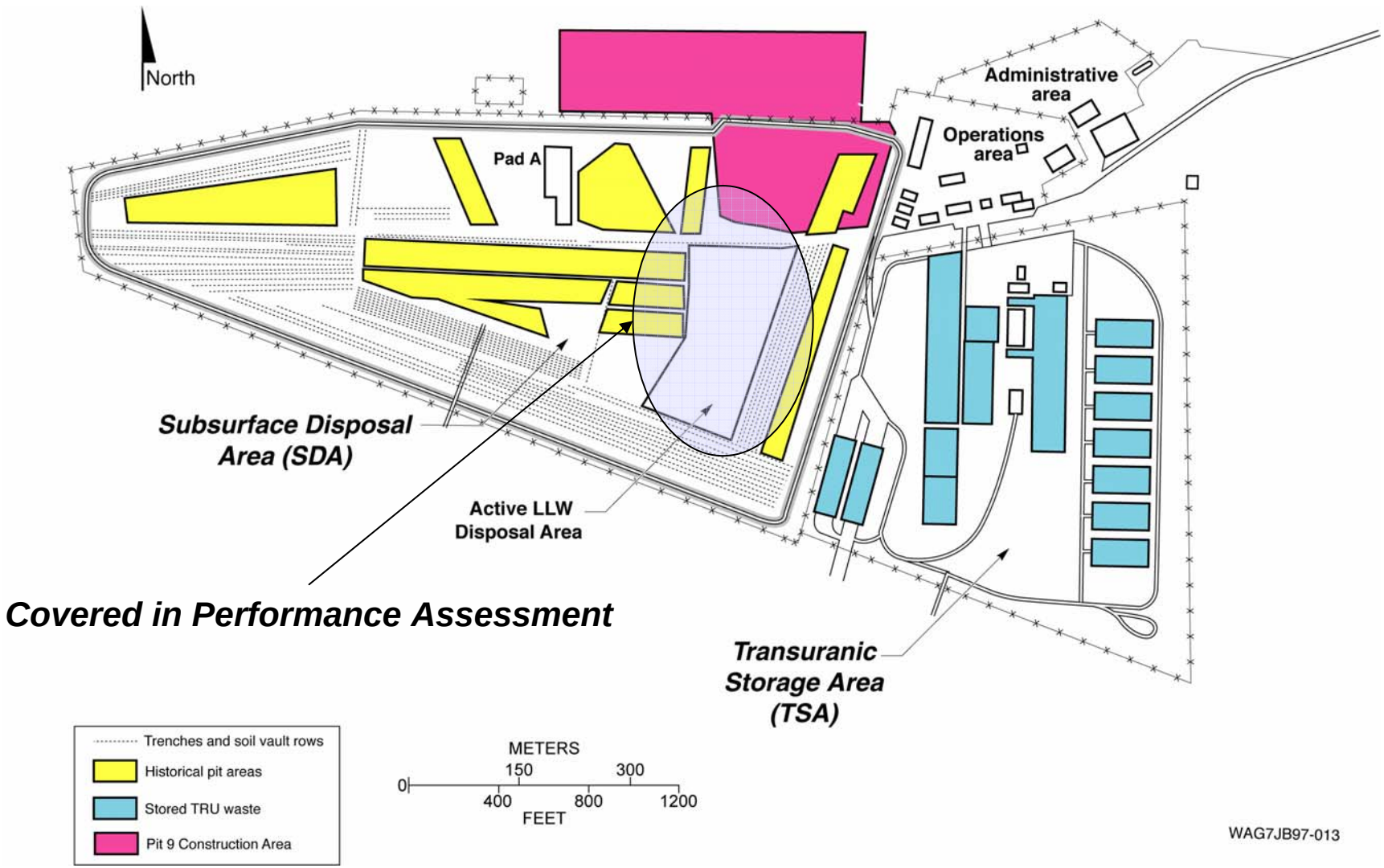
Differences Between CERCLA RIFS and PA

- Objectives
  - RIFS: Calculate risk/evaluate clean-up options
  - PA: Demonstrate compliance with DOE O 435.1
- Health Endpoints
  - RIFS: Carcinogenic Risk or Hazard Quotient and MCL
  - PA: Radiological dose and MCL
- Data
  - RIFS: Data rich in terms of radionuclide and chemical concentrations in the environment
  - PA: May be data rich in characterization data, but lacking radionuclide concentrations in environment with which to validate models
- Modeling Time Frames
  - RIFS: Retrospective and prospective
  - PA: Prospective

Case Study 1: WAG 7 RIFS and RWMC Performance Assessment

- The Radioactive Waste Management Complex (RWMC) occupies 70 ha in the southern part of the INL
- Began disposing of waste in unlined trenches in 1952
- Received TRU mixed hazardous waste from Rocky Flats
- LLW-only disposal began in 1984 in pits 17-20 and disposal of remote handled waste in vaults
- Current disposals are limited to remote handled LLW
- Disposals are slated to cease in ~2015

Radioactive Waste Management Complex



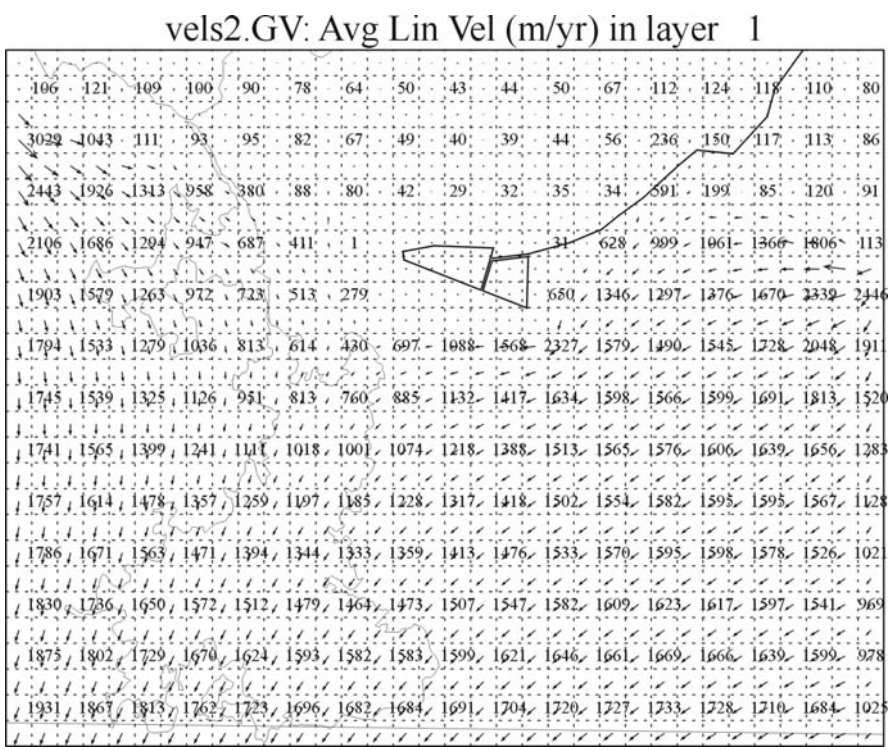
Covered in Performance Assessment

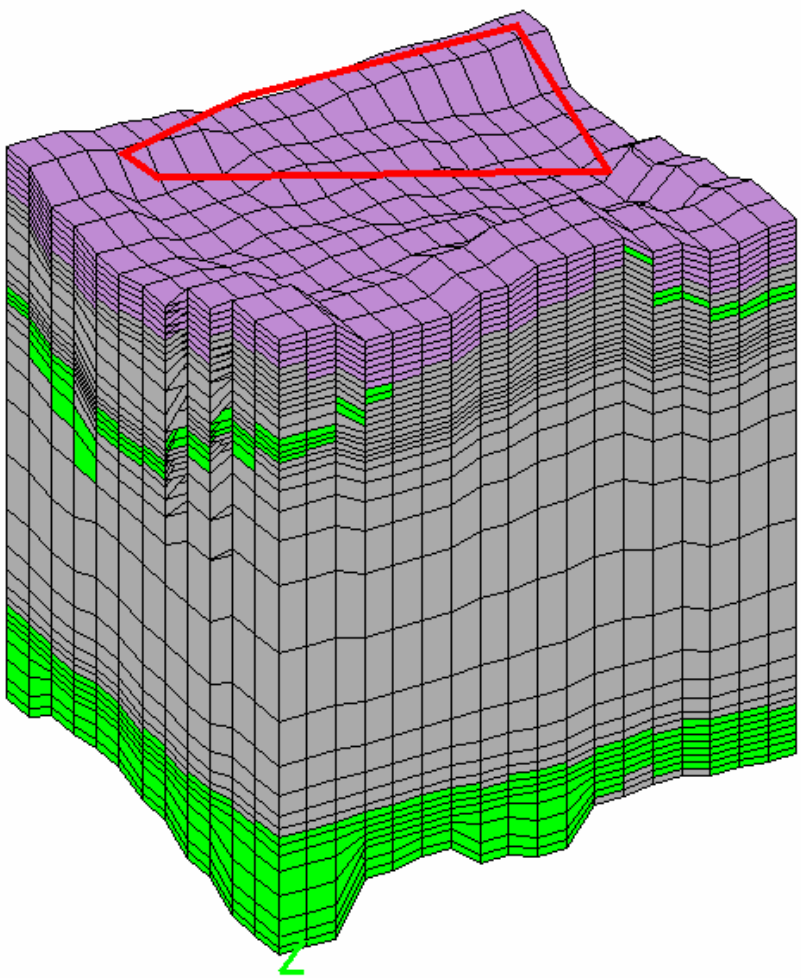
Unique Site Setting

- The Active LLW Disposal Facility is within a CERCLA clean-up area
- Mixed-waste and TRU Waste
  - Chlorinated solvents (e.g. CCl4, TCE, PCE)
  - Inorganics (Chromium, Nitrate)
  - Pu-239 from Rocky Flats
- Retrieval of TRU waste and vapor extraction of Carbon Tetrachloride is ongoing
- Release of radionuclides and chemicals during operations had to be accounted for
- Data sets include radionuclide concentrations in the vadose zone and aquifer along with characterization data

CERCLA Risk Assessment Modeling

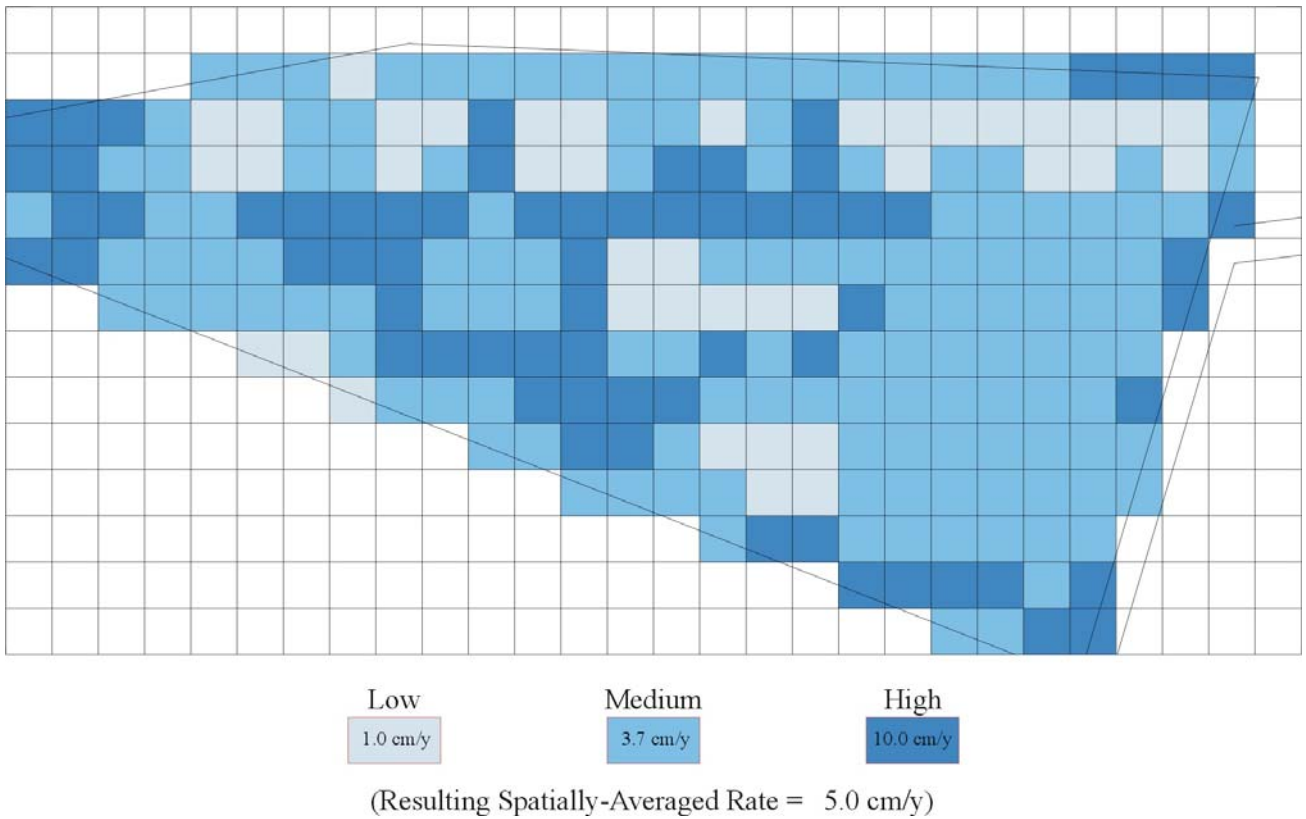
- Three-dimensional TETRAD model for flow and transport in vadose zone and aquifer





CERCLA Risk Assessment Modeling (continued)

- Spatially and temporally varying infiltration rates and waste emplacement rates

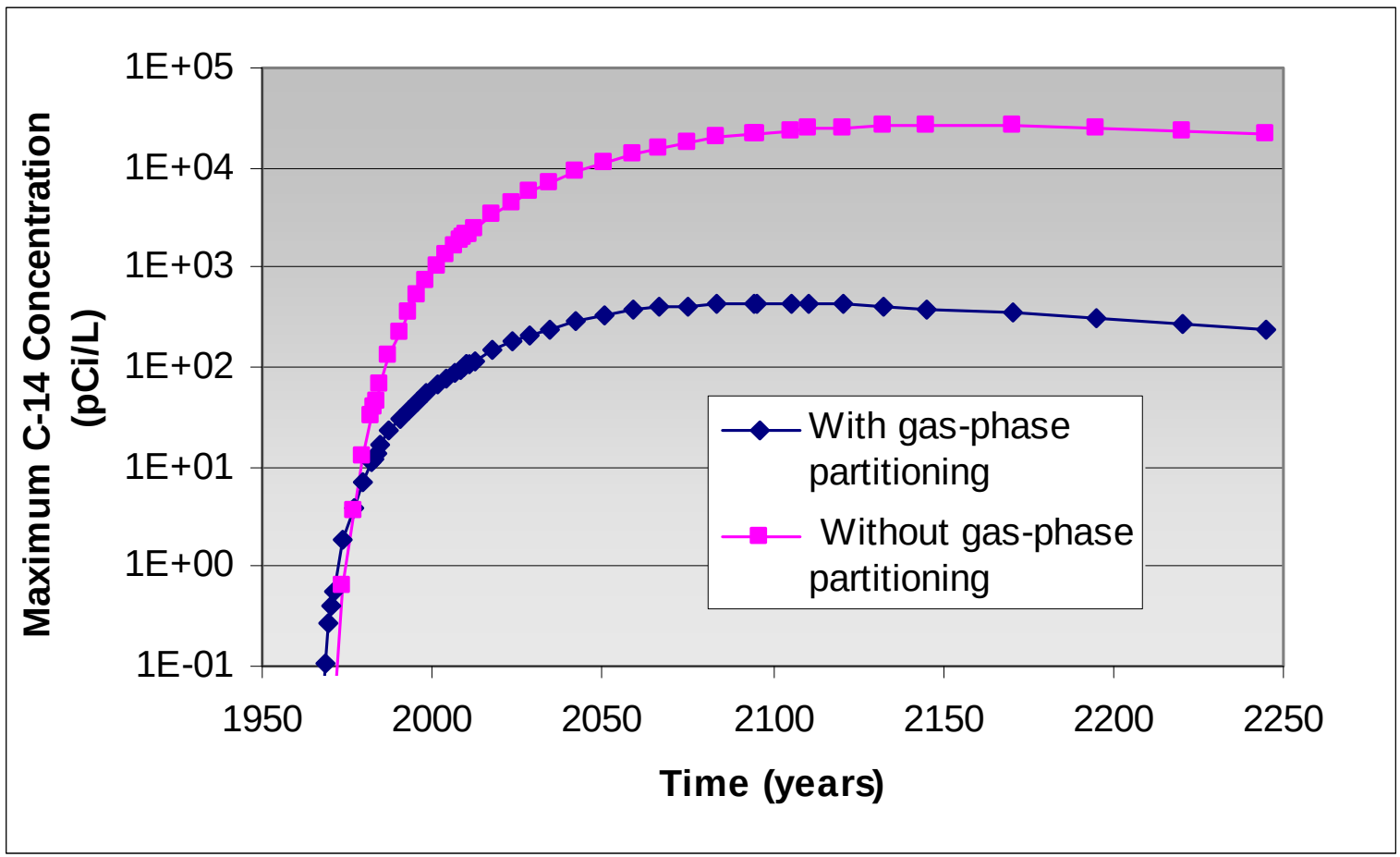


CERCLA Risk Assessment Modeling (continued)

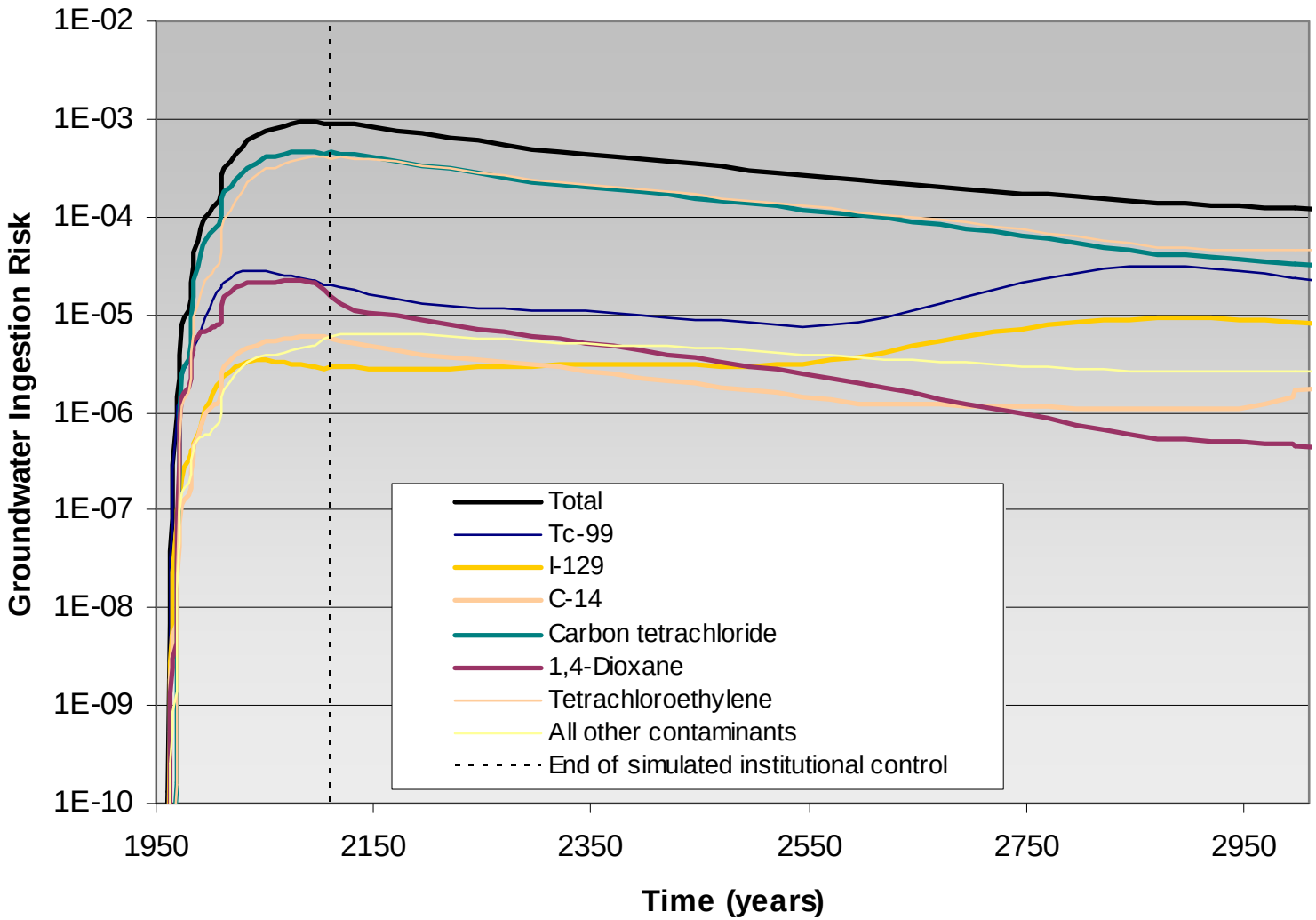
- Waste forms included activated metals, grouted waste forms, and miscellaneous trash
  - Diffusion, dissolution, solubility limited, and surface rinse release mechanisms
- DUST was used to calculate fluxes from the waste to backfilled soil
- Time-dependent waste container lifetimes
- Model calibrated to Carbon Tetrachloride vadose zone data and nitrate plumes

CERCLA Risk Assessment Modeling (continued)

- 2-phase transport for C-14



CERCLA Risk Assessment Modeling Results

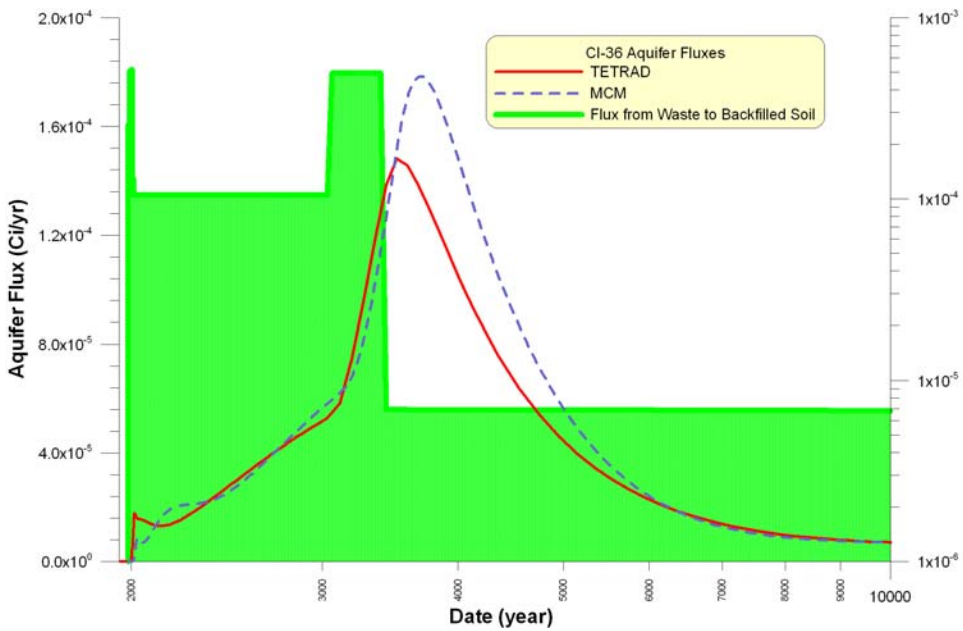


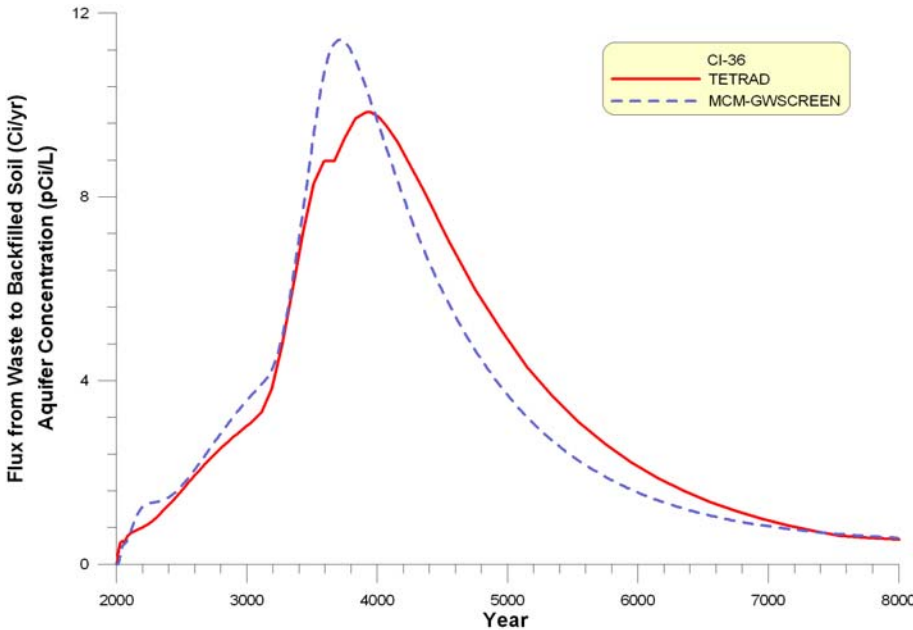
RWMC Performance Assessment

- The PA had different assessment endpoints, assumptions, and requirements
  - WAG 7 TETRAD model could not be used directly
- Source term taken from the DUST simulations
  - Source term for some radionuclides (H-3) needed to be developed
- Vadose zone and aquifer model abstracted from the TETRAD output to improve computational times
- Monte Carlo uncertainty analysis performed

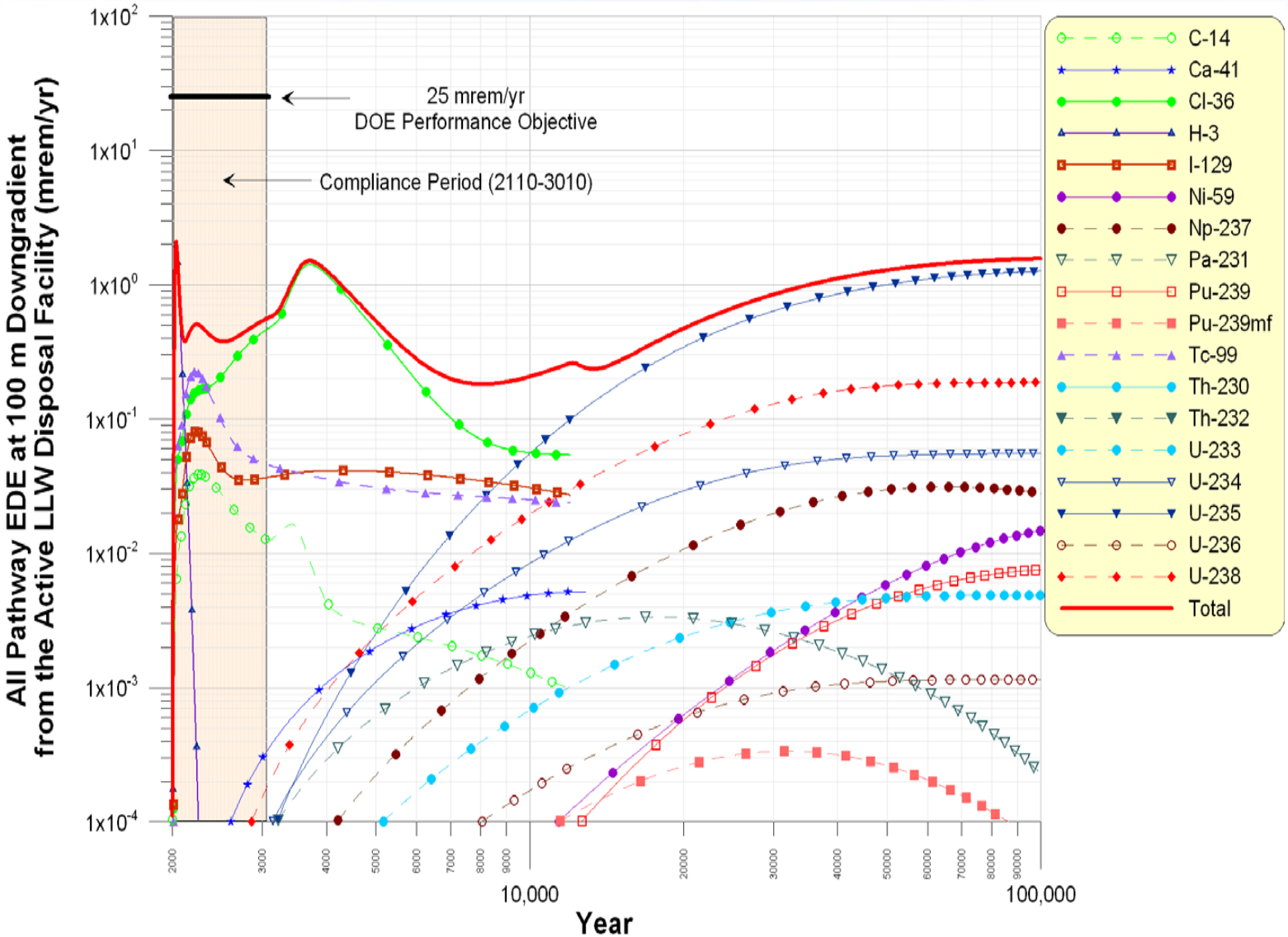
RWMC Performance Assessment (continued)

- Fits of 1-D model to TETRAD Results

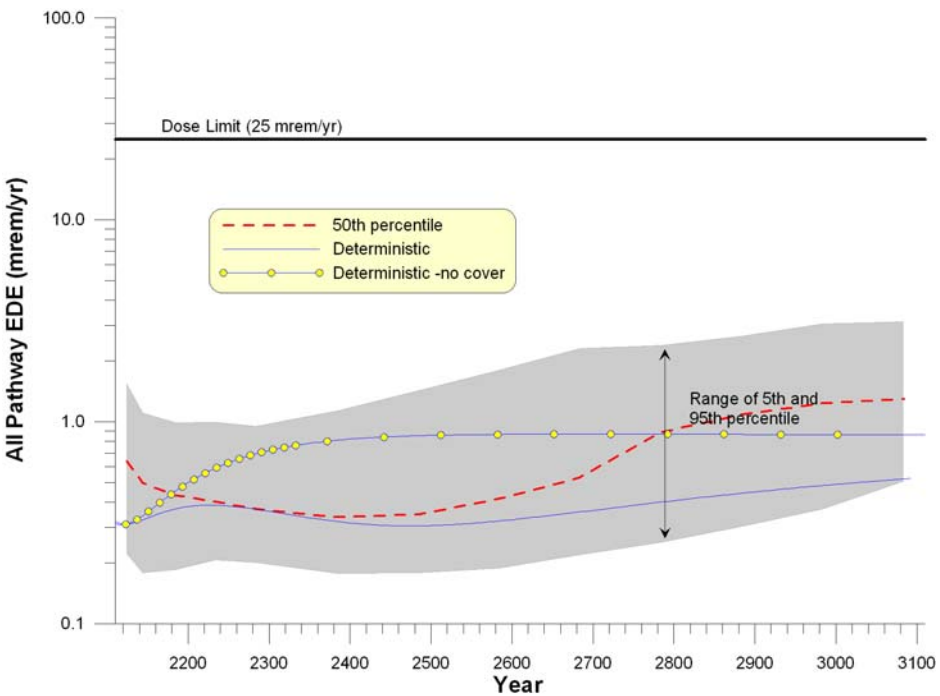


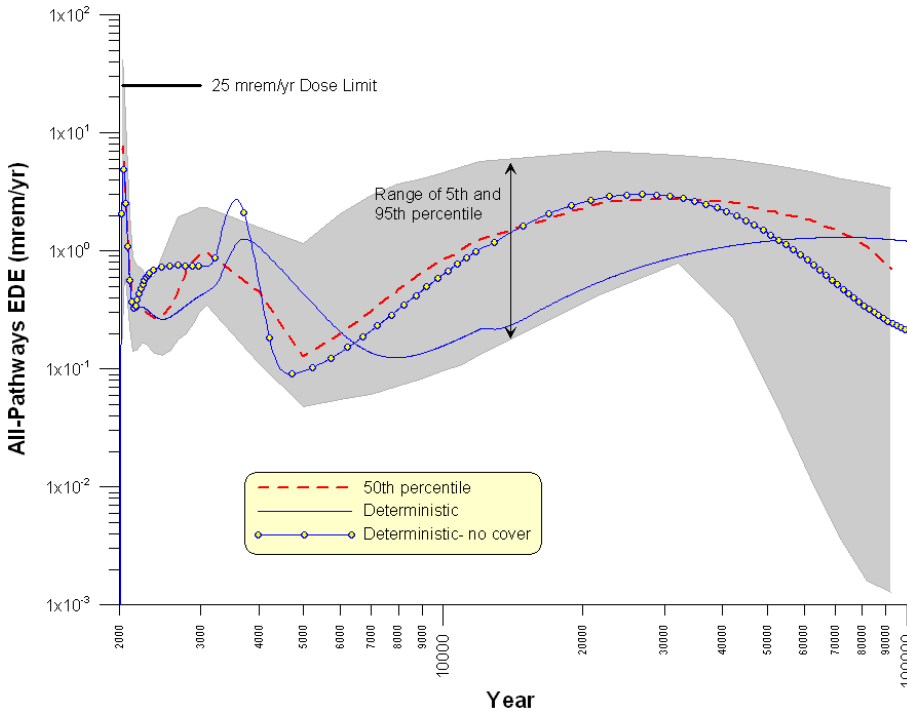


RWMC PA - Results

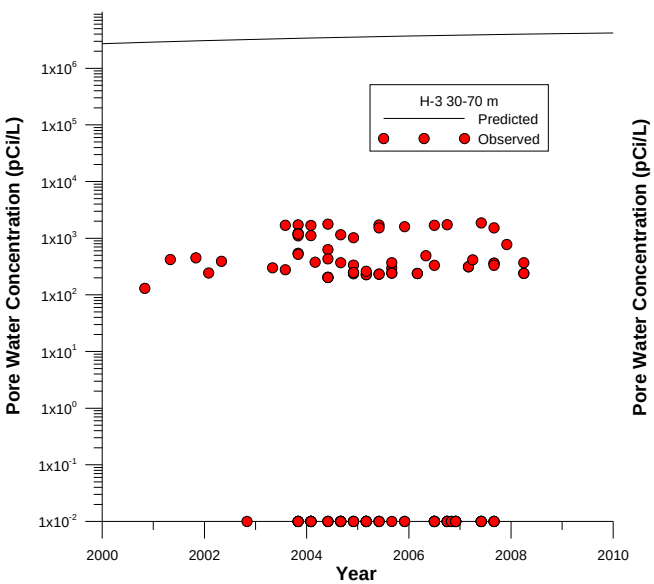


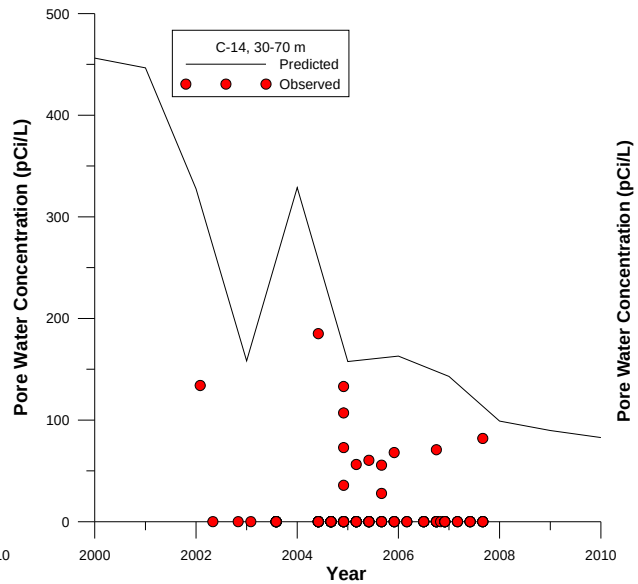
Monte Carlo Uncertainty Analysis

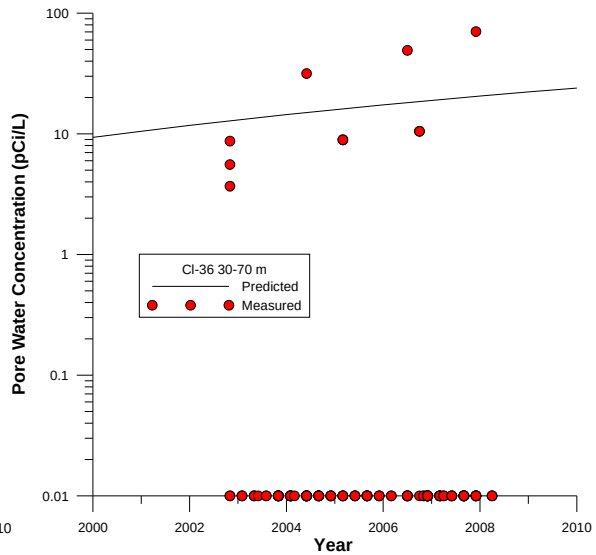




Model Predictions were Compared to Measurements to Provide Prospective





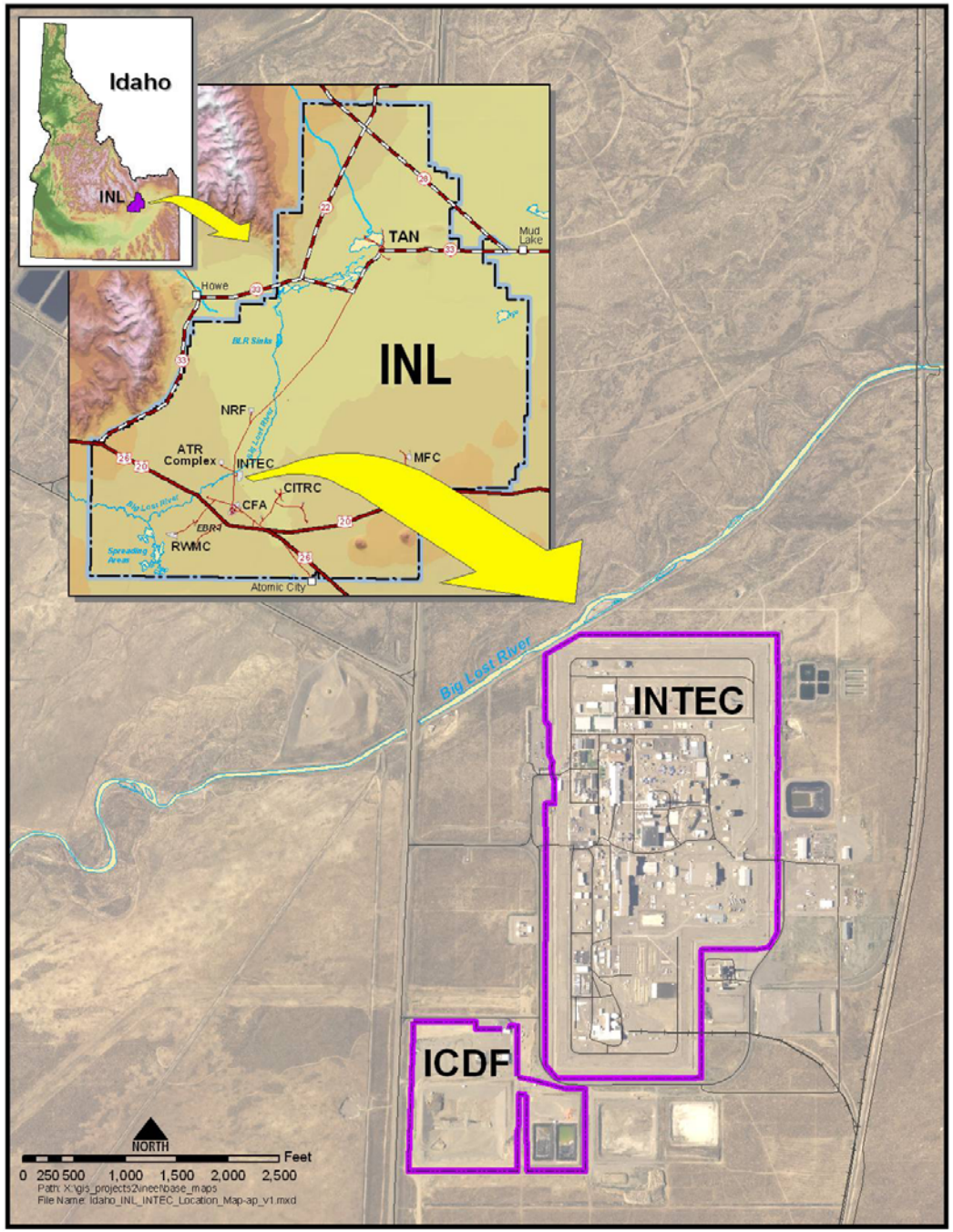


Conclusions – RWMC PA and WAG-7 RIFS

- In general, the performance assessment built upon the knowledge and understanding gained from the WAG 7 RIFS process
- However, different assessment endpoints and requirements dictated different modeling approaches be adapted
  - Cl-36 the was dose driver for the PA during the 1000-year compliance period while Tc-99 was the groundwater ingestion risk driver for the RIFS
    - Cl-36 has a high concentration ratio and results in high doses from food irrigated with contaminanted water
  - Assumptions regarding cap longevity and performance differed

Case Study 2: WAG 3 RIFS and ICDF Performance Assessment

- WAG-3 RIFS addressed Sr-90, Tc-99, I-129, and Nitrate leaks from waste transfer lines and other sources in the Idaho Nuclear Technology Engineering Center (INTEC)
- Idaho CERCLA Disposal Facility (ICDF) is a lined CERCLA disposal facility that receives contaminated soils that contain both radionuclides and chemicals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TAN
Mud Lake
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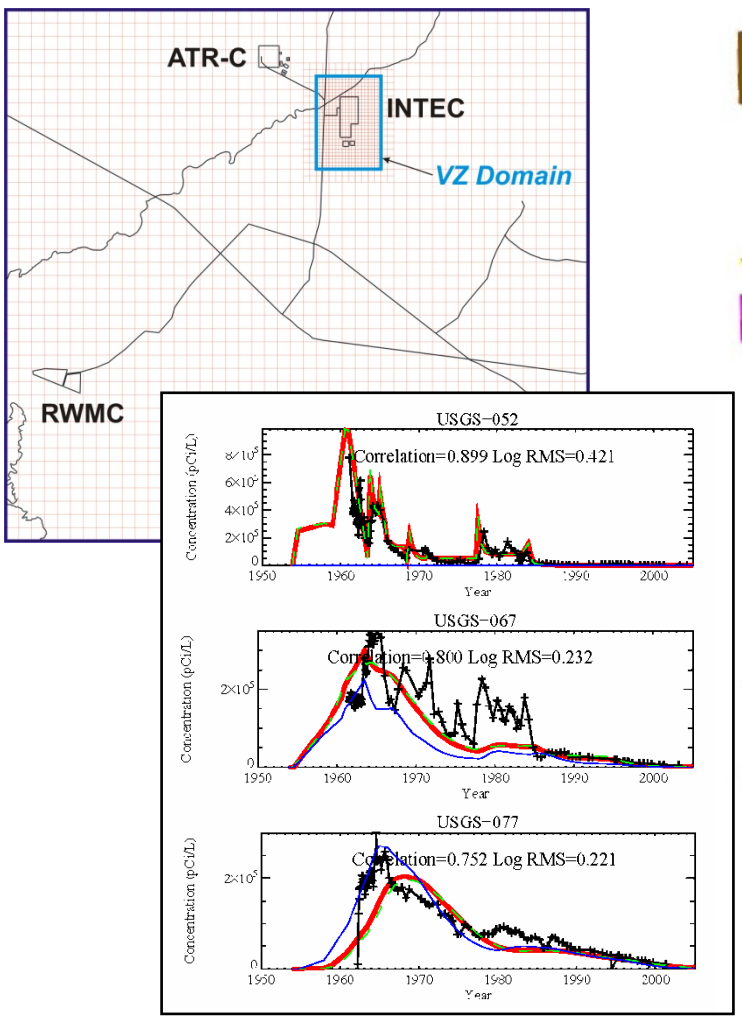
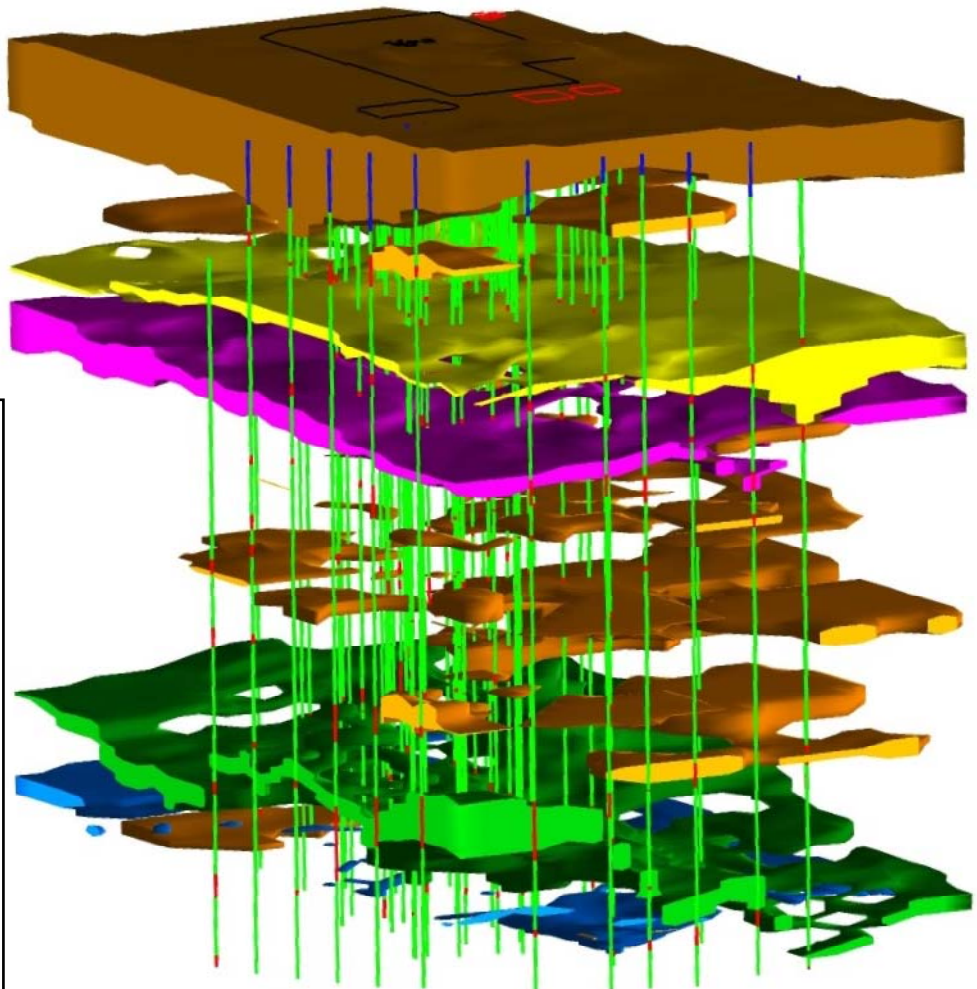
WAG 3 RIFS

- 3-D TETRAD model with geo-statistical interpretation of sedimentary interbed structure
- Geochemical modeling required CPP-31 release for competitive cation exchange with precipitation and dilution (TOUGH-REACT)
- 50-years of water level data and radionuclide concentration data in vadose zone and aquifer for model calibration

Geostatistical Analysis of Interbed/Alluvium Structure

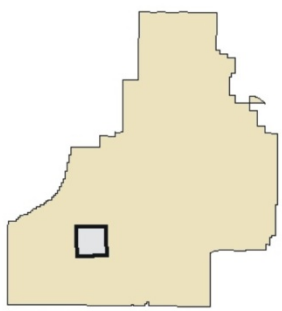




Perched Water Extent

Legend

- Active Wells
- Paved or Light-Duty Roads
- Big Lost River



Feet

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Miles

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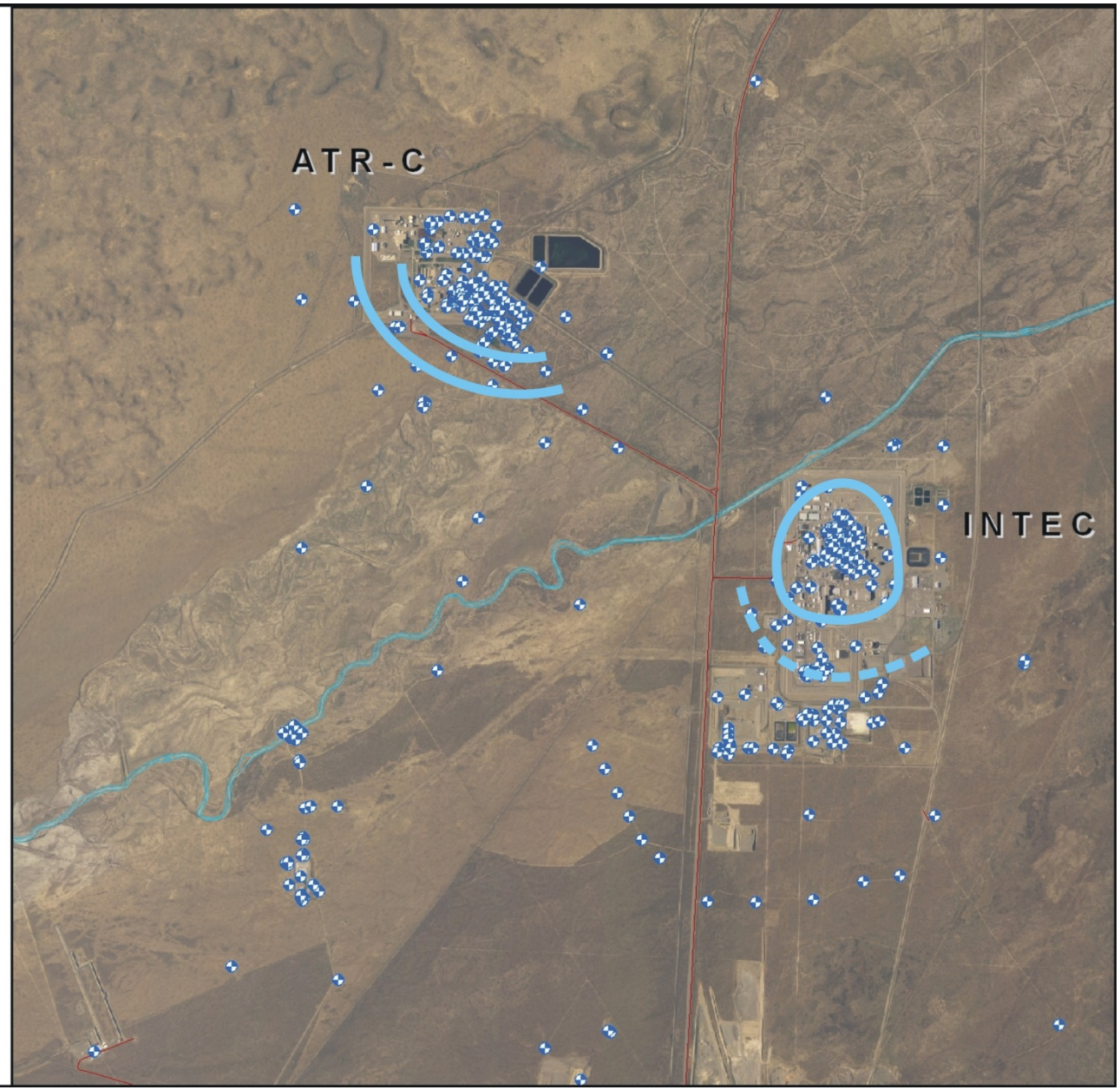


WAG 3 RIFS - Results

- Anthropogenic and natural infiltration from the Big Lost River are the driving hydrologic forces in the northern half of the INTEC facility
- Sr-90 originating from ground surface is typically not a groundwater concern in arid sites. In WAG 3, it was a primary risk driver due to:
  - Chemistry of the waste fluid and large anthropogenic water source allowed rapid migration of Sr-90 to perched water zones and the aquifer
- Other important radionuclides include Tc-99 and I-129

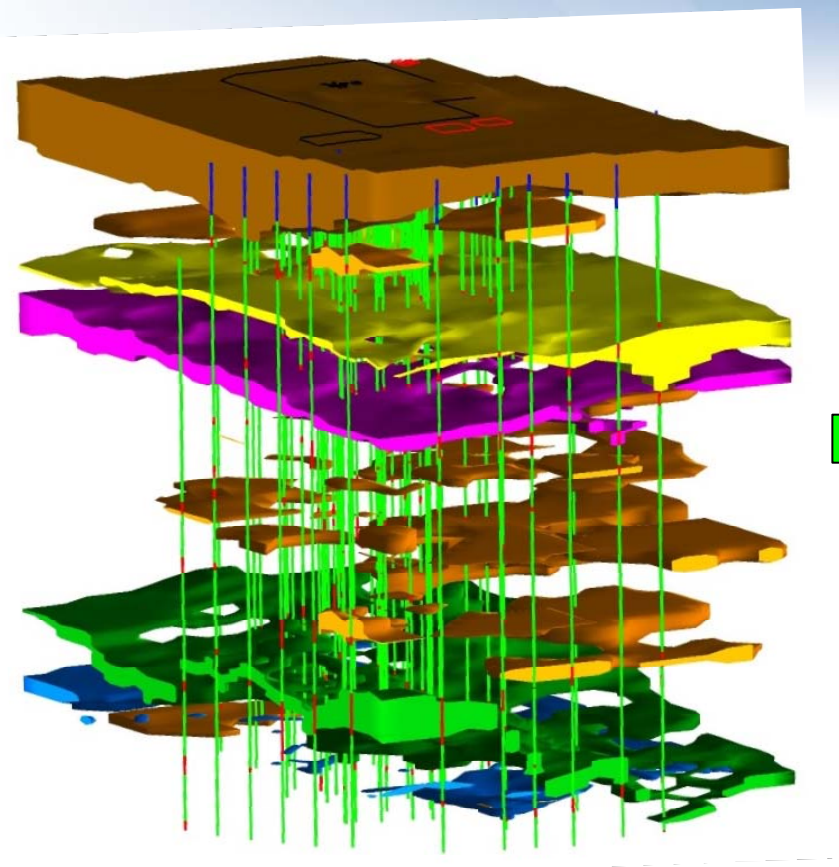
WAG 3 RIFS – Results (continued)

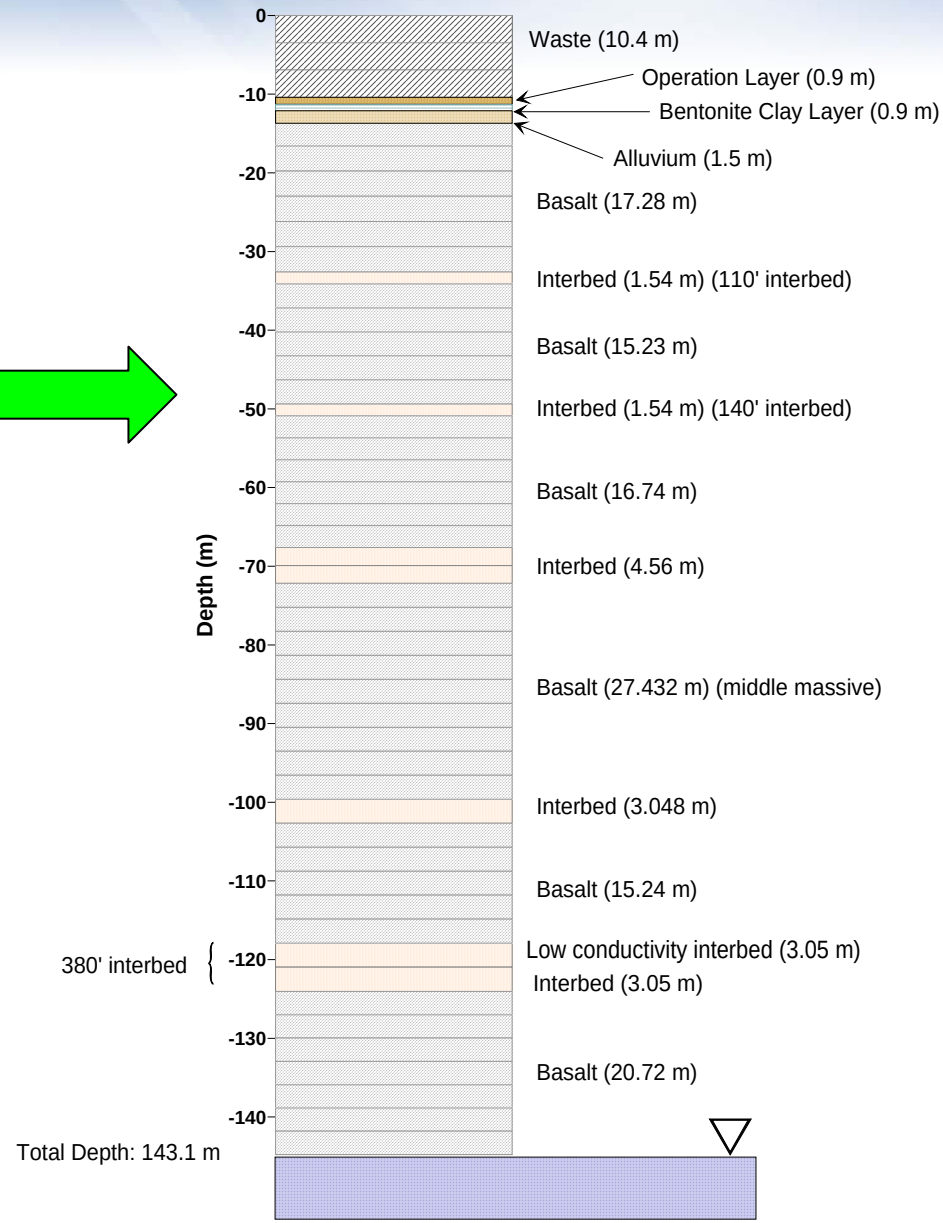
- In the absence of anthropogenic water and influence of the Big Lost River, infiltration essentially gravity-driven one-dimensional flow
  - Total vadose zone water travel time is controlled by the total thickness of contiguous sedimentary interbeds
  - Contaminant sorption is minimal in fractured basalts.
  - Contaminant travel times are controlled by total contiguous sedimentary interbed thickness, and the CEC of the interbeds
  - The WAG 3 model was abstracted into a series of response functions for use in the High Level Waste Environmental Impact Statement

ICDF PA

- Lined CERCLA facility with leachate collection system
- Source term is mainly contaminated soils and some small quantities of activated metals

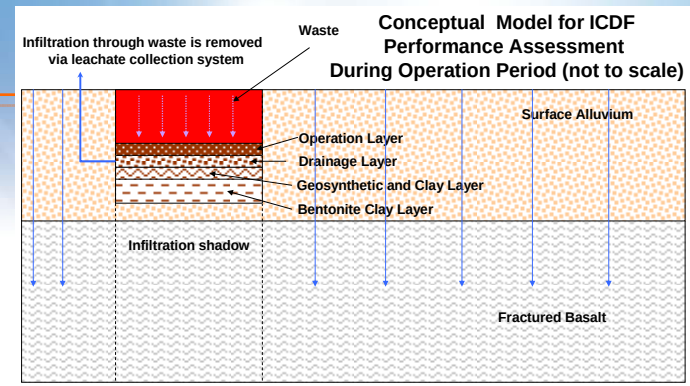
- Hydrologic conceptual model based on the findings of the WAG-3 modeling
  - In the absence of anthropogenic water and influence of the Big-Lost River, water flow is generally one-dimensional and travel time controlled by the presence of sedimentary interbeds

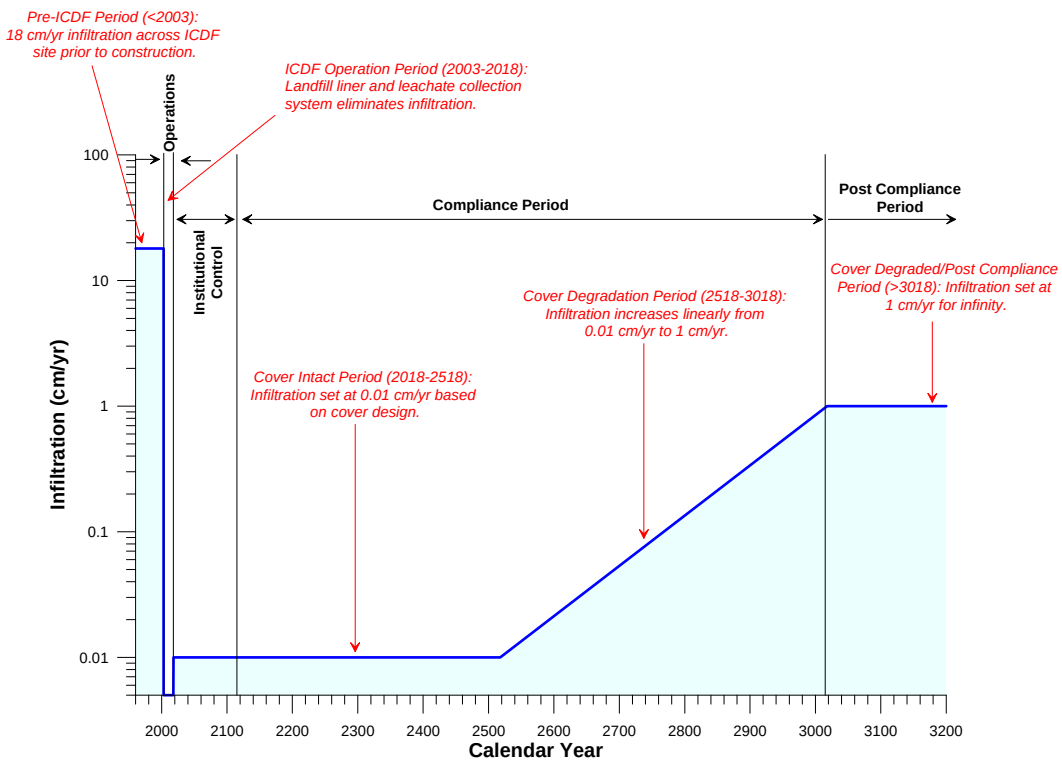


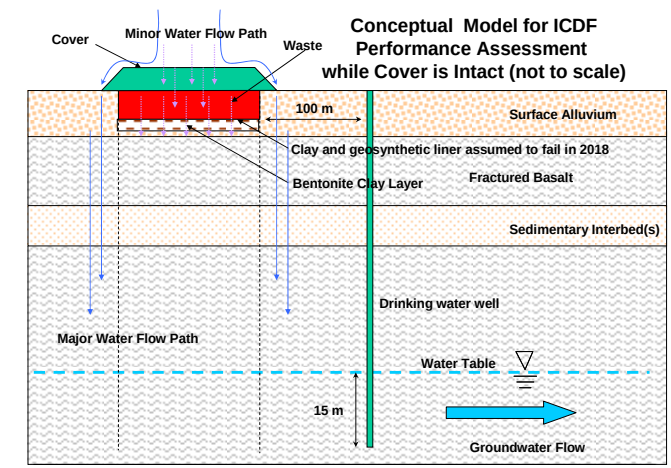


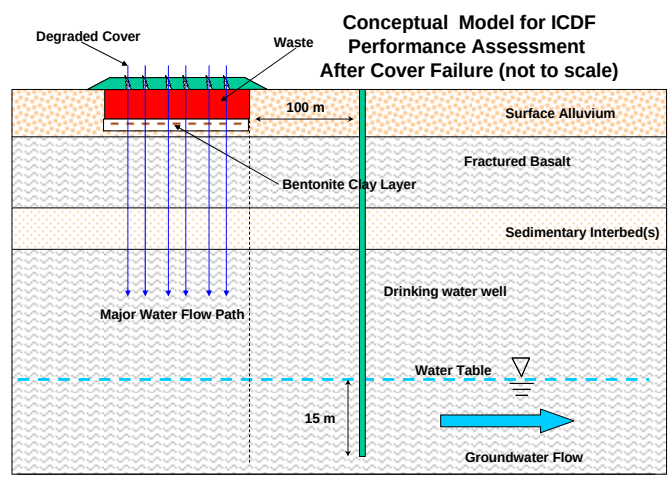
ICDF is outside the influence of the Big Lost River and has no anthropogenic water sources. Therefore, a one-dimensional model was used for the performance assessment

Conceptual model for facility performance assumes the liner fails before the engineered cover









ICDF Performance Assessment

- Revision to PA under DOE-ID review
- New model incorporates
  - Kd values from WAG 3 studies
  - transient infiltration and effects of higher infiltration before construction of the facility
  - revised inventory estimates

Conclusions of WAG 3 RIFS and ICDF PA

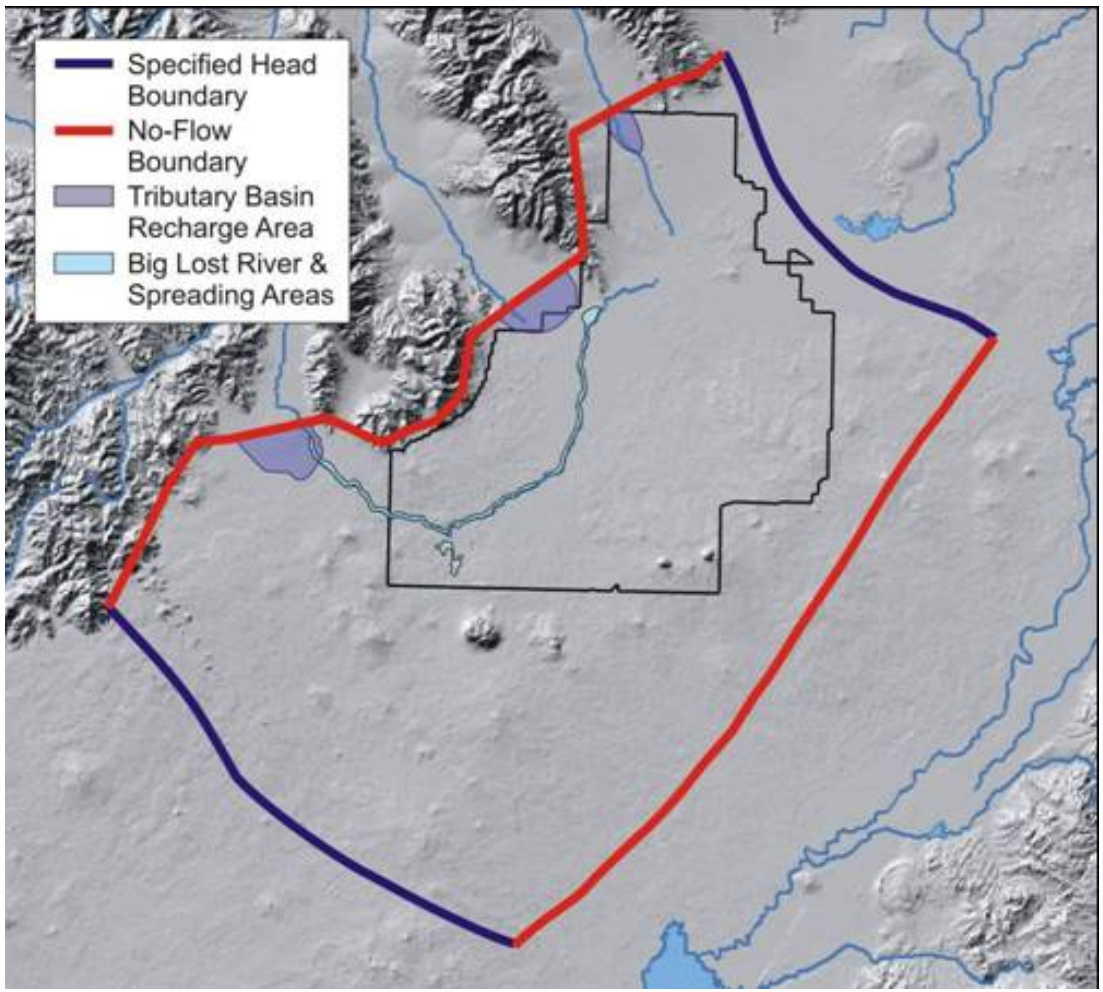
- WAG-3 was essentially a retrospective analysis with 50-years of historical calibration data
- ICDF is a prospective analysis
- WAG-3 was data-rich
  - numerous vadose zone and aquifer wells
  - Radionuclide and chemical concentrations in the vadose zone and aquifer
- Detailed modeling and analysis performed for the WAG 3 RIFS supported modeling assumptions for the ICDF Performance Assessment

Case Study 3: WAG 10 Groundwater Model and RWMC Composite Analysis

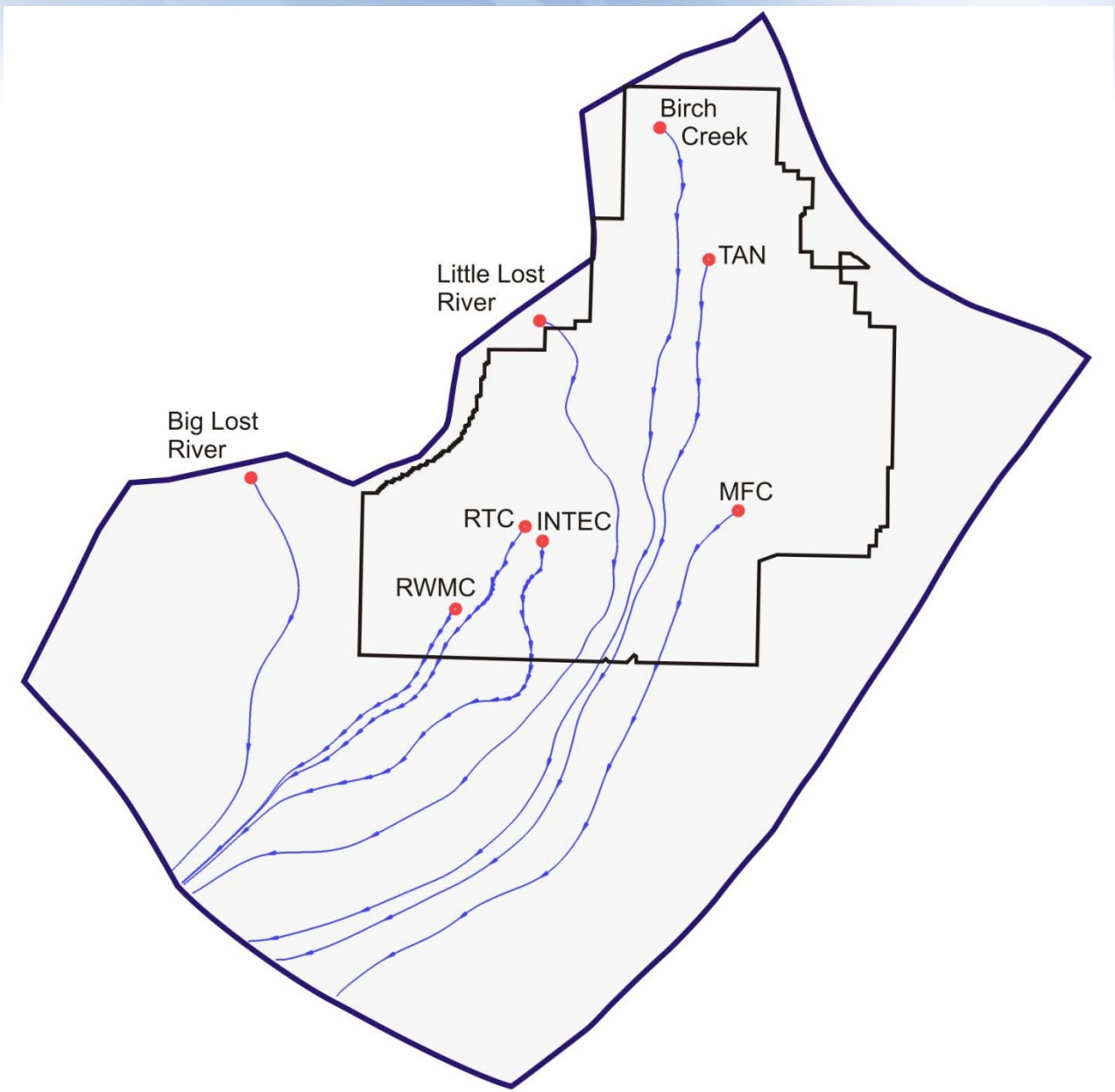
- WAG 10 includes miscellaneous sites and the Snake River Plain Aquifer (SRPA)
- The SRPA contains plumes of H-3, I-129, Tc-99 and Carbon Tetrachloride from past operations
- The WAG 10 RIFS evaluated risk from existing contaminant plumes in the SRPA and future releases from facilities at the INL
- The WAG 10 groundwater model can be used for composite analysis

WAG 10 Groundwater Model Domain

- 3-D MODFLOW/MT3D model encompassing the INL and surrounding area
- Calibrated to water levels and INTEC tritium plume

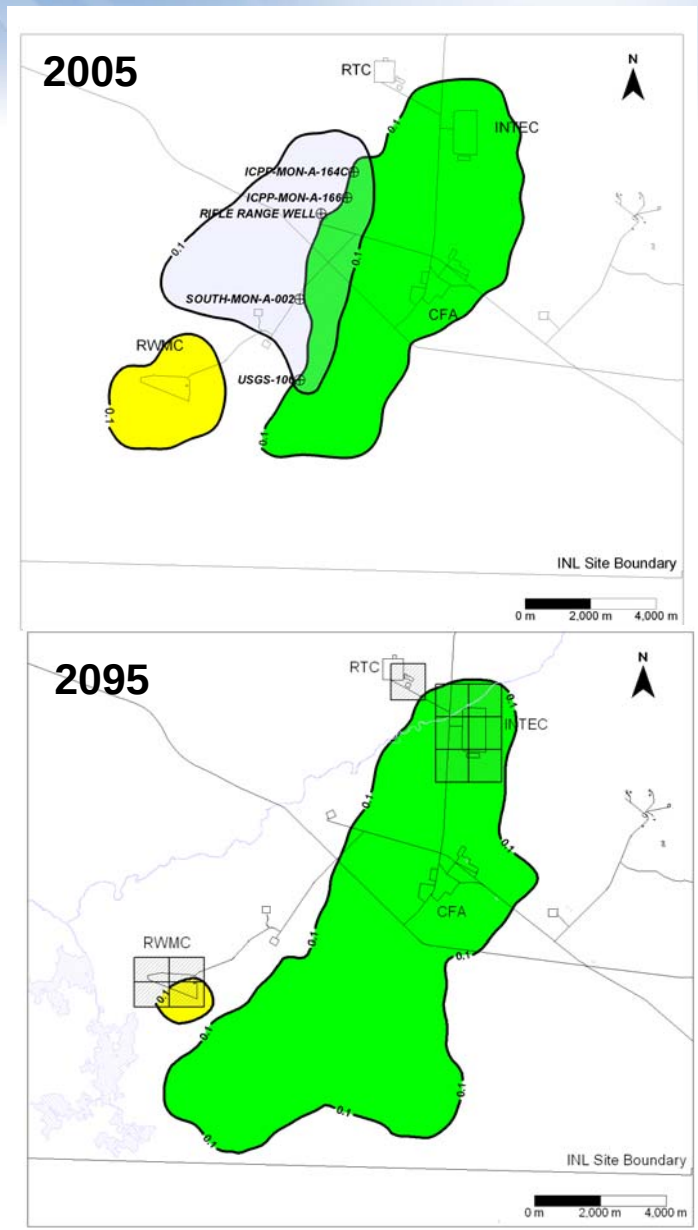


Modeled Flow Paths



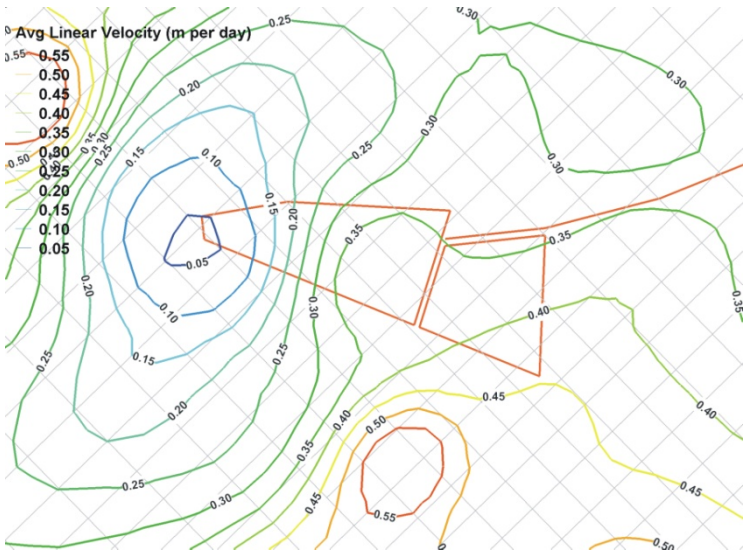
Model Abstraction – Response Surface Model

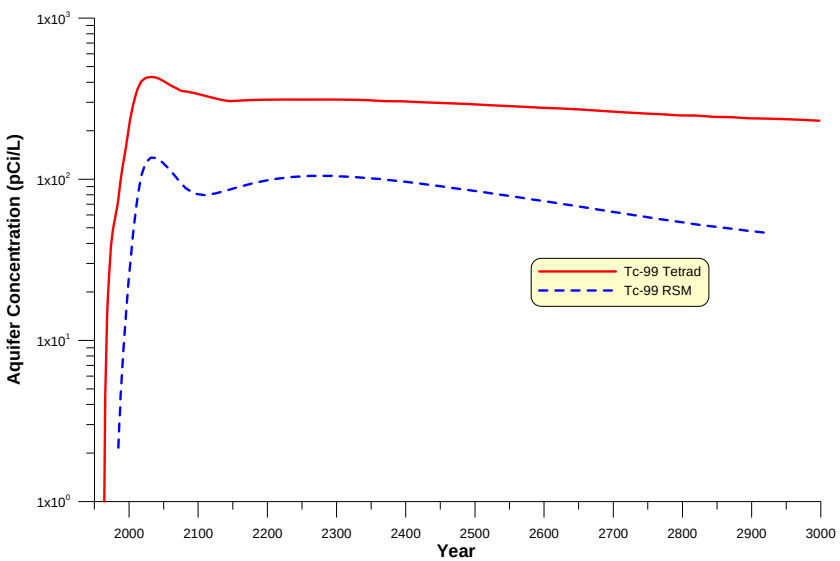
- Long run times and numerous contaminants required development of a Response Surface Model for the RIFS production runs
- The RSM was later used for the RWMC composite analysis and compared to TETRAD simulations



WAG 10 Model and WAG 7 TETRAD Model

- The RWMC had a region of low permeability in the aquifer directly below the facility
- This region was included in WAG 10 model, but did not have the spatial resolution or extent compared to the WAG 7 TETRAD model
- Consequently, predicted near-field concentrations with the WAG-10 model were substantially lower compared to TETRAD.





Conclusions: WAG 10 Model and RWMC CA

- The WAG 10 model was useful for defining sites that may potentially interact with one another
- Spatial resolution in the near-field may limit the overall effectiveness of the WAG 10 model.

Conclusions and Summary

- Objectives and assessment questions are different for CERCLA risk assessment and LLW performance assessment and therefore may require different modeling approaches
  - CERCLA modeling is both retrospective and prospective
  - PA modeling is essentially prospective
- Historical monitoring data has allowed for model calibration to existing contamination in the environment for CERCLA risk assessments
- For prospective LLW performance assessment, calibration and/or validation of the radionuclide transport model is not possible
- At the INL, the LLW performance assessments have benefited from the detailed characterization and modeling performed for CERCLA risk assessments

Suggestions and Considerations for ASCEM

- Consider the objective and assessment question of a performance assessment in contrast with the objectives of an RIFS
- A complex model will require substantially more characterization data to parameterize. Is it practical to collect these data on the scale necessary to parameterize the model?
- Greater model complexity does not always result in a better model, and can even result in a worse model
- In both RIFS and Performance Assessment, the source term drives the problem.
  - No source – No problem!
  - Suggest more effort be placed on understanding and quantifying source releases
- Models do not, and should not, make decisions. Humans make decisions
  - Models should provide knowledge and understanding to decision makers so that they can make informed decisions.