



# **Key Concepts for Early Leak Detection**

**and Questions for the Workshop**

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# Newly Revised NRC Regulations

- Decommissioning Planning Rule
  - Promulgated June 17, 2011 (76 Federal Register 35511)
  - Effective December 17, 2012
  - Applies to all types of facilities
  - Applies to the operational phase of facilities' life cycle
- Revises 10 CFR 20.1406 “*Minimization of Contamination*”
  - **10 CFR 20.1406 (c)** establishes a new requirement for licensees with operating licenses to operate their facilities in a manner that minimizes the introduction of residual radioactivity into the site, including the subsurface, to facilitate remediation of the site for unrestricted use at the time of license termination<sup>1</sup>
- Revises 10 CFR 20.1501 “*Surveys and Monitoring, General*”
  - **10 CFR 20.1501 (a)** amended to explicitly include a requirement for radiological surveys in the subsurface necessary to evaluate residual radioactivity at licensed sites<sup>1</sup>

1. DRAFT REGULATORY GUIDE DG-4014, “DECOMMISSIONING PLANNING DURING OPERATIONS”  
(released for public comment ,December 2011)

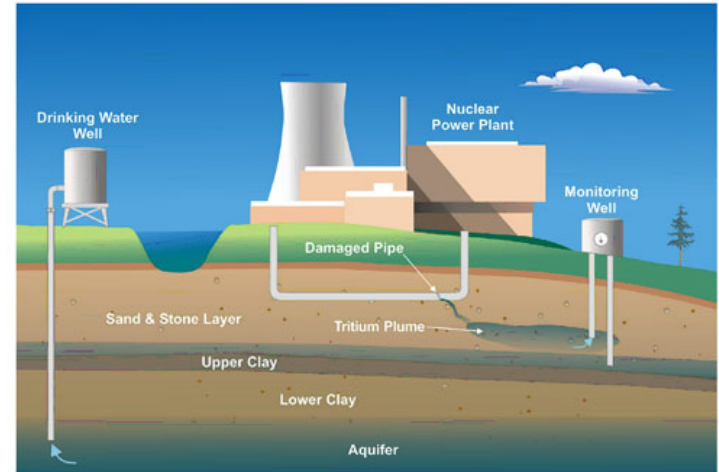
# **NRC Staff Draft White Paper: “*Monitoring for Leaks at Nuclear Power Plants: External to Structures*”**

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- Scoping study
- Identify and assess monitoring methods for detecting early **indicators** of leaks in the subsurface
  - External to but close to SSCs
- Multiple facility types
  - New and existing nuclear power plants (NPPs)
  - Proposed new reactor concepts (e.g. small and modular reactors)
  - Other nuclear facilities
- Identify topics for Long-Term Research Program follow-up

# Leaks with Potential to Impact Groundwater

- Main NRC and Industry focus is on buried piping (in contact with soil)
- Also other sources
  - Tanks
  - Underground piping (in vaults)
  - Spent fuel pools
  - Building drains and sumps
  - Storm drains and retention ponds
  - Sewers and septic fields
- Many leaks do not contain radioactive material but may be from important systems



# Radionuclides in Leaks (NPPS)

- Tritium is most commonly detected radionuclide
  - Currently no concentrations greater than MCL offsite
  - Significant stakeholder concern
- Tritium is not the only radionuclide of concern
  - Fission and activation products
  - Tritium will be detected first due to it's mobility
- Undetected or poorly characterized leaks present potential problems for estimating decommissioning costs

# Leak Detection: Not Just Radionuclides

- Other features of leaks provide signals that can be detected by various techniques
  - Moisture
    - For leaks in unsaturated zone
  - Temperature
    - Temperature of leaking fluids may differ significantly from ambient subsurface temperature
    - Unsaturated or saturated zone
  - Chemistry
    - Specific constituents in leaking fluid may provide contrast in electrical properties compared to ambient subsurface conditions
    - Unsaturated or saturated zone

# Approaches to early leak detection

Monitor the subsurface for:

- 1) Anomalous water content of soils surrounding SSCs,
- 2) Radionuclides contained in the leaking fluid and/ or soil vapor, before they get to the water table, and
- 3) Secondary signals such as changes in temperature or chemical conditions
- 4) Focus on change detection (over time), not absolute values

*“Ideal” methods would be in-situ, close to potential sources, sufficiently robust to maintain their useful life over some years, and sufficiently sensitive that they provide an early signal of leaks.*

# Technology Descriptions

## Single Point Methods

Porous Block Sensors

Capacitance Probes

Time Domain Reflectometry

Tensiometers

Heat Dissipation Sensors

Thermocouple Psychrometer

- **Advantages and Disadvantages**

- Individual sensors interrogate a small volume ☹️
  - *But can be arranged in arrays and networks 😊*
- Some seem to be robust (10 years+ *in situ*) 😊
- Some need frequent maintenance ☹️



# Technology Descriptions

## 2D & 3D Geophysical Methods

- Ground Penetrating Radar (GPR)
- Electrical Resistivity Methods (ER)
- Nuclear Magnetic Resonance Sensing (NMR)
- Fiber Optic Distributed Temperature Sensing (DTS)
- Time Domain Electromagnetic Methods (TDEM)
- Frequency Domain Electromagnetic Methods (FDEM)
- Self-Potential Electrical Methods (SP)

- Cover much greater volumes of the subsurface**
- Some methods are more developed and practical than others.**

# Technology Descriptions

## **Nuclear Methods for Water Content**

Neutron Probe (mainly borehole method)

Gamma-Ray Attenuation (mainly lab method)

## **Detection Methods for Radionuclides**

In-Situ Tritium Vapor Detection

Down-well Real-time Tritium Detector

# Methods we will hear about today

**Electrical Resistivity Methods**  
**Fiber-optic Distributed Temperature sensing**  
**Electric Self-Potential Methods**

- *Robust and well developed*
- *Applied at variety of sites & conditions*

## **Tritium detection methods**

- *Tritium most common radionuclide in leaks*
- *“Fast” transport, leading edge of plume*
- *Partitions to vapor phase*

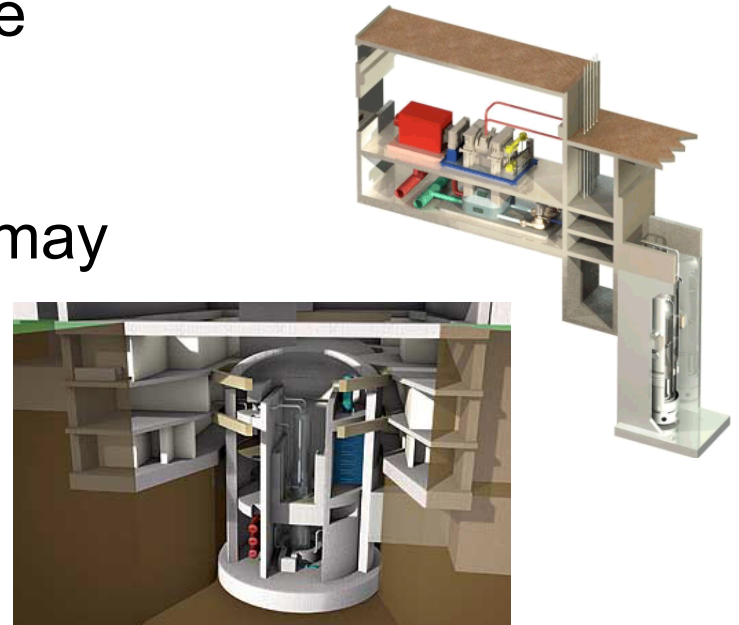
# Implementation Challenges

- Operating facilities
  - Paved areas, buildings
  - Underground infrastructure
  - Electrical noise
- Variability in both leaks and background conditions
  - Episodic vs. continuous leaks
  - Distinguish between leaks and natural subsurface fluctuations (e.g. precipitation)
- Optimal approach may be site-dependent
  - Continuous monitoring or periodic campaigns?



# Leak Detection: Not Just Existing NPPs

- New construction may provide opportunities to incorporate monitoring systems
- Recent interest in small and modular reactor (SMRs) designs
  - Many concepts envision entire reactor building installed underground
  - Monitoring in the subsurface may become more important



# **Leak Detection: Not Just NPPs**

- **In addition to finding leaks at nuclear power plants, early leak detection methods may be useful for other applications**
  - **Engineered covers for Uranium Mill Tailings**
    - Rainwater moving through covers
    - Leachate moving through liners
  - **Fuel Cycle facilities**
    - Reprocessing
    - Fuel fabrication
    - U conversion/deconversion

# Applications Beyond Leak Detection

- Combined application of conservative tracers (e.g. salt water) with geophysical detection methods for identifying preferential flow paths
  - Investigation of existing leak
  - Monitoring well network design

*Suggested to us by John Lane and Fred-Day Lewis*

# Questions for Workshop Participants\*

- 1) What detection/monitoring approaches could have the best potential for application at nuclear facilities?
- 2) Are there data or knowledge gaps that need to be filled before certain methods would be considered for use? If so, what are they? How might these gaps best be addressed?
- 3) What are the challenges to deploying these methods at operating facilities (existing infrastructure, electrical noise, etc.)? How can these be addressed?

*\*onsite and remote participants!*