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Research Insights for Modeling, Monitoring and Remediating Radionuclide Transport in Ground Water

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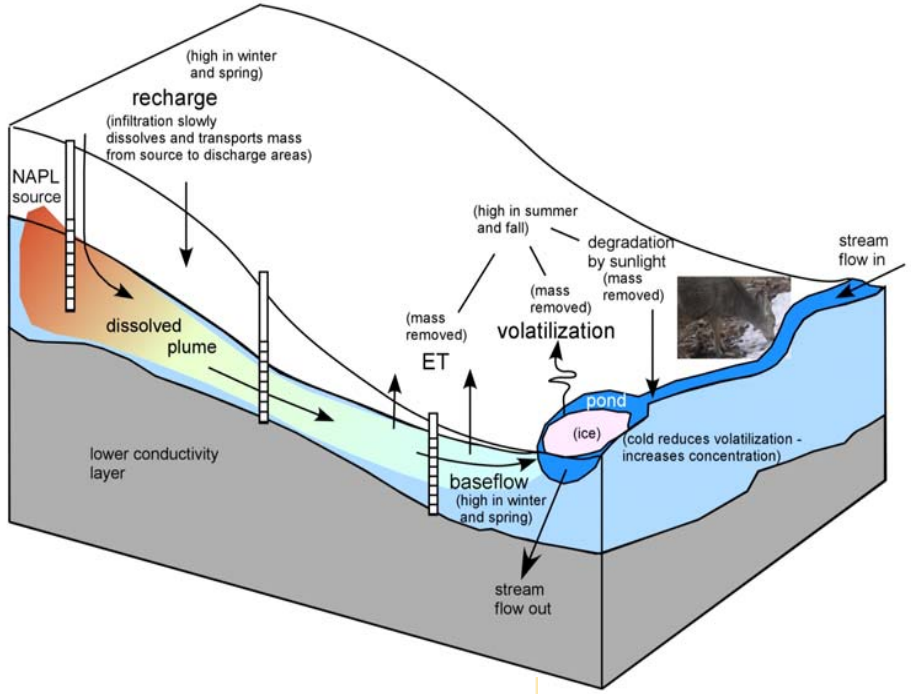
Overview

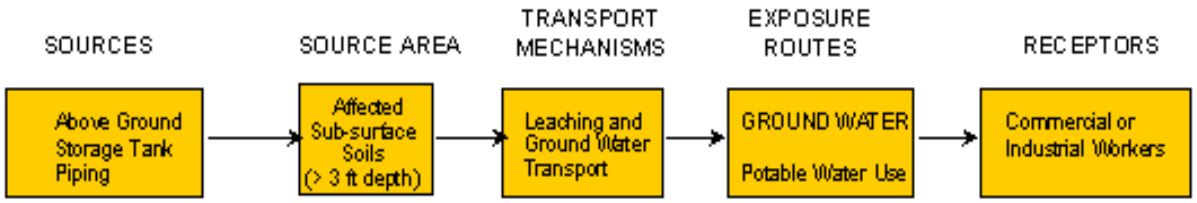
- Conceptual Site Model of Radionuclide Transport
- Site-Specific Modeling Coupled to Monitoring
- Modeling Issues and Benefits
- Monitoring and Modeling Interface - Performance Indicators
- Remediation Decisions based on Modeling and Monitoring
- Application to Nuclear Facility Sites
- Information Sources
- RES Studies in Support of Ground-Water Monitoring & Modeling

Conceptual Site Model

- Hypothetical representation of the site
- Organize and communicate information
- Subject to testing with new characterization and monitoring data
- Supports remediation decision

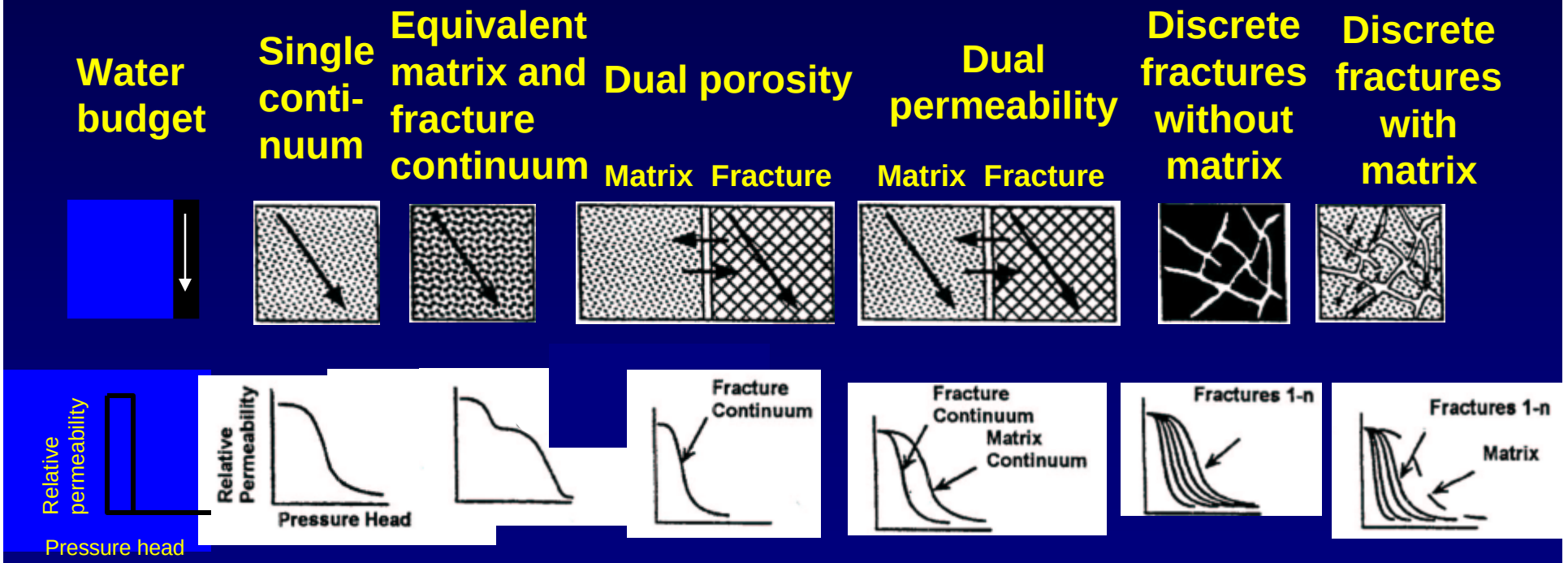


Exposure Pathway Flowchart



Hierarchy of Conceptual Flow Models

Models to simulate flow in soils, sediments, unsaturated fractured rock (after Altman et al., 1996)



Complexity

Model abstraction

Site-Specific Modeling Coupled to Monitoring

Why monitor and model?

Characterize natural and engineered systems:

- ✓ **Collect information to identify significant Features, Events and Processes**
- ✓ **Develop and evaluate site conceptual models**
- ✓ **Guide data collection including monitoring, sampling and geophysical surveys**
- ✓ **Technical bases for determining remediation**

Photo by John Selker, Oregon State University

Ground-Water Modeling Benefits

- ✓ Integrates site and source characterization and monitoring data at various scales into a logical framework
- ✓ Identifies vulnerabilities to drinking water sources
- ✓ Reduces uncertainties and helps to identify locations for monitoring to confirm hydrogeologic system behavior
- ✓ Forecasts impacts (doses due to exposure and uptake)
- ✓ Provides bases for prompt action (e.g., corrective activities)
- ✓ Assists in designing and monitoring remediation program
- ✓ Communicates understanding of the system to the public and facilitates technical interactions

Monitoring and Model Interface

- ✓ **Confirm system behavior is within envelope of the expected performance**
  - of engineered structure, systems and components
  - of natural systems
  - of regulatory requirements

- ✓ **Site-Specific Model**
- will probably not be simplified (abstracted) version used in PA
- may include state variables not in abstracted version
- state variables are potential ***Performance Indicators***
- should evolve with performance monitoring analyses

Remediation Decisions Based on Modeling & Monitoring

Table 1.1. Context for *In Situ* Bioremediation of Uranium in the Saturated Zone

	~ ←**Increasing cost** ---------- ~ **Increasing technical uncertainty**→ ←Active remediation Passive remediation →							
	Physical removal		***Chemical remediation***	***Bioremediation***				***"No action"***
PROCESS	Excavation and removal	Pump and treat	Abiotic treatment zones or walls	**Forced gradient displacive amendment**	**Forced gradient non-displacive amendment**	**Natural gradient displacive amendment**	**Natural gradient non-displacive amendment**	Monitored natural attenuation
COMMENTS	Usually highest cost and worker risk	May require extended operation period with limited results	Issues with pore clogging and rerouting of flow or breakthrough and predicted lifetime	Cost for maintaining gradient. provides control on flow direction, displacement of contaminant may confound results.	Cost for maintaining gradient. Control on flow direction	Difficult to separate injectate dilution from microbial effects	Minimal dilution effect. Limited donor concentration	May require extended period of monitoring with risk that outcome may not meet regulatory requirements

from Long, Yabusaki et al, 2008 (PNNL-17295)

Monitoring Program Considerations

- Environmental Pathway Identification & Assessments

- ✓ Anticipate what Radionuclides may be released (H-3, Sr-90, Cs-137, Co-60, etc) and their Sources
- ✓ Detectability of Radionuclides close to the Sources
- ✓ Identify Surface- and Ground-Water Relationships
- ✓ Examine Vulnerability of Local Drinking Water Sources (Ground- and Surface-Water Sources)
- ✓ Estimate Potential Radionuclide Transport Pathways
- ✓ Site-Specific Data as Input to Models, i.e., hydraulic conductivity and radionuclide partition coefficients (k_d)
- ✓ Ground-Water Transport Analysis for Estimating Radionuclide Fluxes to the Accessible Environment

Monitoring to Determine Efficacy of In Situ Bioremediation

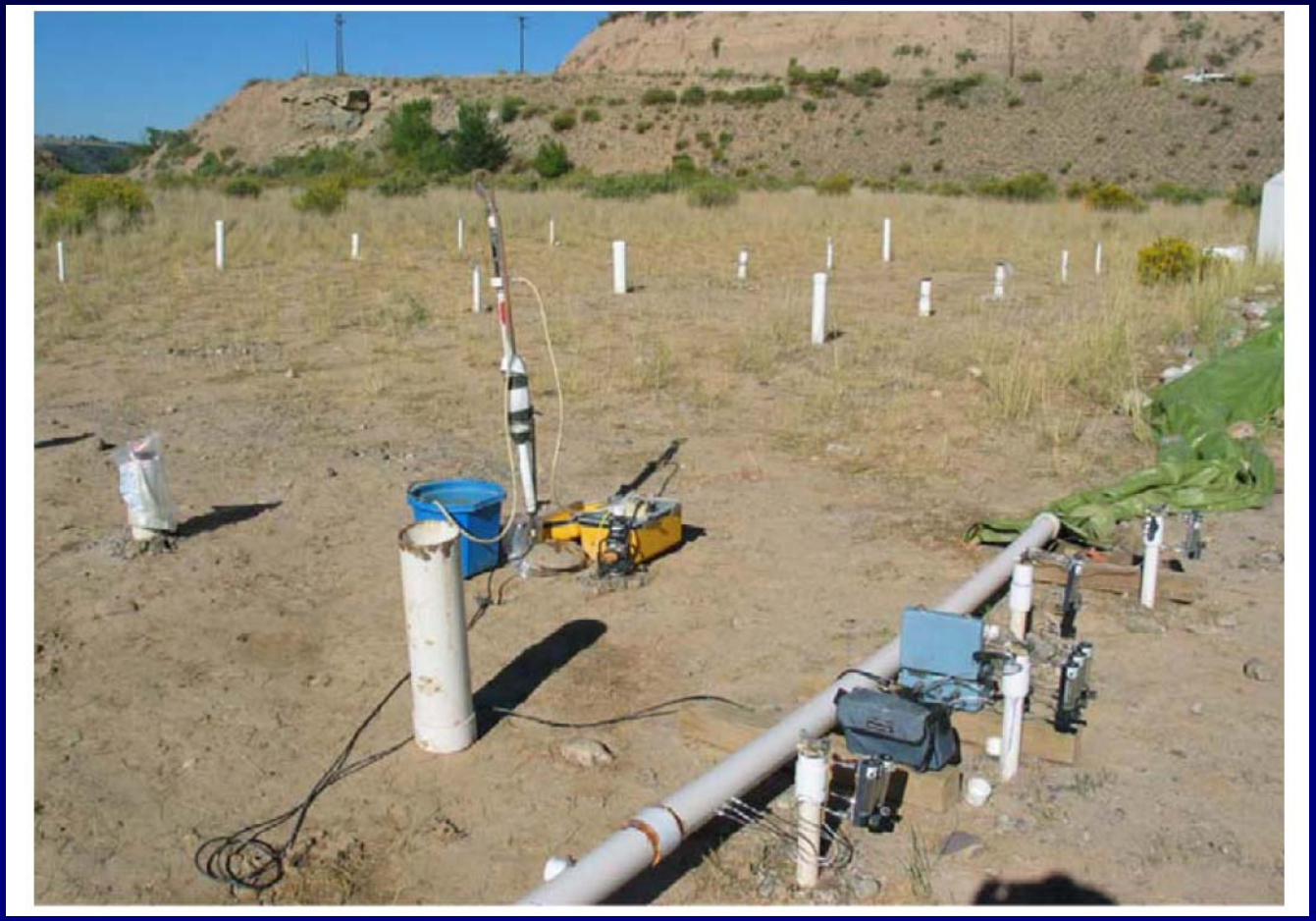


Photo of wells and sampling apparatus including flow cell for measurement of pH, Eh, DO, T, and conductivity during slow purge sampling. Foreground shows injection manifold and stainless steel injection lines to injection wells. [From Long, Yabusaki et al, 2008 (PNNL-17295)]

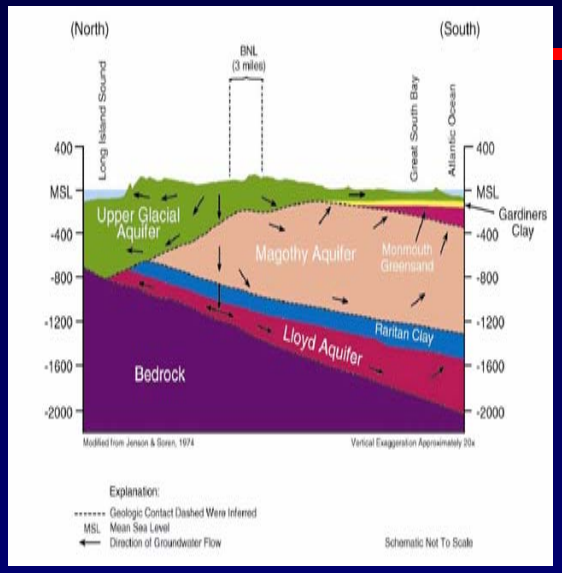
Application to Nuclear Facility Sites

Site Characterization, Performance Assessment & Radiological Environmental Monitoring Programs together should:

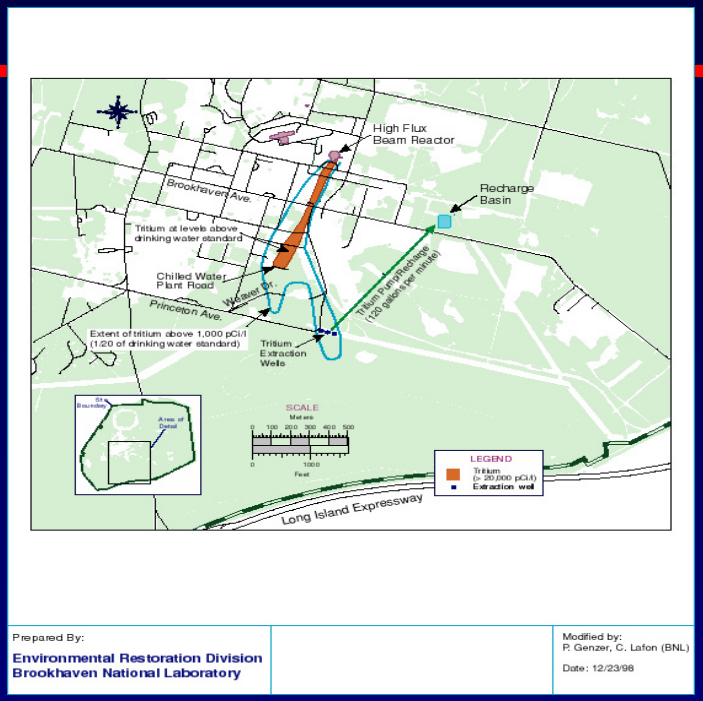
- ✓ Develop Site Conceptual Model
- ✓ Identify Potential Sources of Radionuclide Leaks, Spills and Releases & Focus on Detectability and Monitoring Methods
- ✓ Systematically and Quantitatively Assess Predictive Uncertainty in Flow and Transport Modeling
- ✓ Utilize Monitored Performance Indicators to Parameterize, Calibrate and Test Alternative Conceptual Site Models
- ✓ Use a Statistically Rigorous Approach, such as the Bayesian Model Average Approach, to Compare Models and Analyze Monitoring Data

Provides the Technical Bases for Decision Making such as the Need for and Approaches to Remediation

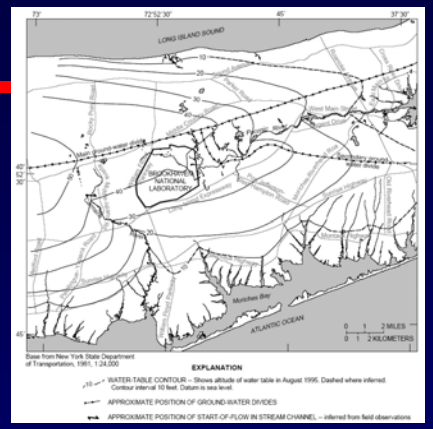
Case Histories - Brookhaven



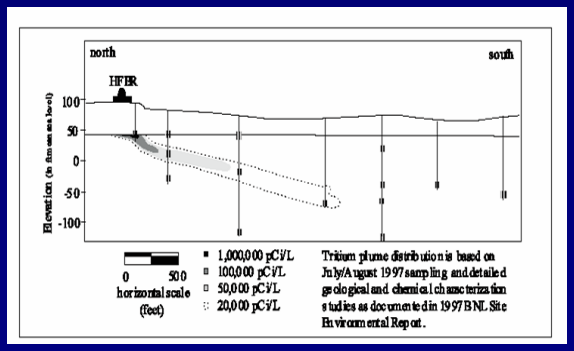
Regional Geologic Setting



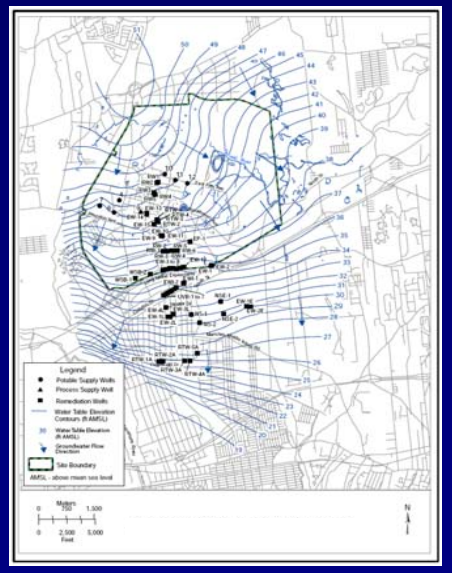
Tritium Plume Plan Map



Regional Ground Water Flow

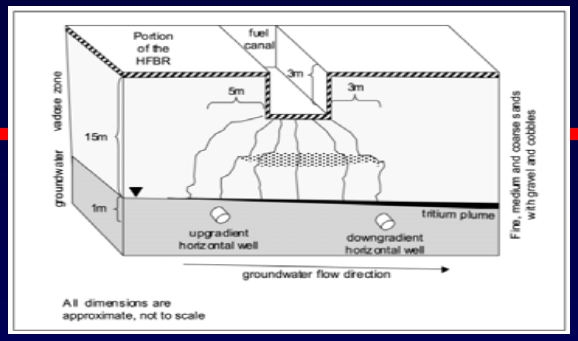


Tritium Plume X-Section



Site Ground Water Flow

Synthesis of CSM & Flow and Transport Models



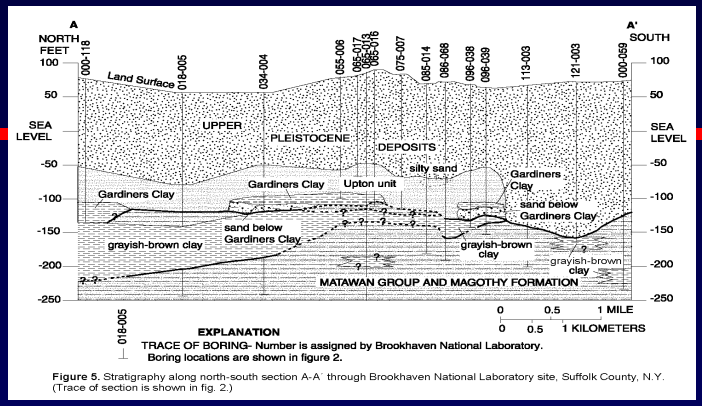
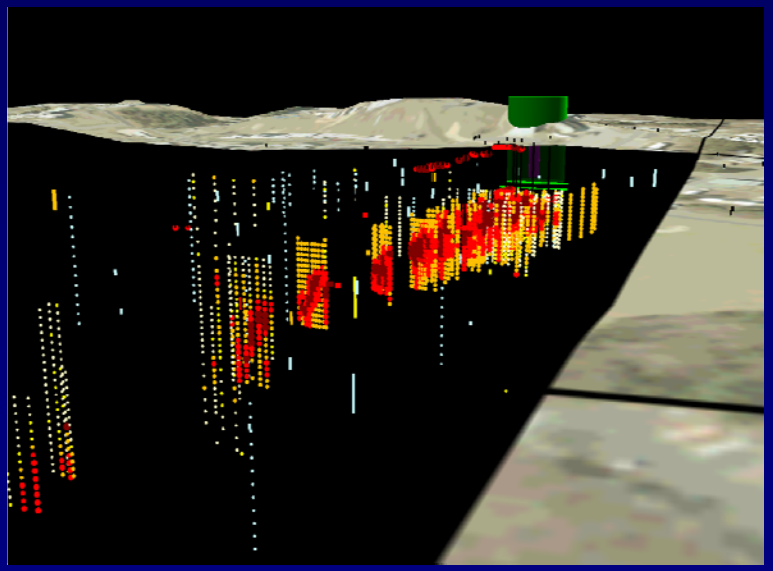


Figure 5. Stratigraphy along north-south section A-A' through Brookhaven National Laboratory site, Suffolk County, N.Y. (Trace of section is shown in fig. 2.)

- AES developed a CSM that incorporated influence of nearby pumping wells and 3-D visualization of data
- Used flow and transport modeling to validate that our CSM reflected observed monitoring data. (Modeling was done in Excel, MODFLOW, and GMS)
- Once validated, used flow and transport modeling to evaluate remediation alternatives



Information Source – NUREG/CR-6948

- Technical bases for developing guidance on ground-water monitoring for NRC-licensed sites
- Systematic methodology to integrate monitoring with modeling
- **http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6948/v1/index.html**

NUREG/CR-6948, Vol. 1

Integrated Ground-Water Monitoring Strategy for NRC-Licensed Facilities and Sites: Logic, Strategic Approach and Discussion

Manuscript Completed: July 2007
Date Published: September 2007

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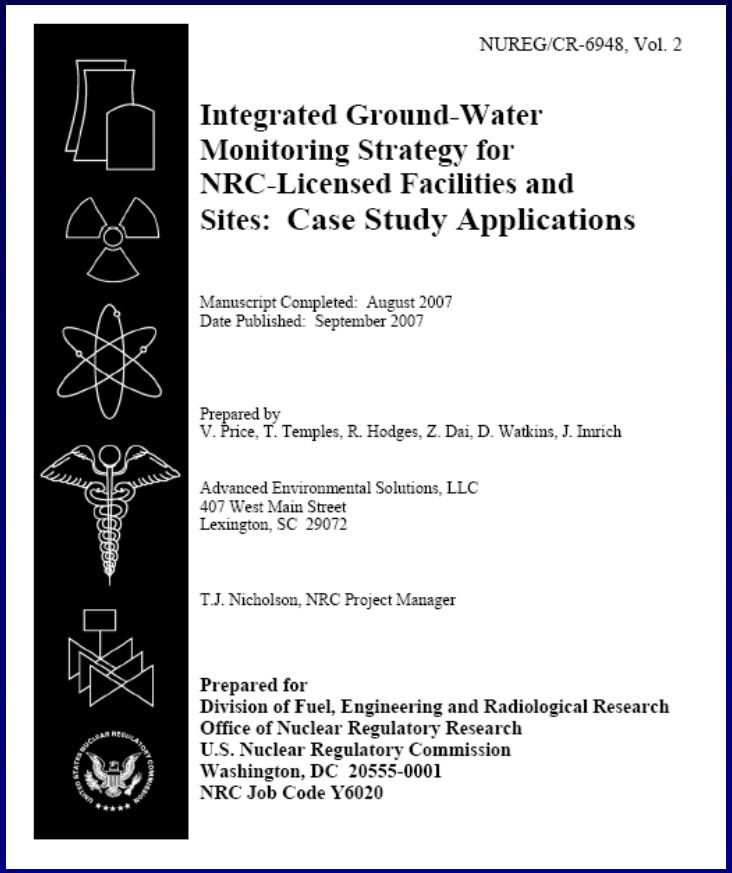
Washington, DC 20555-0001
NRC Job Code Y6020

Information Source – NUREG/CR-6948

- Lessons-Learned for developing guidance on ground-water monitoring for NRC-licensed sites
- Case Studies which includes Brookhaven radionuclide plume remediation and monitoring
- **http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6948/v2/index.html**



NUREG/CR-6948, Vol. 2

Integrated Ground-Water Monitoring Strategy for NRC-Licensed Facilities and Sites: Case Study Applications

Manuscript Completed: August 2007
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RES Studies in Support of Ground-Water Monitoring & Modeling

- **Issue AES's "Integrated Ground-Water Monitoring Strategy for NRC-Licensed Facilities and Sites" (NUREG/CR-6948)**
- **Assess contaminant transport in soils using ARS's extensive field databases to identify and demonstrate model abstraction techniques, and assess uncertainties (NUREG/CR-6884)**
- **Test PNNL Uncertainty Methodology at Hanford 300-Area to identify and quantify conceptual model, parameter and scenario uncertainties (NUREG/CR-6940)**
- **Apply USGS surface-complexation models of U adsorption and retardation using field data from the Naturita Site (NUREG/CR-6820)**
- **Assess the efficacy of *in situ* bioremediation to sequester U through monitoring and modeling of Performance Indicators (PNNL-17295)**