Integrating Monitoring with Performance Assessment

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Performance Assessment

- Performance assessments are used to demonstrate compliance with dose criteria
- Performance assessments may adopt 'conservatism' in order to manage uncertainty
- In theory, actual risk and the performance assessment compliance risk estimate would be identical
- In practice, the actual risk is unknown and the compliance risk estimate likely represents a substantial deviation

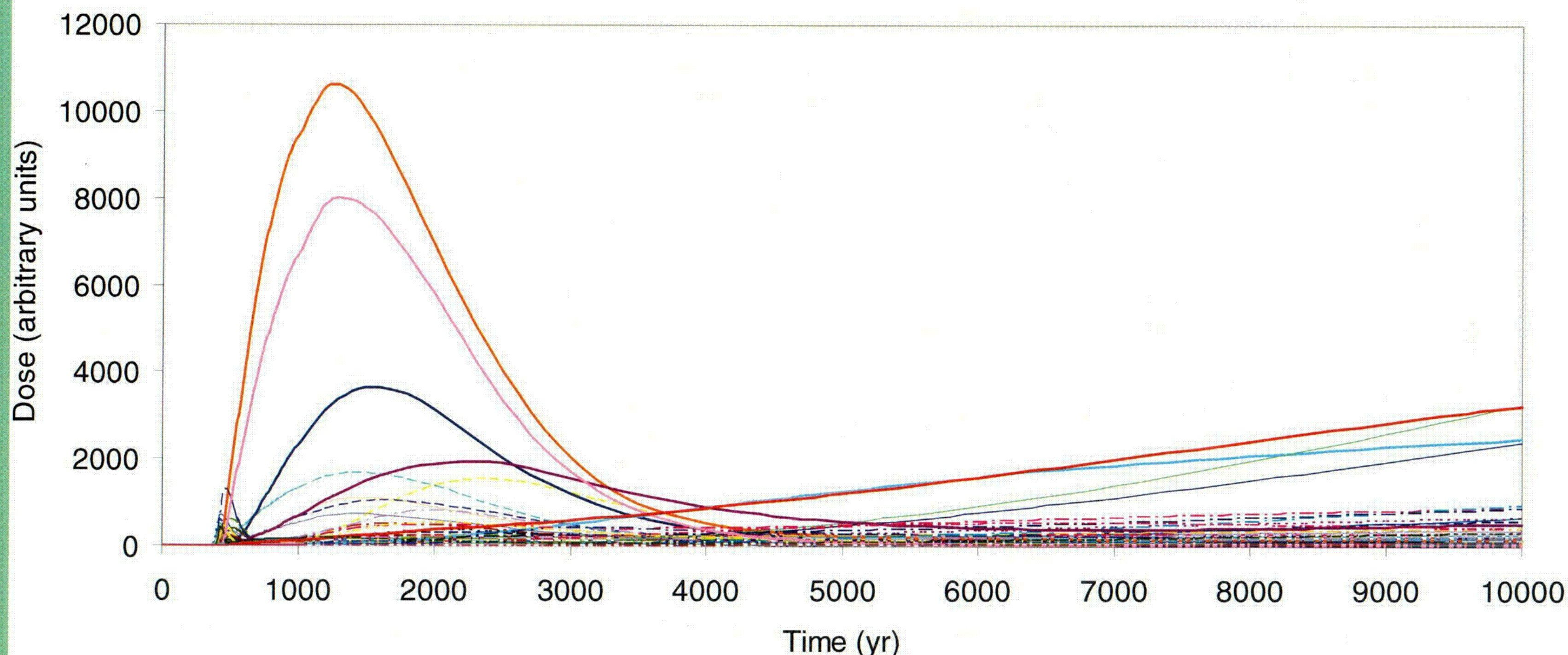
Model Support

- Performance assessment results are only as good as the support provided for the models
- Performance assessments can not be validated in the traditional sense
- Building confidence in performance assessment results can take a variety of approaches
- Model support is essential to regulatory decision making

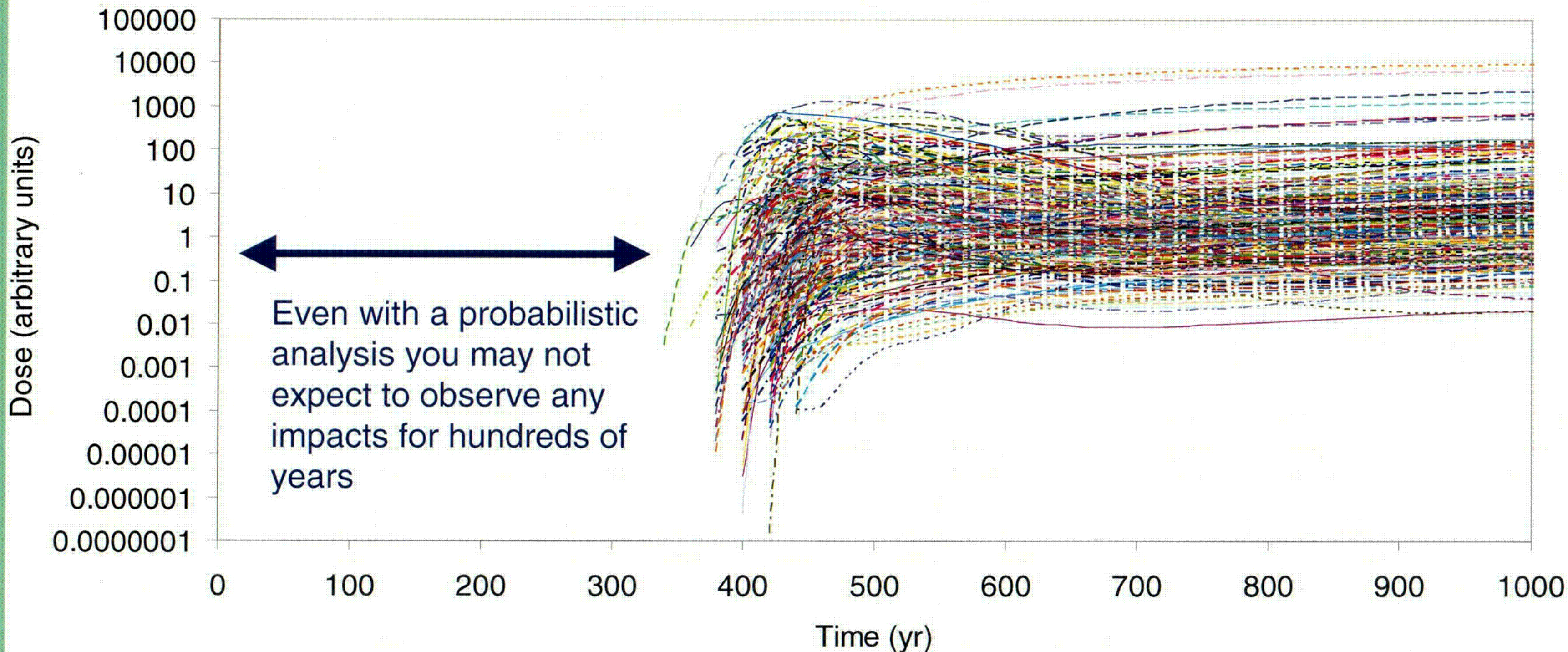
Monitoring

- Traditionally, monitoring is used to observe the concentration of contaminants in environmental media
- Monitoring systems are rarely developed to corroborate the performance assessment conceptual models
- Monitoring of engineered systems for waste issues has been limited and sporadic, but when done extensively has yielded extremely valuable observations

Monitoring and PA: The Problem



Monitoring and PA: The Problem

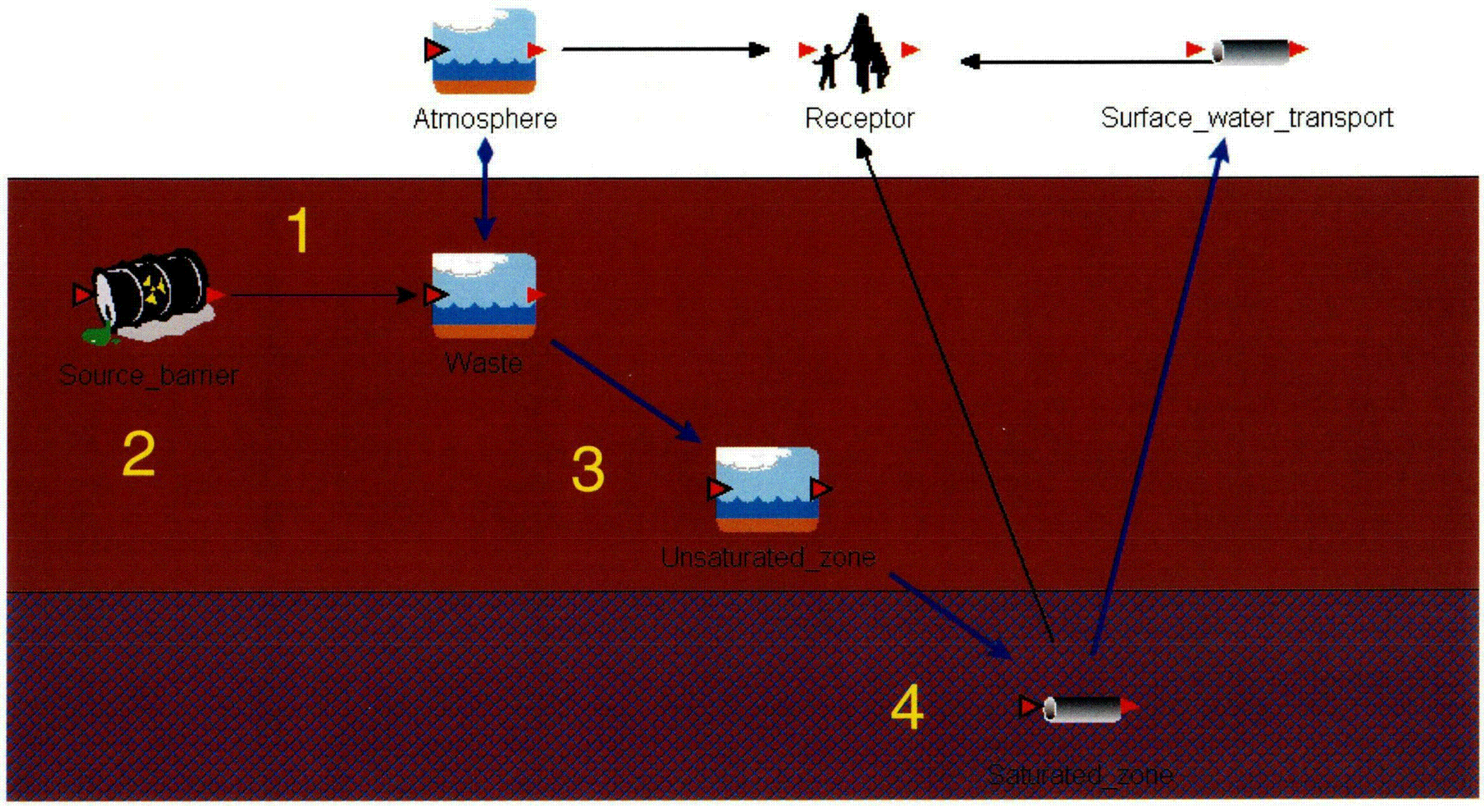


- A very distant future NRC regulator (Dick Codell's great^13-grandson) would be the first person to observe impacts

Performance Indicators

- Compliance monitoring (i.e., traditional environmental monitoring), should be supplemented with monitoring of performance indicators
- Indicators of natural and engineered system performance should be identified considering the performance assessment estimates
- Performance indicators are observables that are precursors of eventual dose impacts
- Successful use of performance indicators would be to confirm the conceptual representation of the system
- In most cases it is expected that observed environmental concentrations will not compare well with performance assessment estimates

Performance Indicators - Examples



Performance Indicators - Examples

- For points 1 through 4 on the previous slide, use of conservative tracers and dyes may go a long way to confirming conceptual models of environmental transport
- Different dyes and conservative tracers could be deliberately introduced into various regions of the system during construction, which could be used to confirm the hydrologic conceptual model
- Moisture content may be a gross indicator of the saturation state of the system, but may not give sufficient information about moisture flow rates (e.g., due to discrete features which may dictate transport)

Performance Indicators - Barriers

- Performance indicators of engineered barriers would be very specific to the barrier type and functionality
- Example – bulk cementitious barrier performance may be evaluated by analyzing alkalinity in water near the barrier and the in situ stress of the barrier
- Small representative samples of barrier materials may be installed in the same environment of the barrier and retrieved at different intervals to verify degradation rates and processes.

Monitoring

- Caution is needed to ensure the monitoring system does not introduce pathways for water or contaminants
- Caution is also needed in interpreting the results of monitoring, which will likely be uncertain and possibly complex
- Confirmation should be based on verifying the conceptual representation of the system, and not on matching numbers

Conclusions

- Monitoring plans should have an objective of supplying confirmation of performance assessment conceptual models, in addition to satisfying regulatory requirements of characterizing environmental concentrations
- Monitoring plans need to recognize the spatial and temporal challenges
- Monitoring should be designed into the system (e.g., conservative species and dyes)
- Confirmation of conceptual models is different from matching performance assessment model estimates with observed impacts

Contaminant Transport Considerations at the Hanford Site

Mike Fayer
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Presented at the ACNW WG Meeting

September 19-20, 2006

Rockville, MD

Battelle

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Outline

- Recommendations
- Generic Transport Considerations
- Site-Specific Examples
- *Summary*

Contaminant transport in the subsurface environment is governed by a complex relationship of site- and contaminant-specific features, events, and processes. Recognizing and addressing that complexity is key to adequately understanding, monitoring, and predicting contaminant transport.

Recommendations

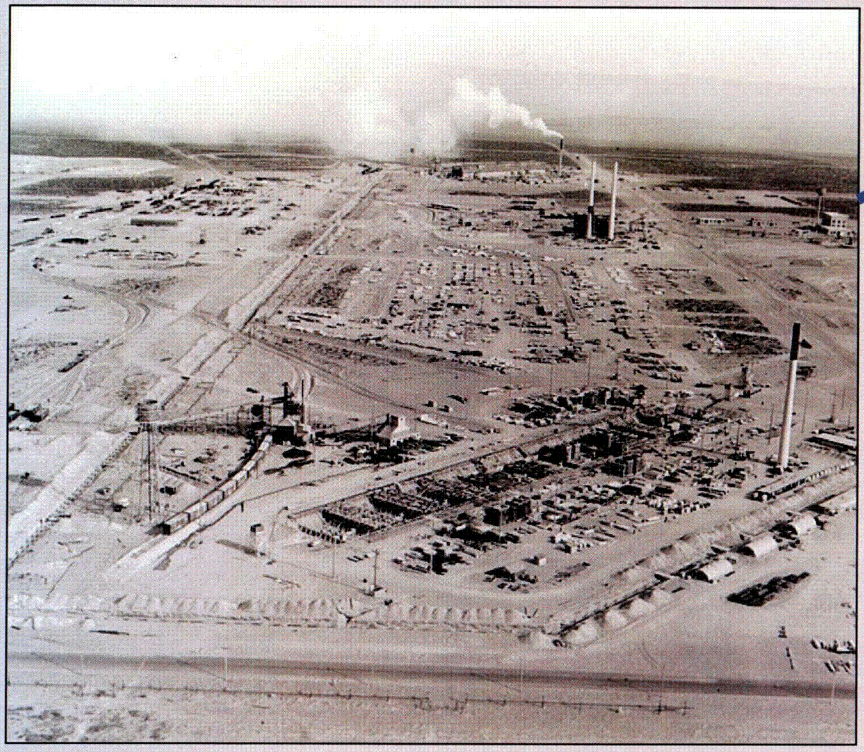
- Expand Definition of Compliance Monitoring and rename Compliance Assessment
  - Regulatory
  - Environment, Safety, &Health (ES&H)
  - Performance
- Assign Compliance Assessment Owner
  - Monitoring
  - Modeling
- Conduct Regular External Peer Reviews
- Include Entry Portals for New Data, Science, Legal, and Public Interests

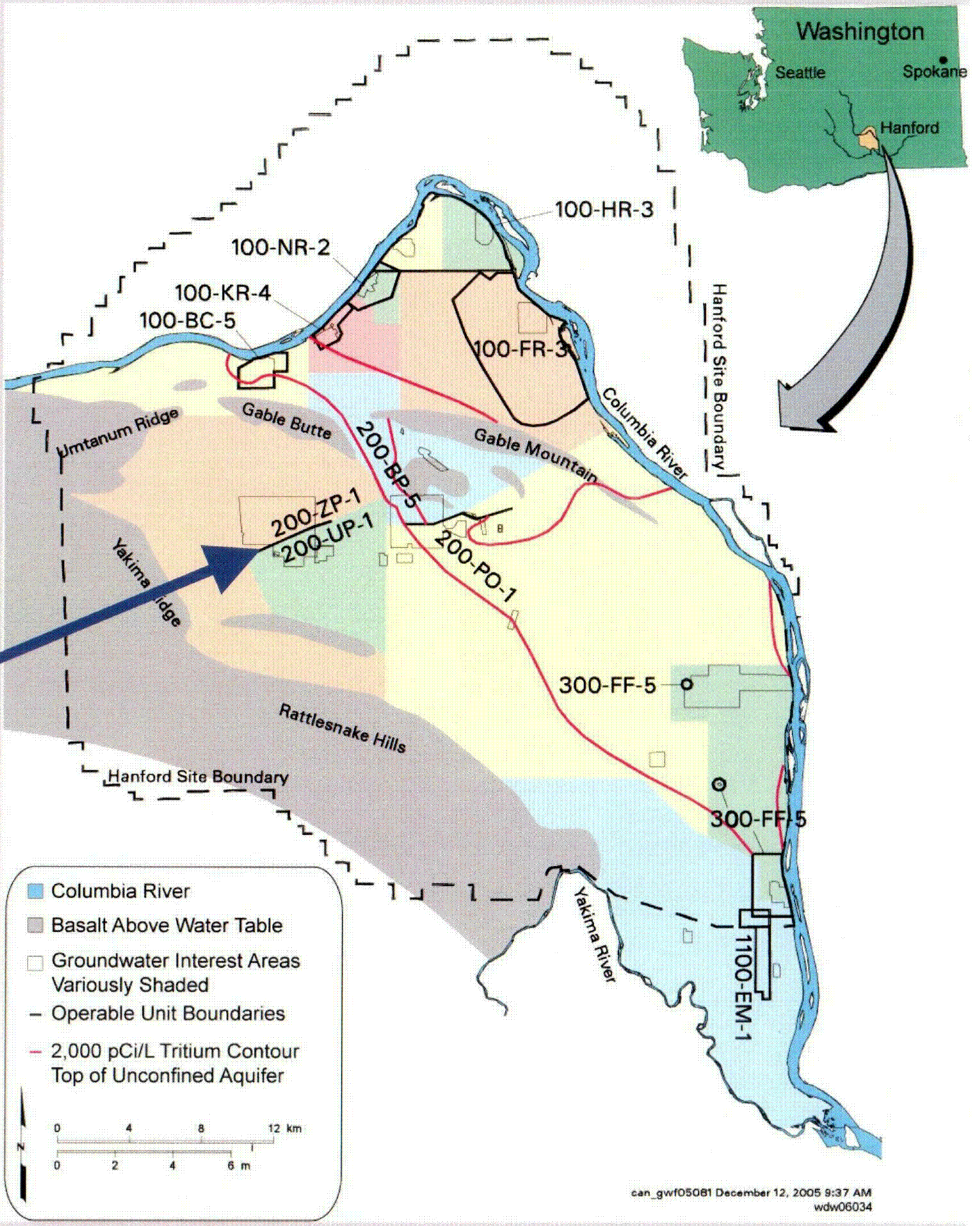
Some Generic Transport Considerations

- Gas, liquid, aqueous solution, solid?
- Dilute or concentrated?
- Pure or mixed?
- Diffusion or advection dominated?
- Uniform, homogenous, and isotropic geologic media – or not?
- Constant or variable flow conditions?
- Constant or variable transport conditions?
- Future conditions within baseline conditions?

Hanford Site

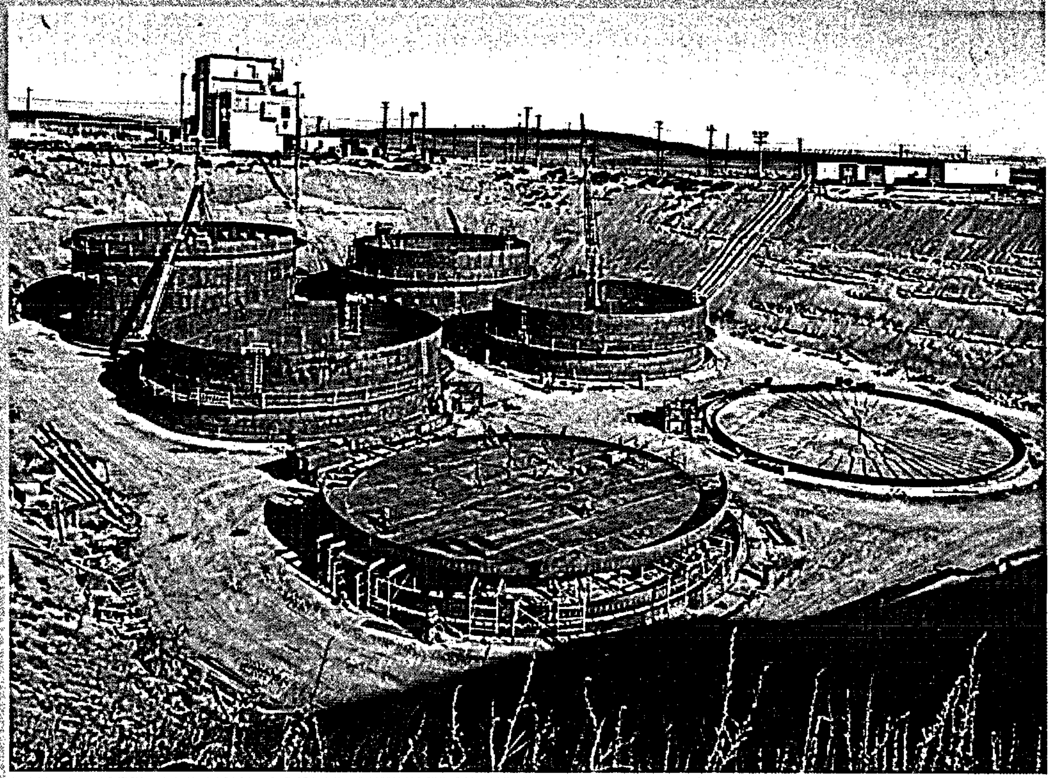
- Construction started in 1943
- 1517 km^2 (586 mi^2)
- Ceased production 1987
- Remediation is current mission





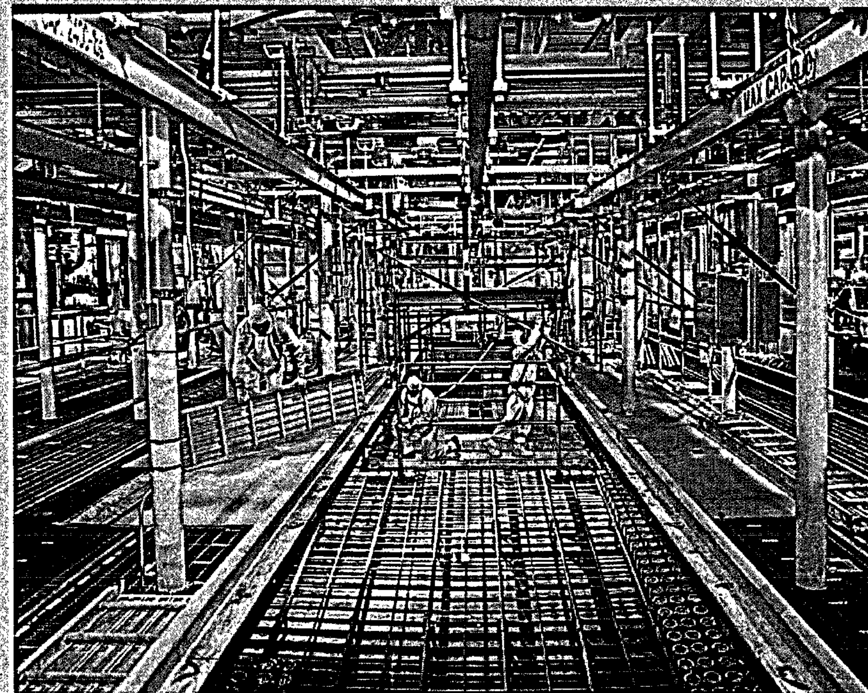
Example 1: Insufficient Early Characterization

- Fluid properties different than water
- pH as high as 14
- Ionic concentrations > 5 molar
- Dissolution/ precipitation
- Unknown leak points
- Poorly known geology beneath



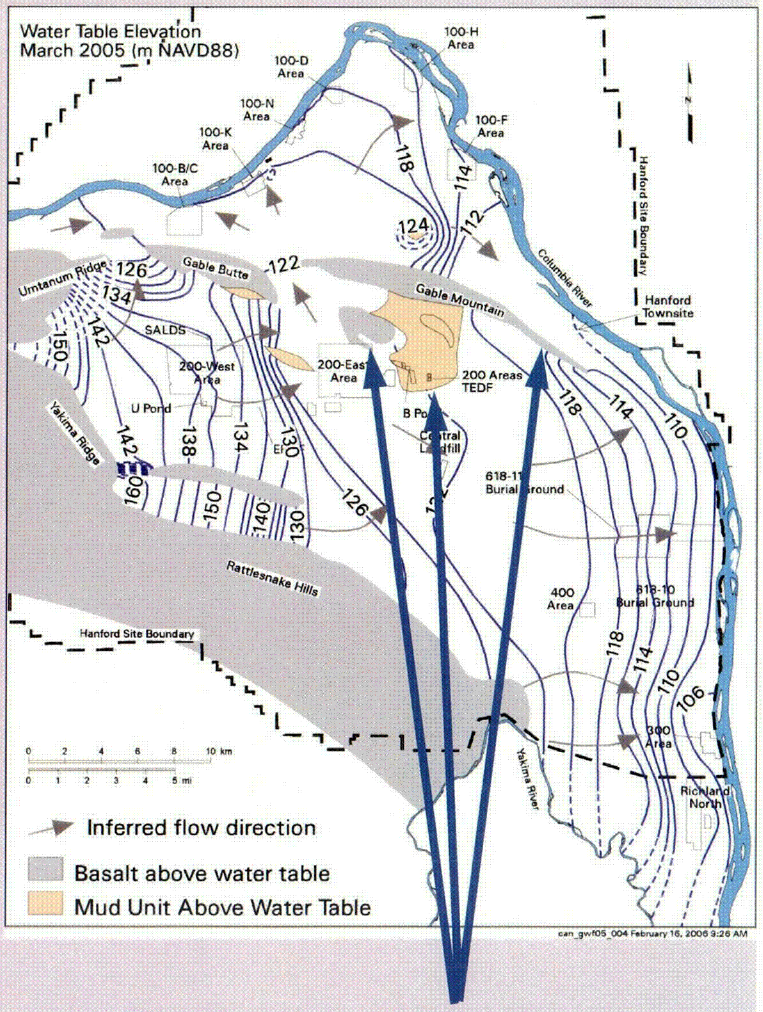
Example 2: Untested Monitoring System

- Groundwater contamination beneath K basins suggested leaking pool
- Leak detection system did not detect leak
- No record that leak detection system ever tested to confirm functionality



Example 3: Changing Flow Conditions

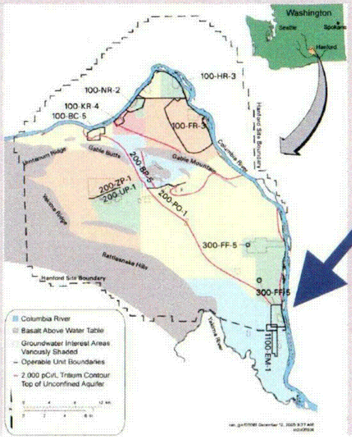
- Groundwater rising 1944 to 1979
- Boreholes screened in upper 5 m of aquifer
- Groundwater falling 1979 to present
- Net result:
  - Loss of groundwater monitoring as wells go dry
  - Water table dropping below basalt and mud tops in some locations, altering flow rates and directions
  - Some borehole locations no longer provide meaningful results



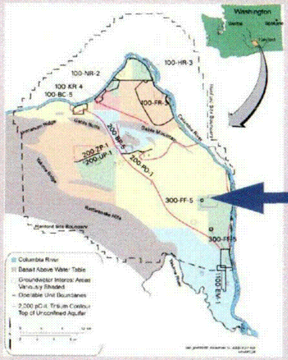
Basalt and mud tops appearing above water table in last 10 years

Example 4: Changing Flow Conditions

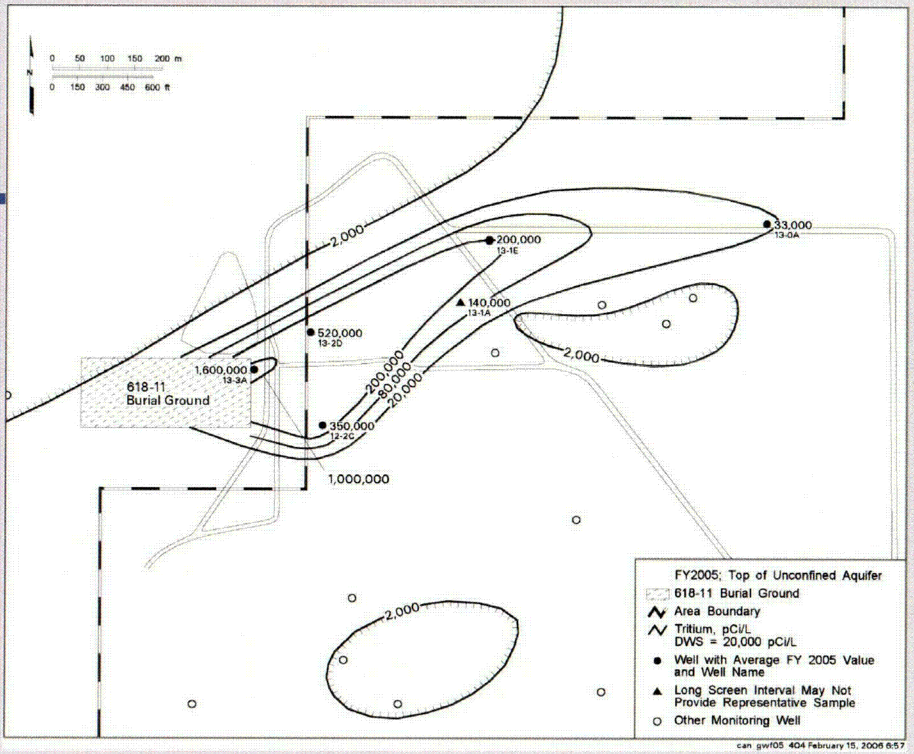
- Burial grounds, reactors, and disposal trenches near river
- Limited source remediation; unknown uranium source(s) remains
- Recurring contamination from vadose zone caused by surface infiltration and intermittent high river stage



Example 5: Inventory Uncertainty

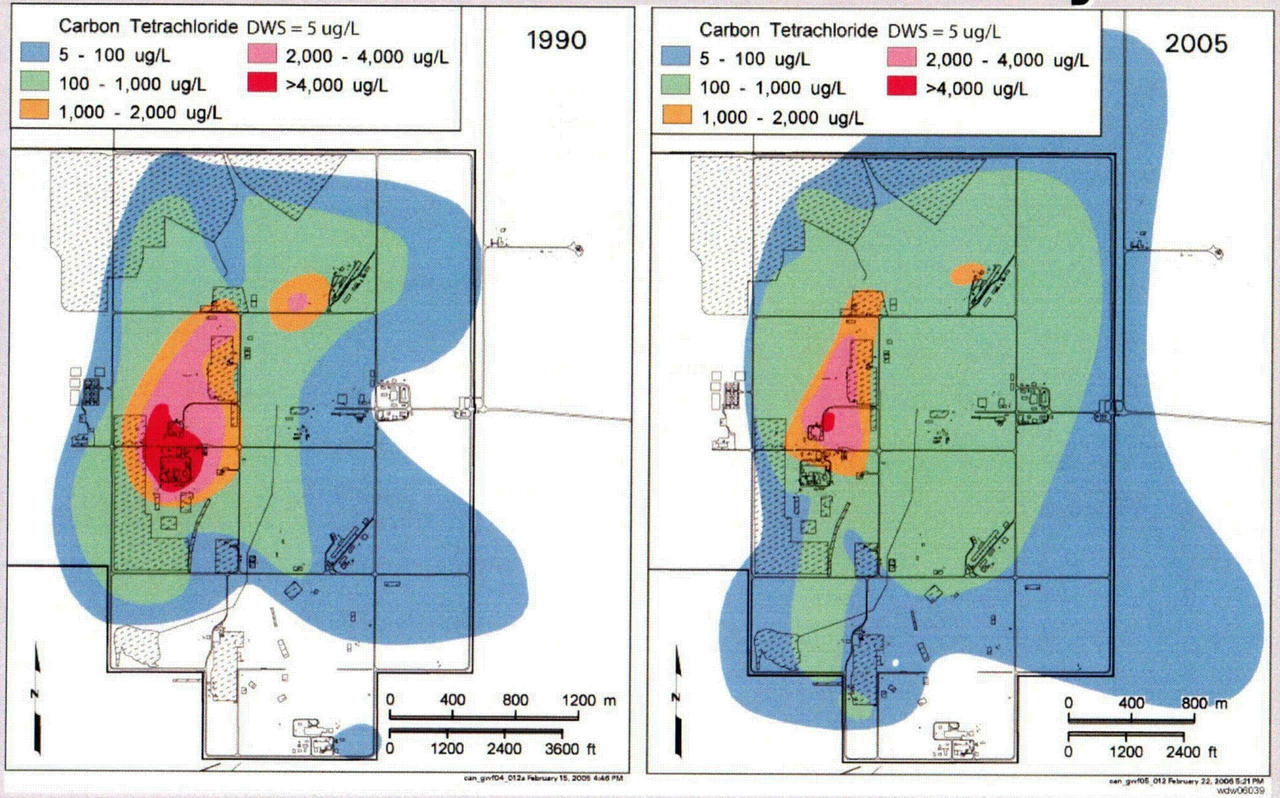


- Burial ground not monitored for tritium (not in inventory)
- Measurement to track regional plume in 1999 yielded unexpectedly high concentration of tritium (initially > 1 M pCi/L, later peak at >8M pCi/L) compared to nearby groundwater concentrations ranging from 2,000 to 20,000 pCi/L
- Significant effort expended to understand, quantify, and monitor new tritium plume (more wells; soil gas)



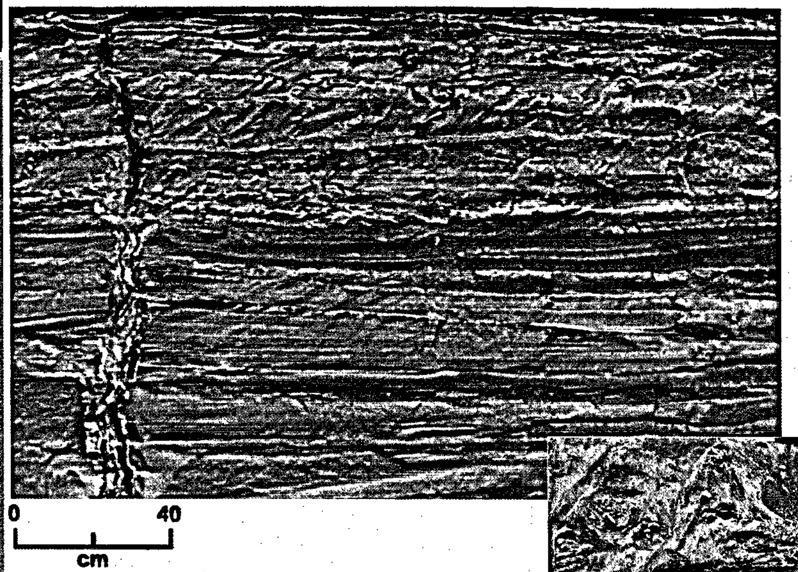
2005 Tritium Plume at 618-11
(plume undetected prior to January 1999)

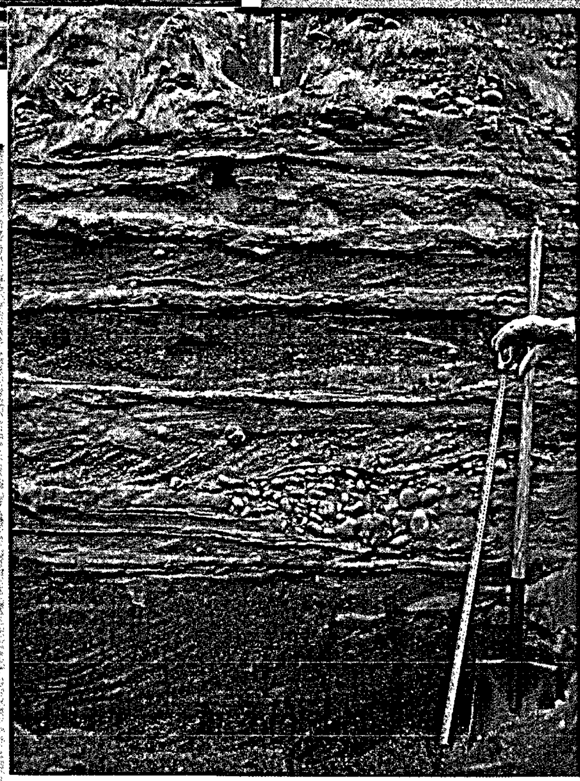
Example 6: Contaminant Source Location Uncertainty

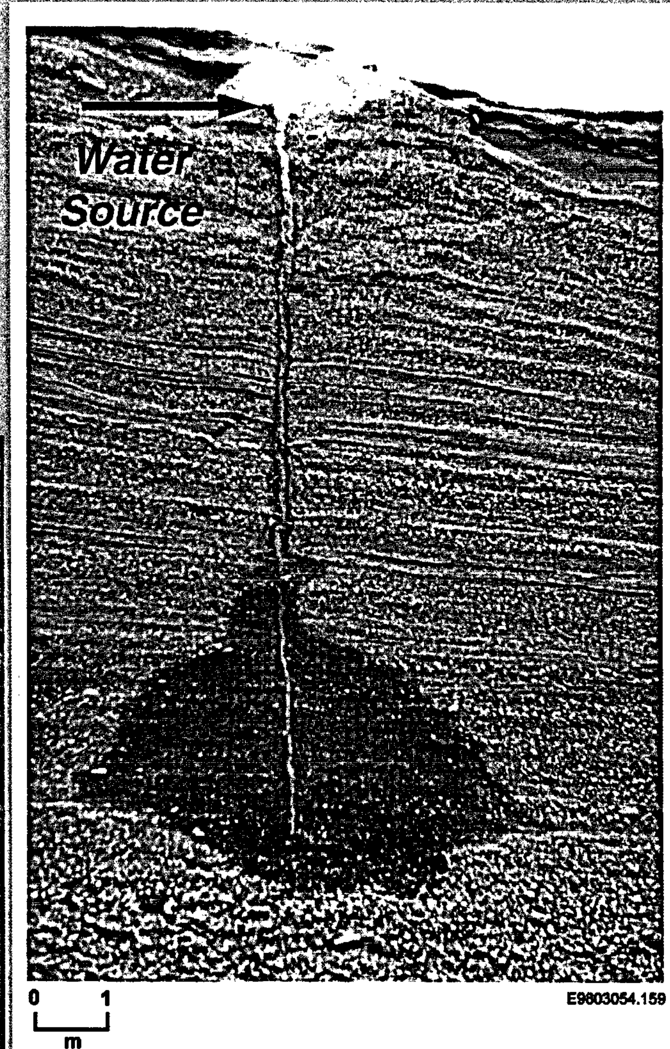


- Carbon tetrachloride (CCL_4) disposed to vadose zone
- Mass balance of removed and detected CCL_4 shows a shortfall
- Where is remaining CCL_4?

Example 7: Complex Subsurface





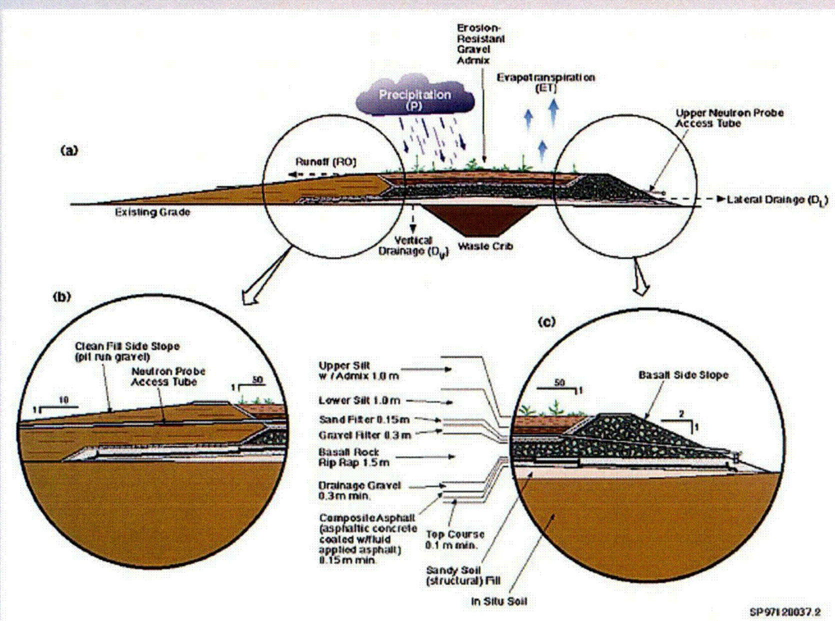


- Geologic features are not perfectly flat, continuous, uniform, homogeneous, or isotropic
- Manmade features (e.g.,boreholes, transfer lines, tanks) add to variability
- Such variability has implications for pathways, hydraulics, and geochemistry

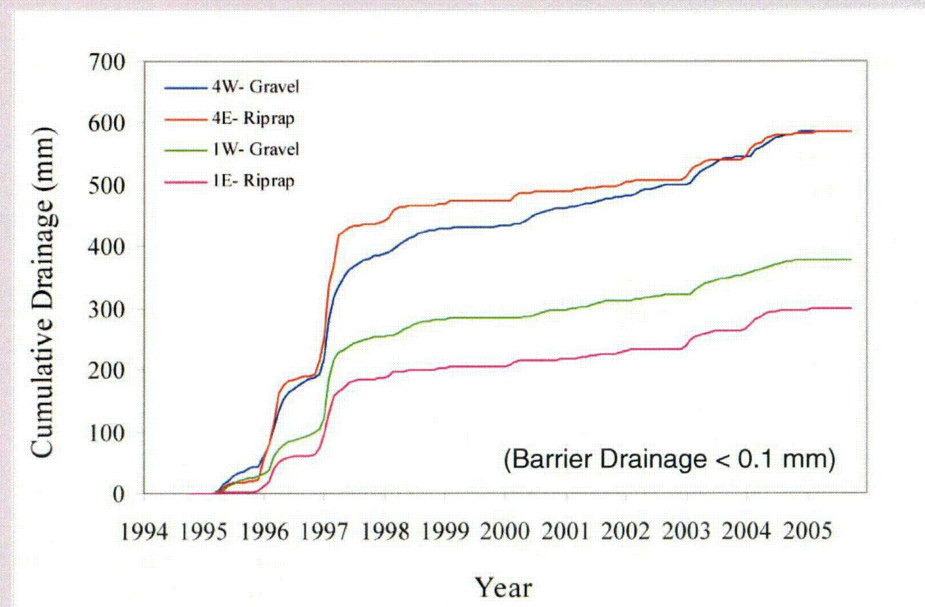
Example 8: Unintended Consequences

- Top of surface barrier works as designed: d < 0.1 mm/yr
- Large gravelly side slopes create infiltration source: d > 20 mm/yr

Prototype Hanford Barrier



Cumulative Side Slope Drainage



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Summary

Contaminant transport in the subsurface environment is governed by a complex relationship of site- and contaminant-specific features, events, and processes. Recognizing and addressing that complexity is key to adequately understanding, monitoring, and predicting contaminant transport.

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Barnwell Low-Level Radioactive Waste Disposal Facility Groundwater Migration Modeling Overview

presented to the ACNW
September 19, 2006
by Vernon Ichimura

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Overview

- Focus on compliance demonstration in groundwater and surface water
- Assumptions, judgment, and measurements
- Determine maximum hypothetical dose rate by the following evaluations:
  - Pre-licensing Evaluation - - 1971
  - USGS Site Characterization - - 1982
  - NRC Environmental Assessment - - 1982
  - Barnwell Site Environmental Radiological Performance Verification Model - - 1996
  - Barnwell Site Environmental Radiological Performance Verification - - 2003

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Pre-licensing Evaluation

- Began in 1967.
- Obtain existing information from the Savannah River Site and "Barnwell Nuclear Fuel Plant" Safety Analysis Report.
- Solicit opinion of experts.
- Characterization by collecting data
    - Geology – Boreholes
    - Hydrology – Water Level
    - Water Quality and Chemistry
    - Ion Exchange Properties
- Development of a Conceptual Migration Model.

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Pre-License – Safety Analysis

Nuclear Safety Associates, 1971

- Assumed Inventory
  - Gross Beta - Gamma 60,000 Ci
  - Strontium 90 40,000 Ci
  - Cobalt 60 150,000 Ci
  - Plutonium 239 80,000 Ci
- Source Term Calculated from "release fraction" estimated from existing disposal sites and dilution by infiltration.
- Assume infiltration of 6 inches.

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Pre-License – Safety Analysis (continued)

- Distance of travel 3,000 feet.
- Assumed shortest groundwater travel-time 75 years.
- Assumed radionuclides travel-time 750 years.
- Assumed stream flow rate is 10 cubic feet per second.
- Assumed mixing in the stream.
- Showed with decay, all radionuclides should be 1,000 to 10,000 times lower than Maximum Permissible Concentration.

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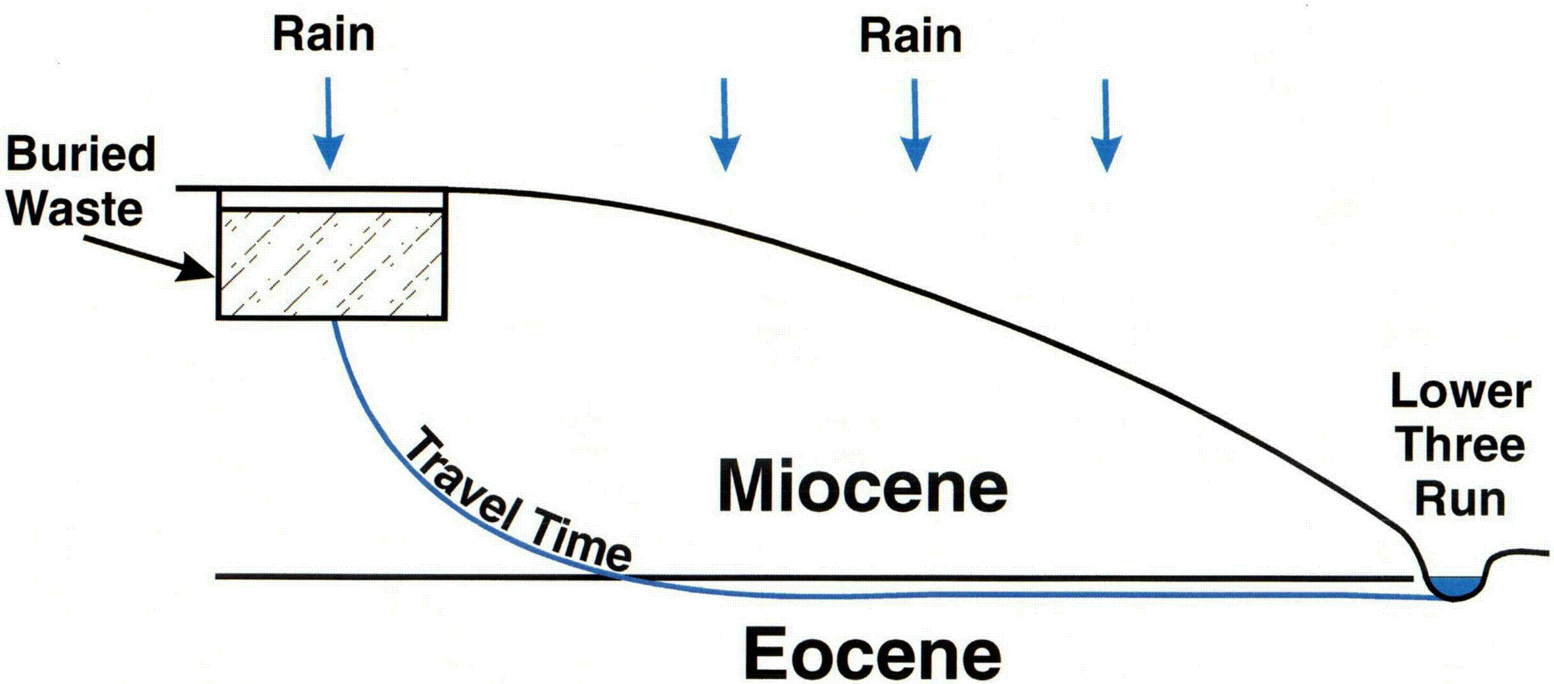
Conceptual "Barnwell Burial Model" 1971



copied from Nuclear Safety Associates, 1971

USGS – Cahill, 1982

- Site specific characterization by observations and measurements
  - Stratigraphic interpretations
  - Geophysical logs
  - Hydraulic properties
  - Water elevation data
  - Stream flow rates
  - Water chemistry
  - Measurement of radioactivity in cores

USGS – Cahill, 1982 (continued)

- Development of a 3-dimensional finite difference regional flow model - - calibrated to
  - Measured groundwater levels
  - Measured hydraulic properties
  - Measured stream flow rates

USGS – Cahill, 1982 - Results

- Recharge rate is approximately 15 inches/year.
- Showed "zone 1 and zone 2" contributed to most of the groundwater flow to local streams.
- Showed groundwater movement is towards Mary's Branch Creek.
- Estimated groundwater travel-time from the disposal site to the creek is approximately 50 years.

Environmental Assessment

NUREG 0879, 1982

- Assumption that most recharge to zone 1 enters zone 2.
- Two dimensional finite difference flow model.
- Flow model is two dimensional.
- Assumption that study area is surrounded by "No-Flow" boundaries.
- Assumption that all groundwater enters a creek.
- Calibrated by matching heads by adjusting hydraulic properties.

Environmental Assessment

NUREG 0879, 1982

(continued)

- Two dimensional, finite difference transport model, with retardation and decay.
- Assumed source-term 1/10 percent of total activity (January, 1981) is released over 100 years. The list of radionuclides are:
  - » Tritium
  - » Carbon 14
  - » Cesium 134
  - » Cesium 137
  - » Cobalt 60
  - » Iron 55
  - » Strontium 90
- Calculated concentrations of radionuclides available to a hypothetical user of groundwater at the creek.

Environmental Assessment

NUREG 0879, 1982

(continued)

- Showed tritium is the most important radionuclide at the creek.
- Calculated hypothetical dose rate is less than 4 mrem/year from tritium at the creek.
- Calculated hypothetical dose rate is approximately 5 mrem/year from strontium 90 at the creek (at a later time).
- Negligible contribution from other radionuclides.

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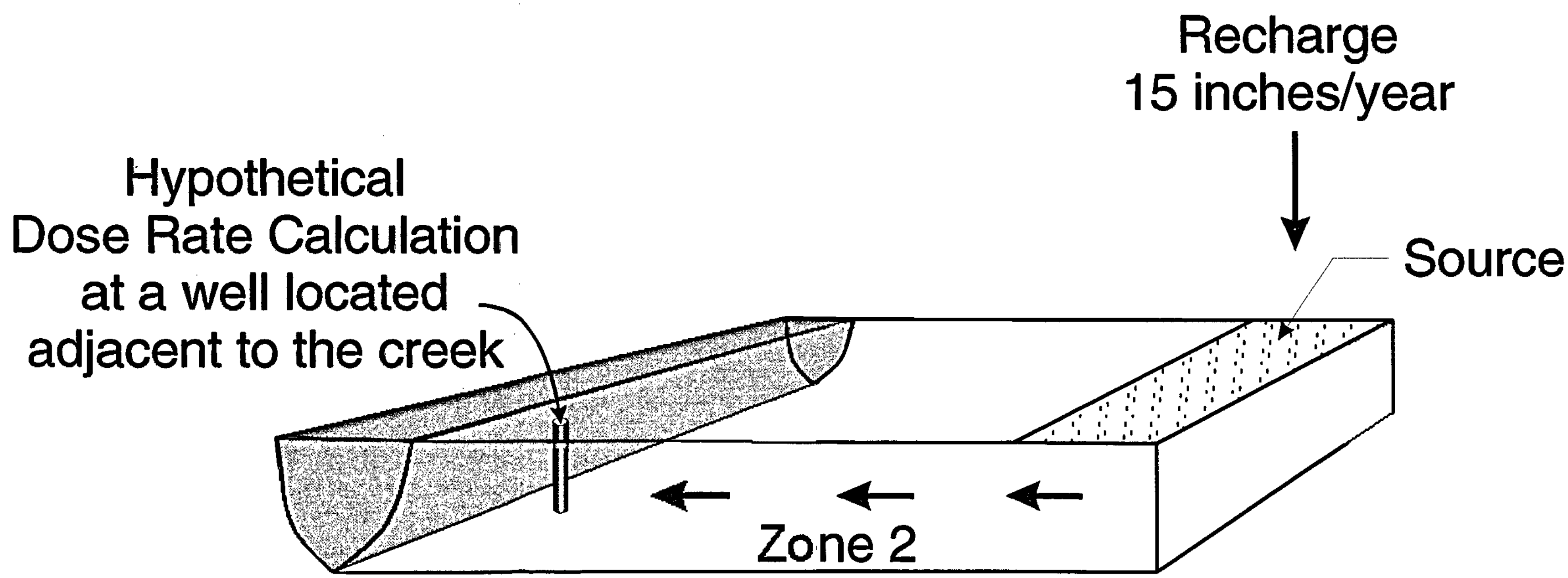
Conceptual Migration Model



NUREG 0879

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Barnwell Site Environmental Radiological Performance Verification, 2003

- Model development - - 1996
- Based on numerous measurements
  - Continue collection of geologic and hydrologic data
  - Routine measurements - - Environmental Monitoring
  - Special Studies - - Stream Flow Measurements
    - - Special Characterization Studies
    - - Radionuclide Inventory Characterization
- Some statistics - - Groundwater Monitoring
  - Greater than 400 sample locations
  - Long-term measurements (approximately 25 years)

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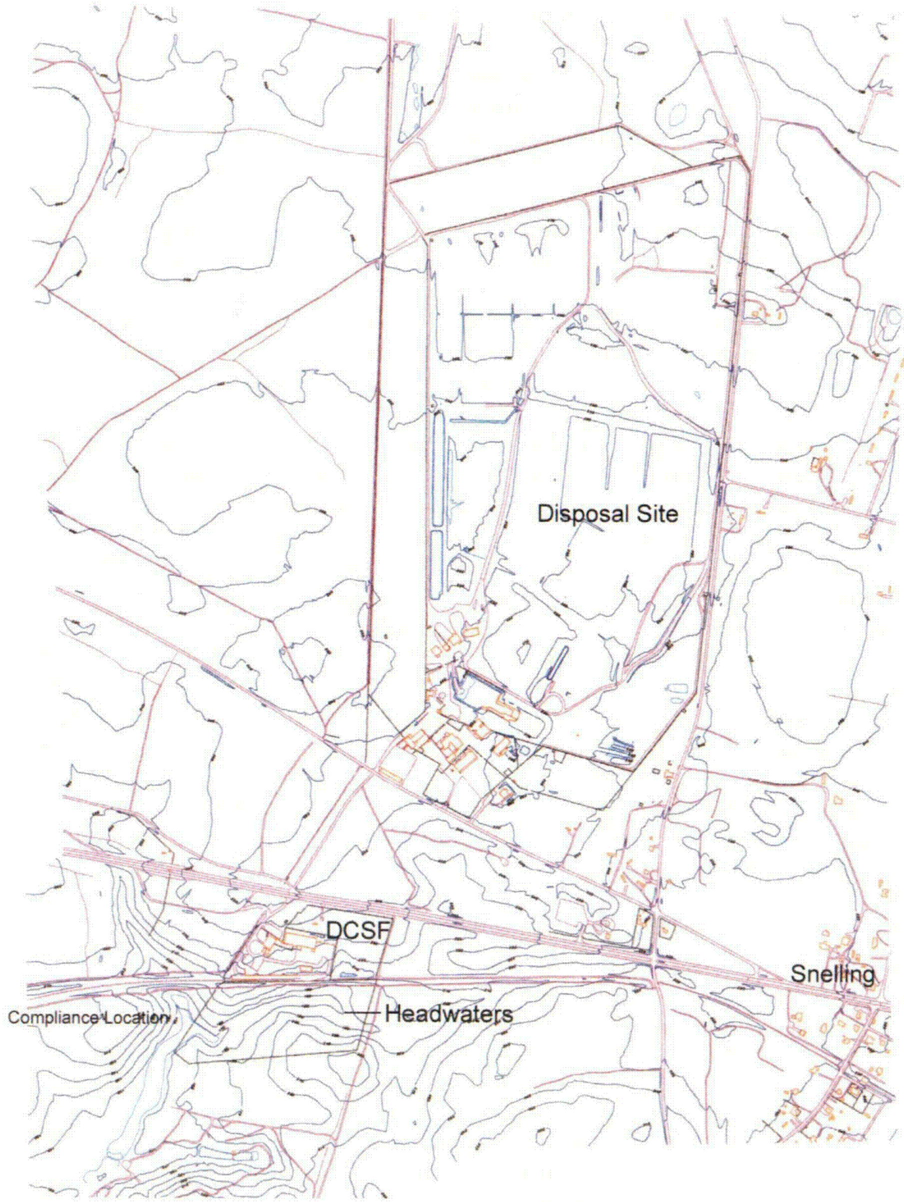

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Elevation 250'

Surfacial Sand

Depth (ft)	Epoch	Formation	Description
0–100	Miocene (Zone 1)	Tobacco Road Formation	Red, yellow, and purple sandy clays to clayey sands
100–200	Upper Eocene (Zone 2)	Dry Branch Formation	Medium to coarse brown, white, and yellow sands
200–300		McBean Formation	Sand to clayey sand yellow tan or greenish-brown
300–400		Congaree Formation	Coarse white and brown sands with some quartz gravel
400–		Ellenton Formation – Clay Unit	Dark gray to black micaceous clay and sandy clay
–500–		Ellenton Formation – Sand Unit	Medium to coarse white and gray sand with streaks of brown clay and quartz gravel

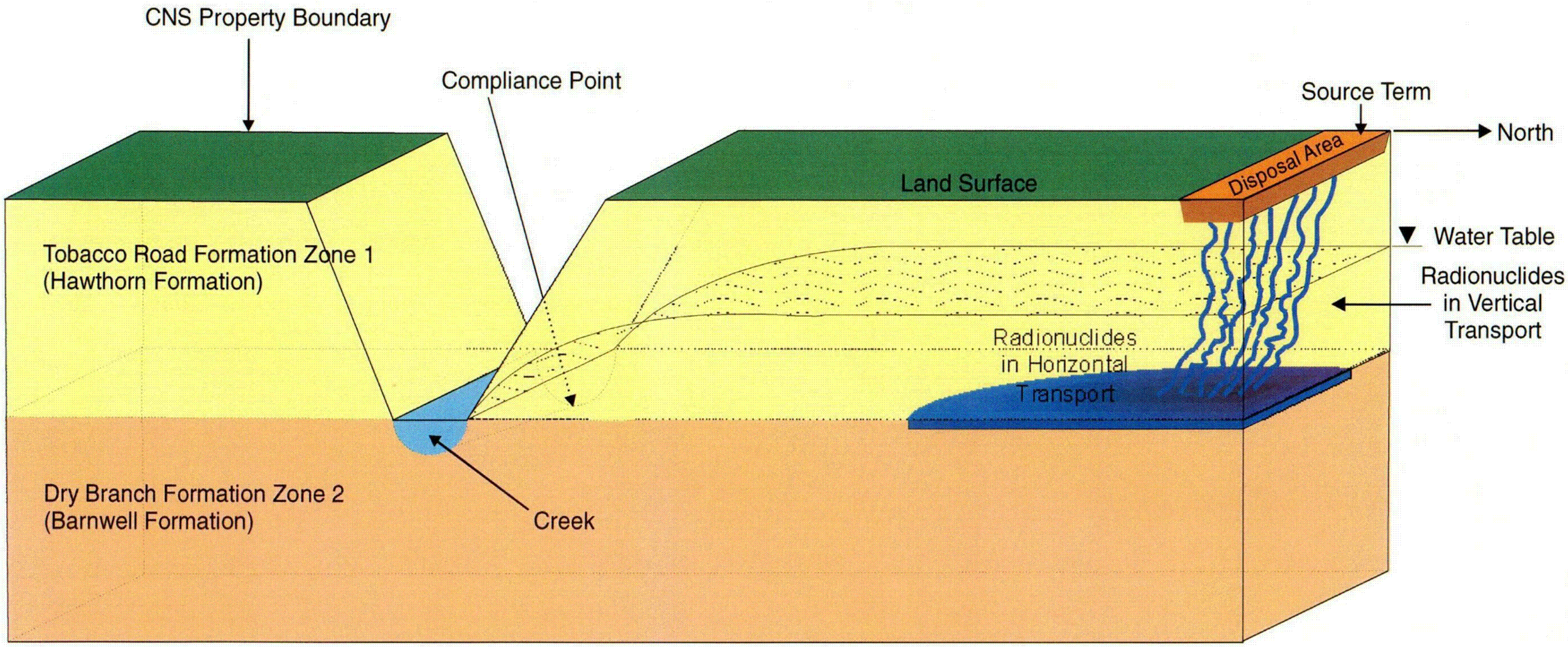
Approximate position of trench bottoms.

Approximate position of outflow to Mary's Branch

1200 ft of Sediments

Generalized stratigraphic column for Barnwell site adapted from Cahill (1982) and Nystrom and Willoughby (1991).

Conceptual Model of Radionuclides in Transport



Conceptual model for the transport of mobile radionuclides.

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Numerical Model

- Three-Dimensional Flow
- MODFLOW and MODPATH
- Transport in Zone 2 - - Numerous one-dimensional stream tubes – advective transport with decay and retardation.
    - Source term – measured maximum average
    - Source term – calculated from radionuclide inventory
- Stream Flow - - a series of mixing cells to calculate dilution.

Calibrated To

- Measured hydraulic properties.
- Measured average groundwater elevation measurements.
- Measured Stream flow rate.
- Measured pond falling head rates.
- Measured radionuclide (tritium) arrival and location measurements.
- Measured maximum-average tritium and carbon 14 concentrations.

Model Results

- Maximum hypothetical dose rate – tritium 13 mrem/year
- Maximum hypothetical dose rate – carbon 14 <1 mrem/year

Measurement

- Hypothetical dose rate – tritium <5 mrem/year
- Hypothetical dose rate – carbon 14 <1 mrem/year

Real Dose Rate

- Negligible

Projection

- Methodology
  - Determine radionuclide inventory at the Barnwell Site.
  - Determine a source-term calibrated to tritium and carbon 14 inventory.
  - Assume distribution coefficients from Sheppard and Thibault, 1991, are applicable.
  - Calibrate a model for tritium and carbon 14.
  - Determine which radionuclide arrives at the compliance location within 2,000 years.
  - Calculate hypothetical dose rate from radionuclides which arrive within the 2,000 year period.

Projection

- Results
  - Tritium and carbon 14 are most important.
  - Iodine 129 and technetium 99 are small dose contributors.