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# Field Test of Vapor-Phase Ammonia Injection for Vadose Zone Remediation of Uranium

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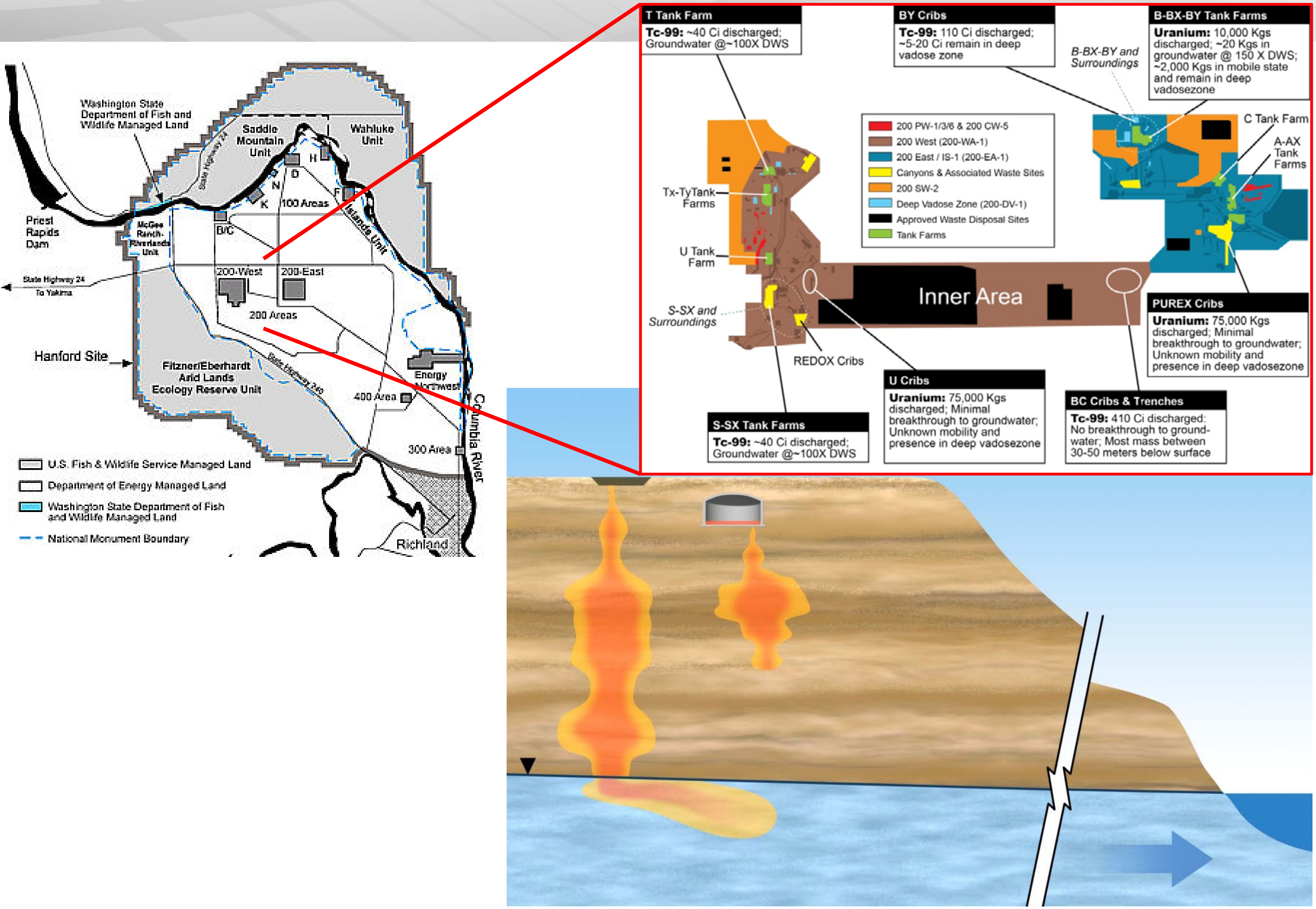
# Introduction



- Large inventory of contaminants in the vadose zone at Hanford: concern as a potential source of future groundwater contamination
- Efforts underway to develop in situ vadose zone remediation for radionuclide contaminants
- Uranium is of concern because of its large inventory and mobility

# Introduction



# Introduction

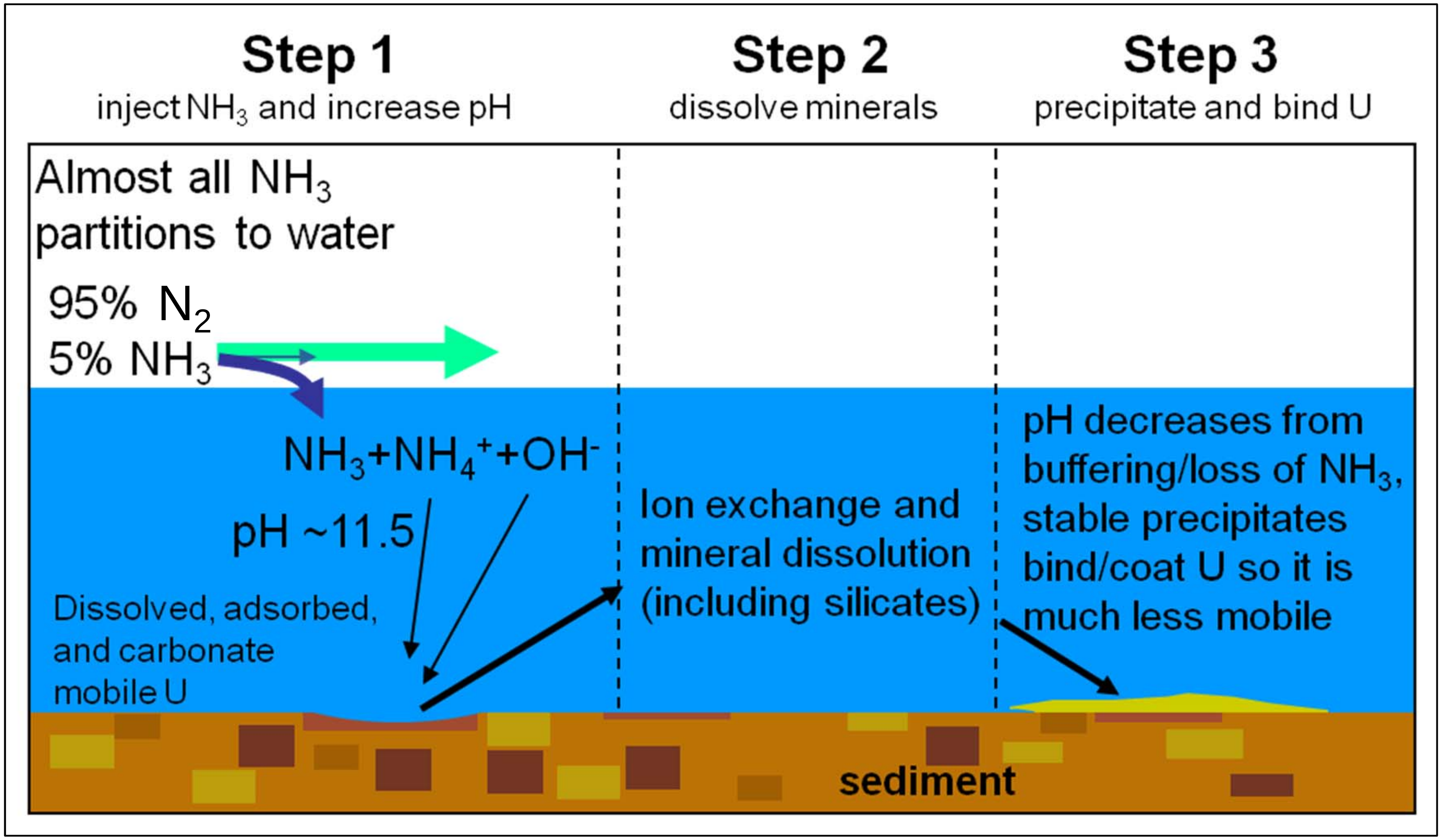


- Investigating geochemical manipulation to change the subsurface conditions in a way that slows downward migration of the contaminants
  - Focus of efforts is use of amendments delivered in the gas-phase

- Development from concept to field application
  - Concept:  Introduction of caustic waste fluids to the subsurface dissolves part of the sediment.  Subsequent precipitation can bind or coat contaminants and render them less mobile.

# Ammonia Treatment

- Ammonia can be delivered in the gas phase and creates caustic conditions in the pore water.



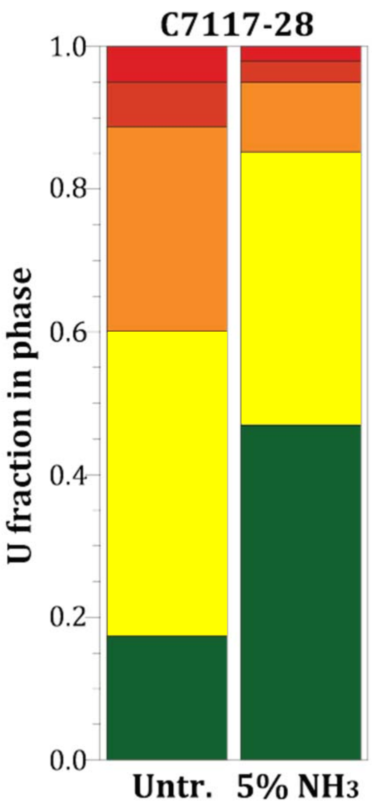
# Evaluating Treatment Effectiveness

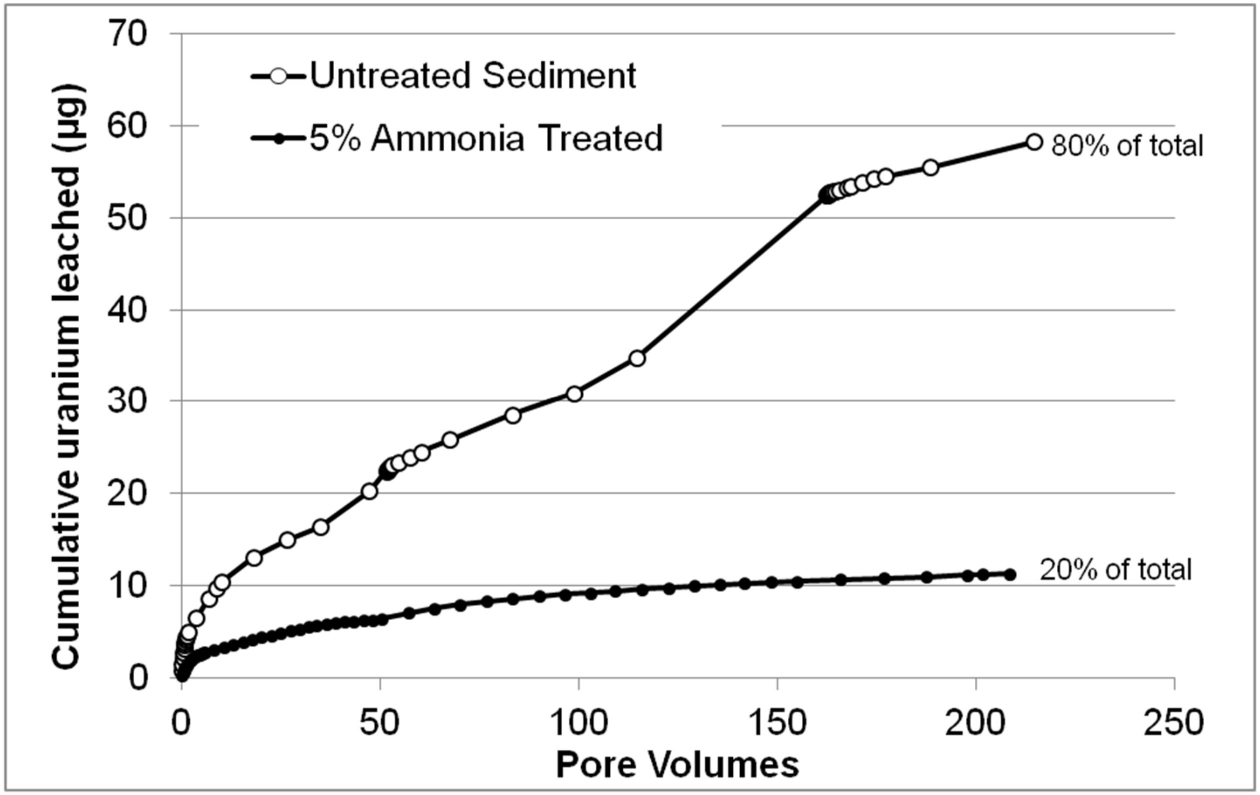


- Sequential extraction method

  - Groundwater (mobile in pore water)
  - Ion exchange (mobile, sorbed)
  - pH 5 acetate (moderately mobile, carbonate rind)
  - pH 2.3 acetic acid for 1 week (slow release, carbonate)
  - 8M Nitric acid at 95C (functionally immobile, total)

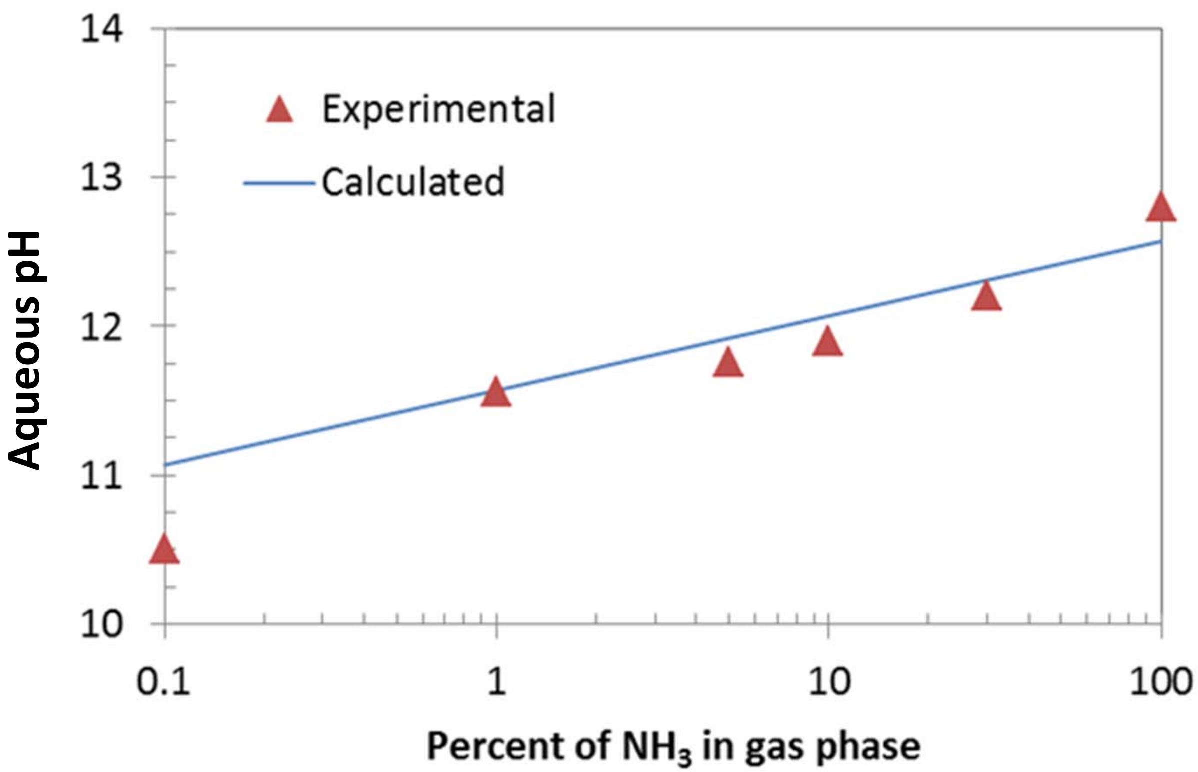
# Sequential Extraction and Leaching Results



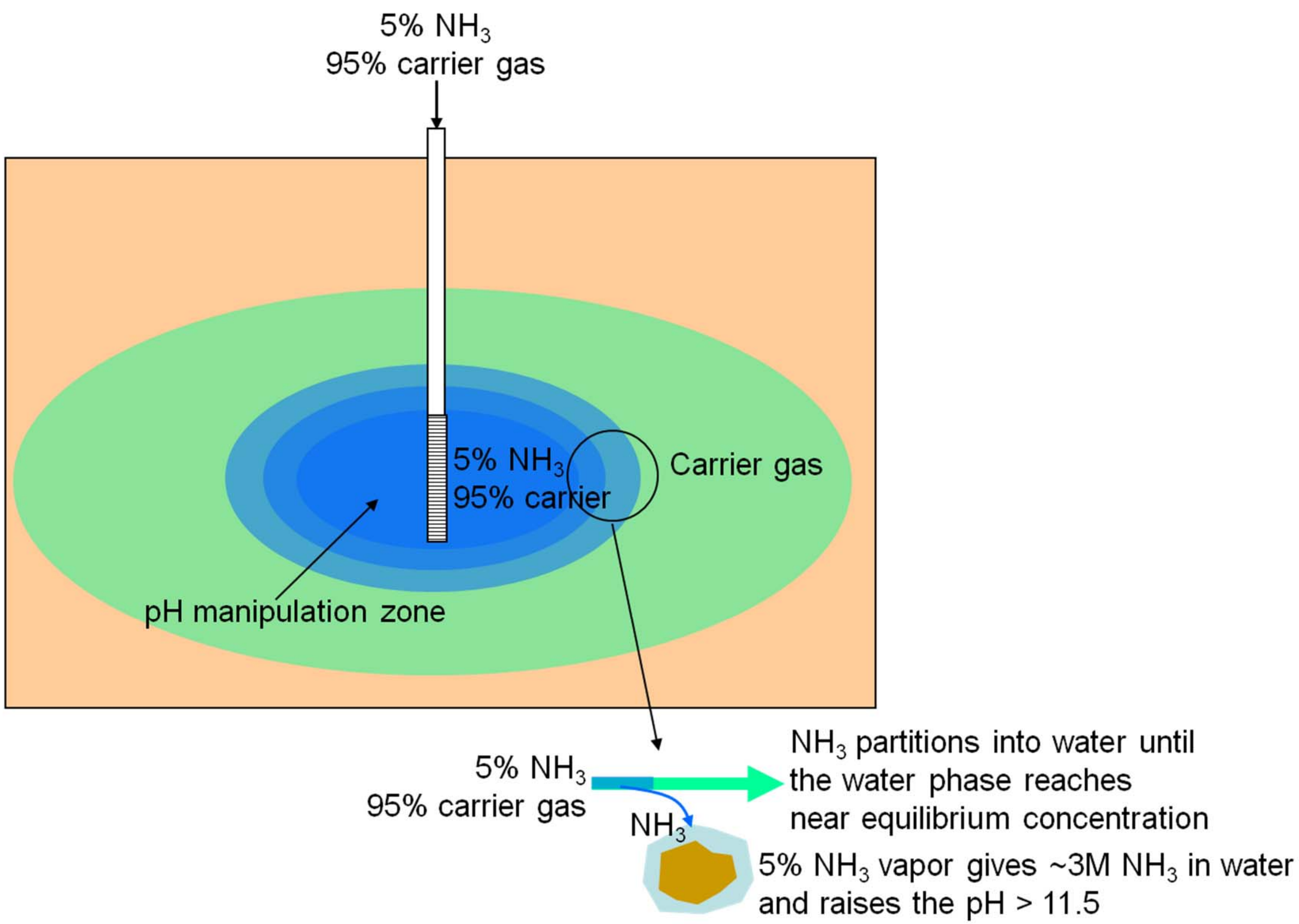
# Ammonia Partitioning into Water

- Partitioning is reasonably well predicted by Henry's Law such that field design calculations can be developed



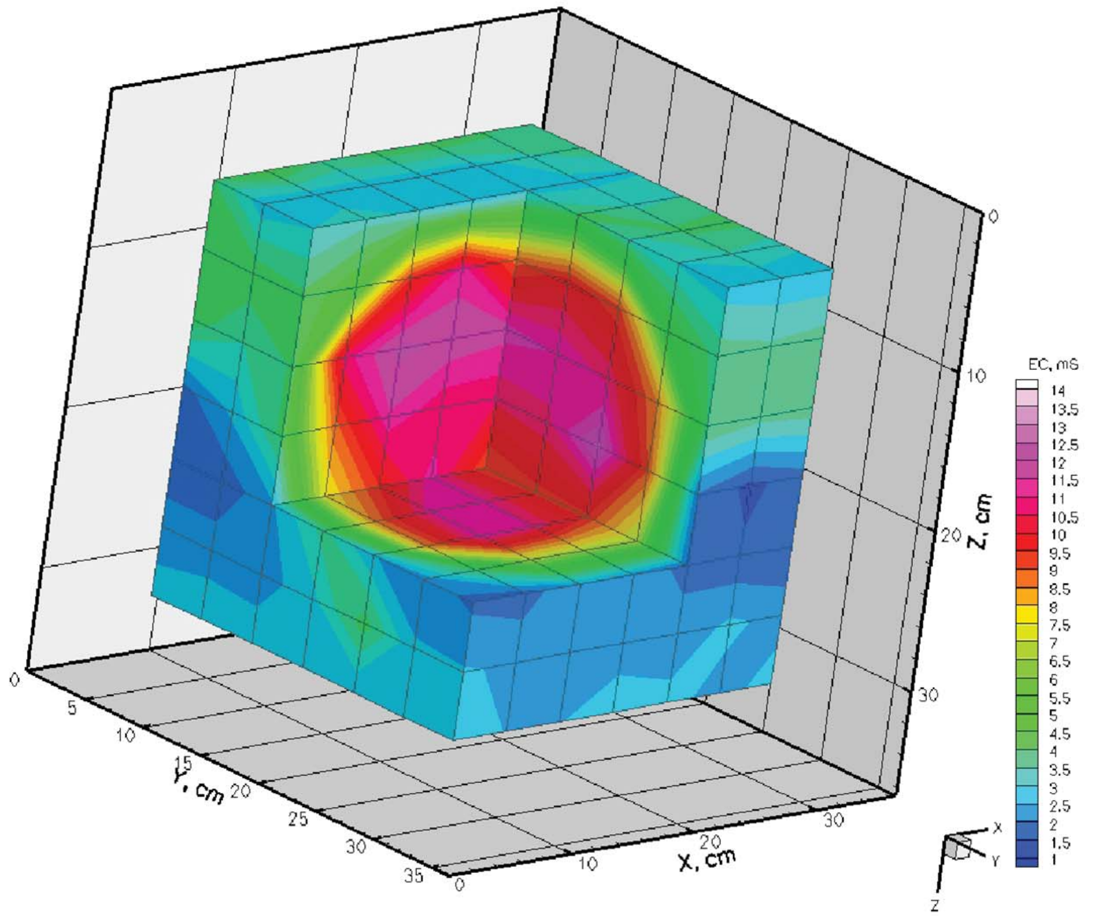
# Field Design





# Ammonia Delivery

- Ammonia injected into a cube of sediment



# Treatment of Low Permeability Zones

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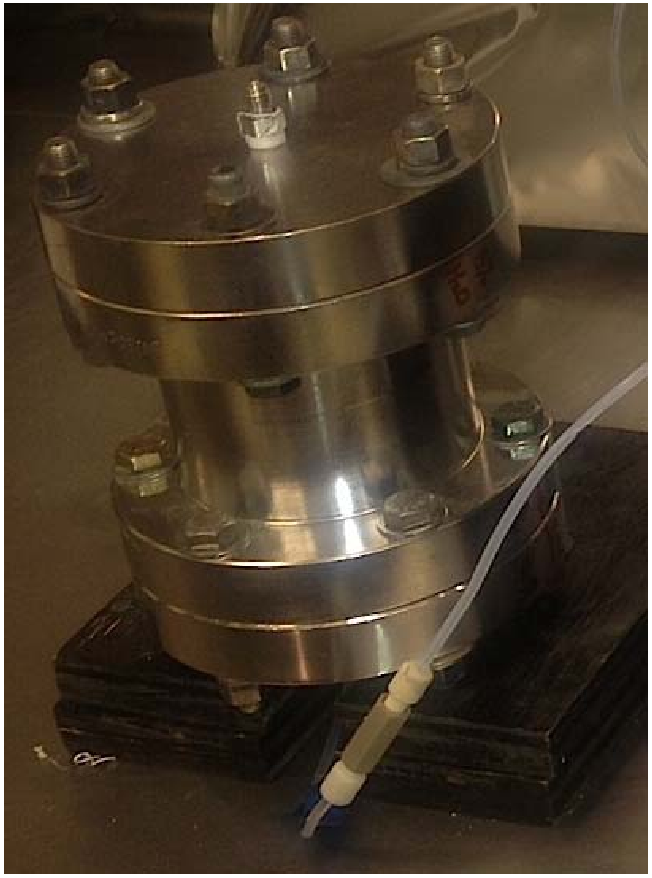
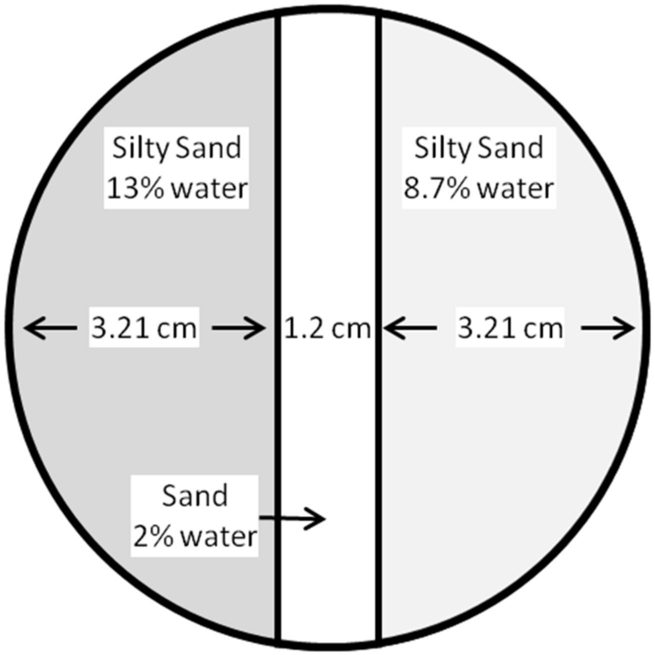
- Plan view of packing for a large soil column test (10 cm length)





# Vadose Zone Considerations

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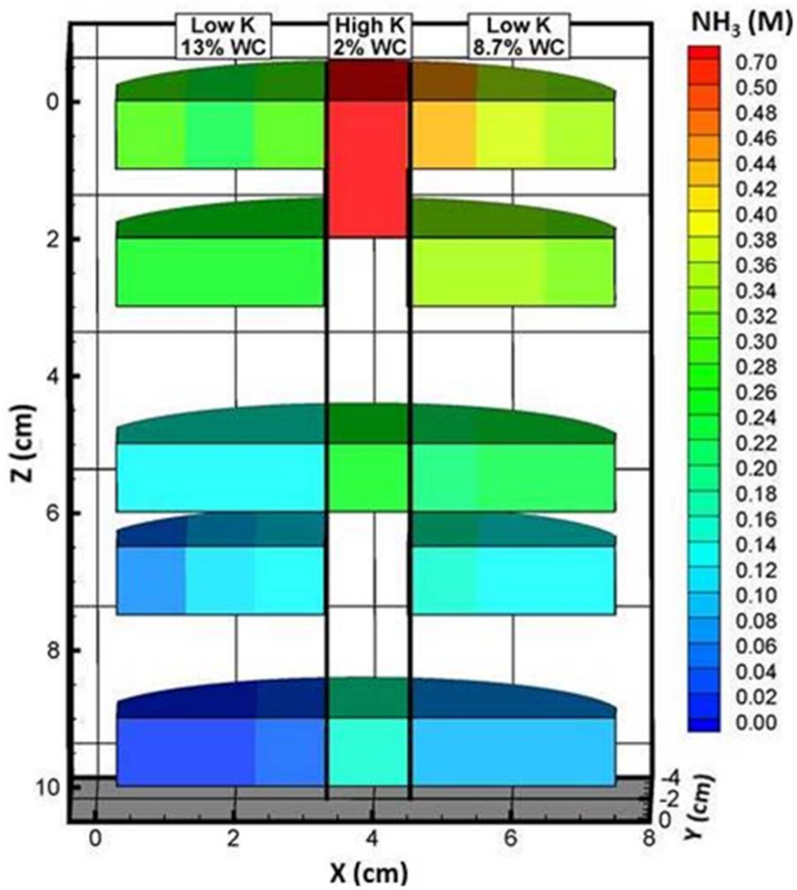
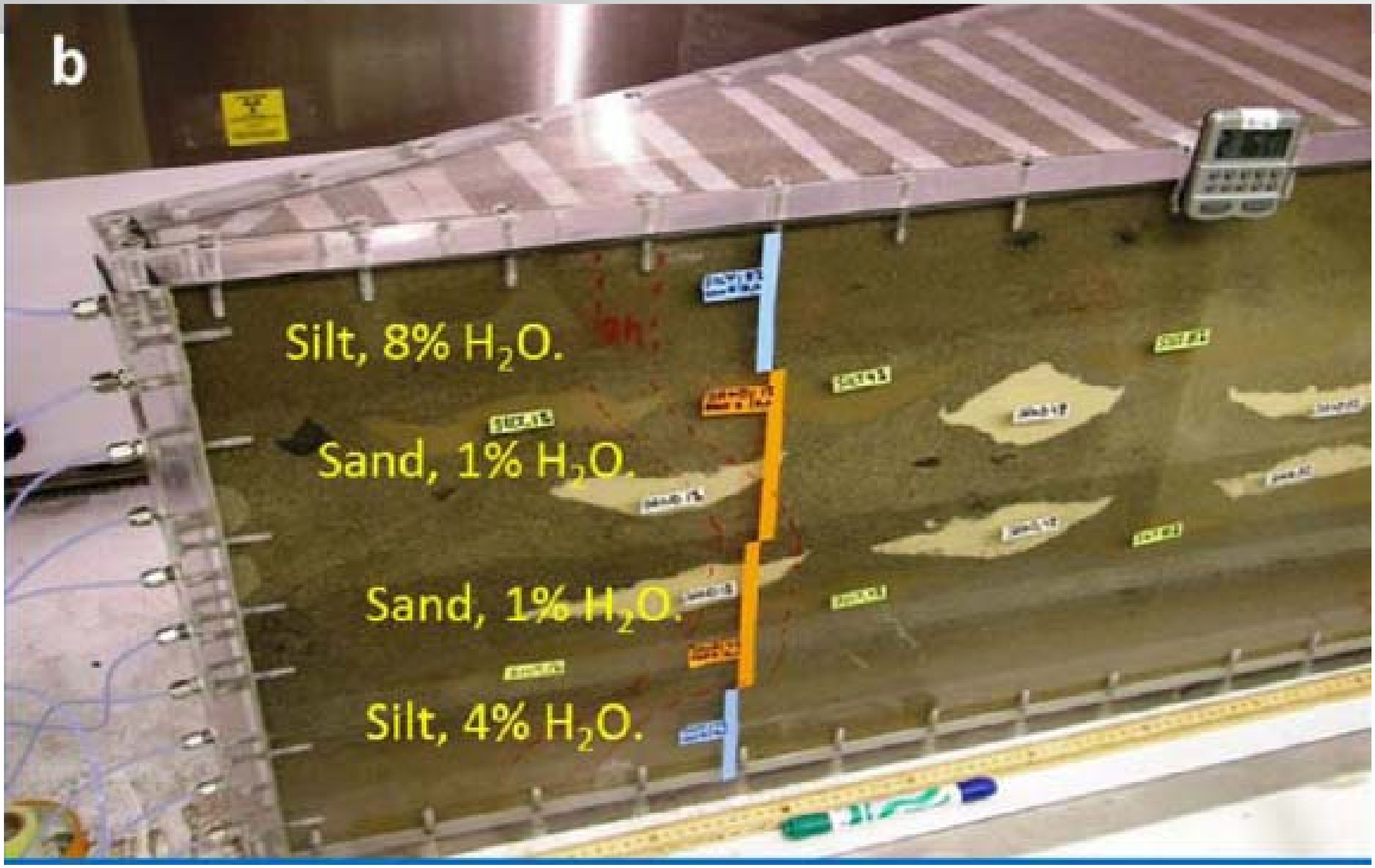
- Diffusion of a 0.1 M ammonia pore-water concentration front (pH > 11) from a 5% ammonia gas boundary
  - 5 cm/week, and 8.7% moisture silty sand
  - 3.4 cm/week for 13% moisture silty sand

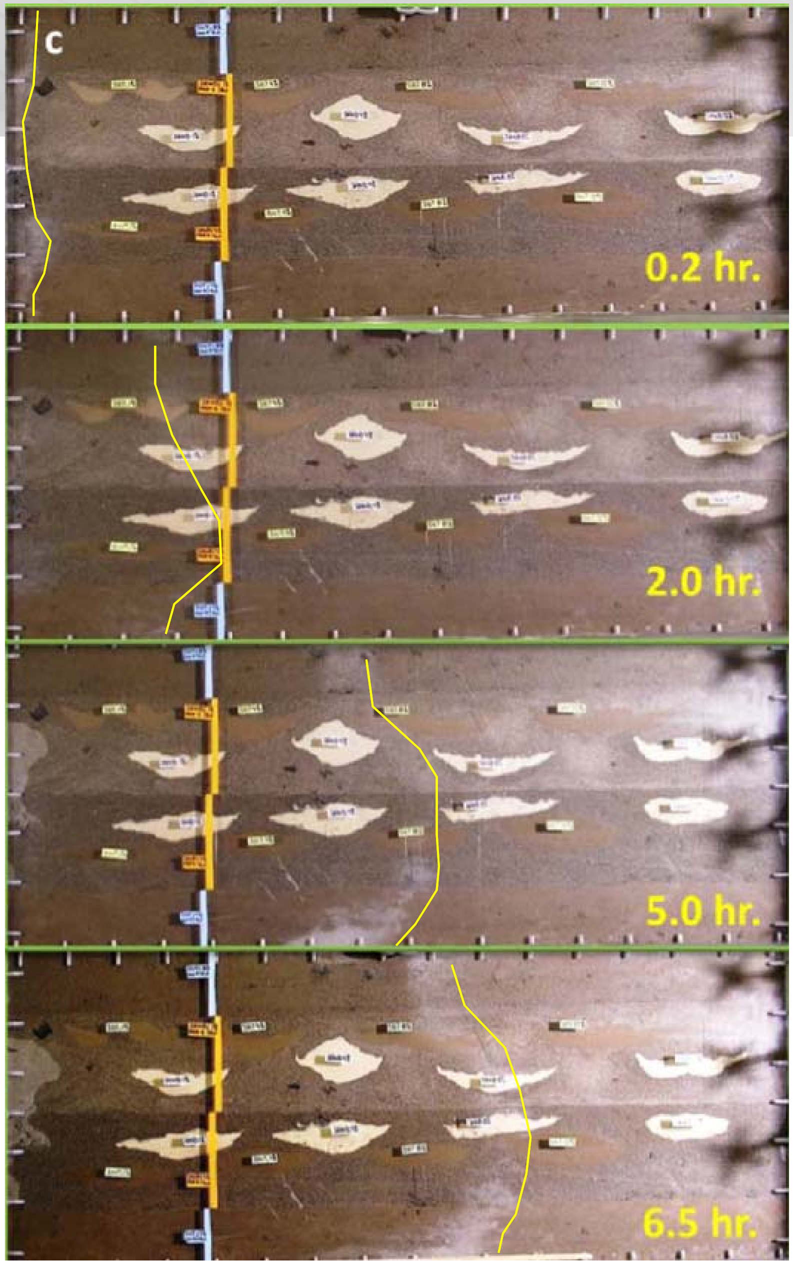


# Laboratory Injection

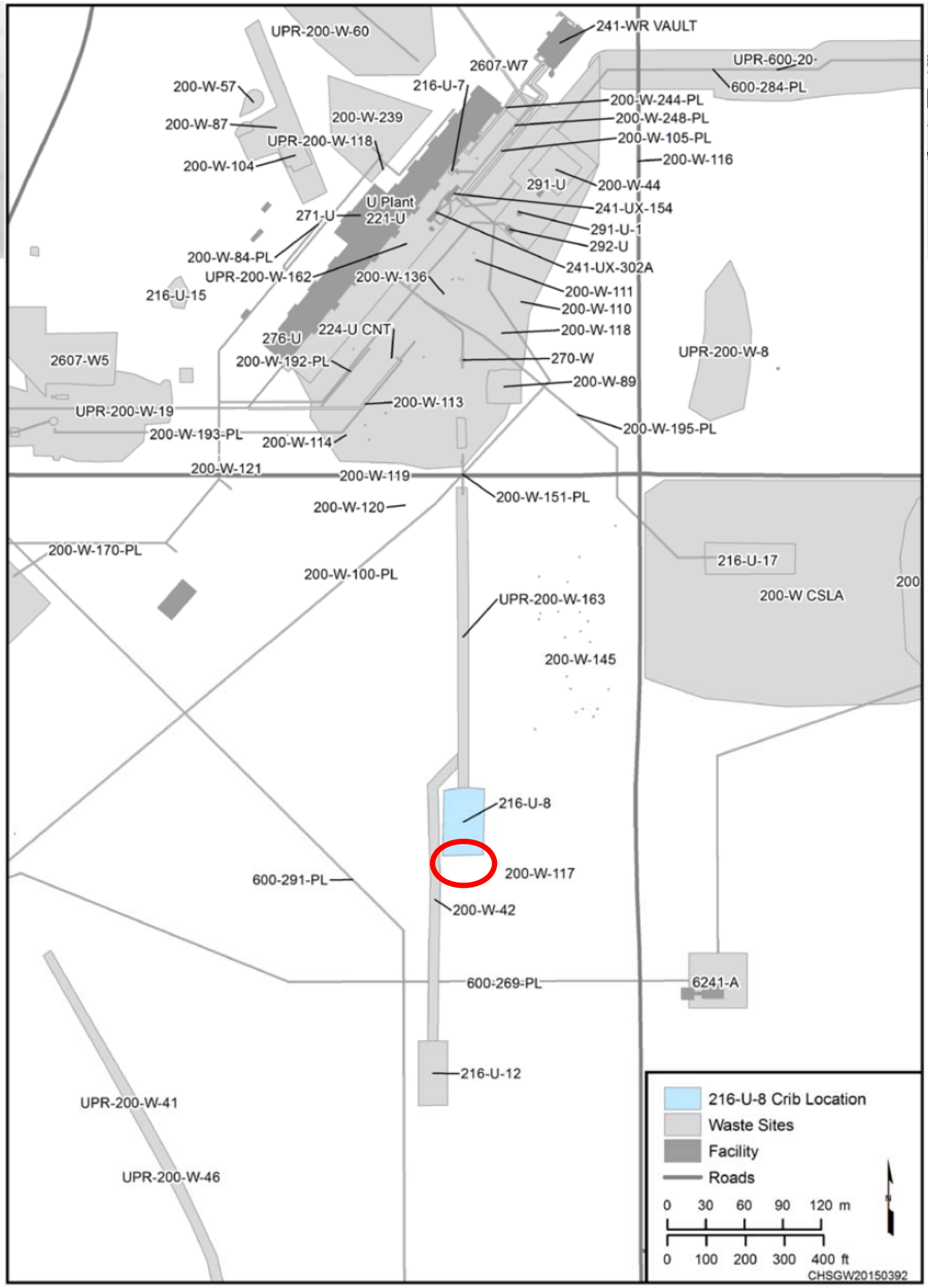


# Laboratory Injection

- Injection across permeability contrasts showed relatively even movement of the injection front.
- Post injection analysis showed ammonia distribution into fine sand and silt lenses



# Test Location: 216-U-8 Crib



# Uranium Distribution and Target Test Zone at the 216-U-8 Site

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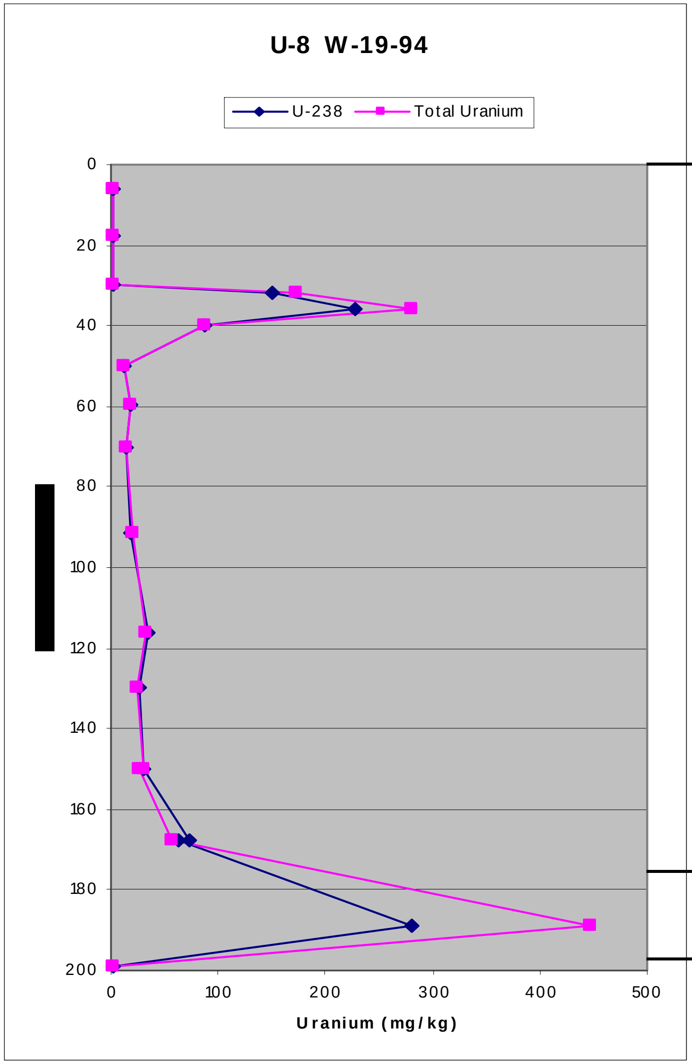
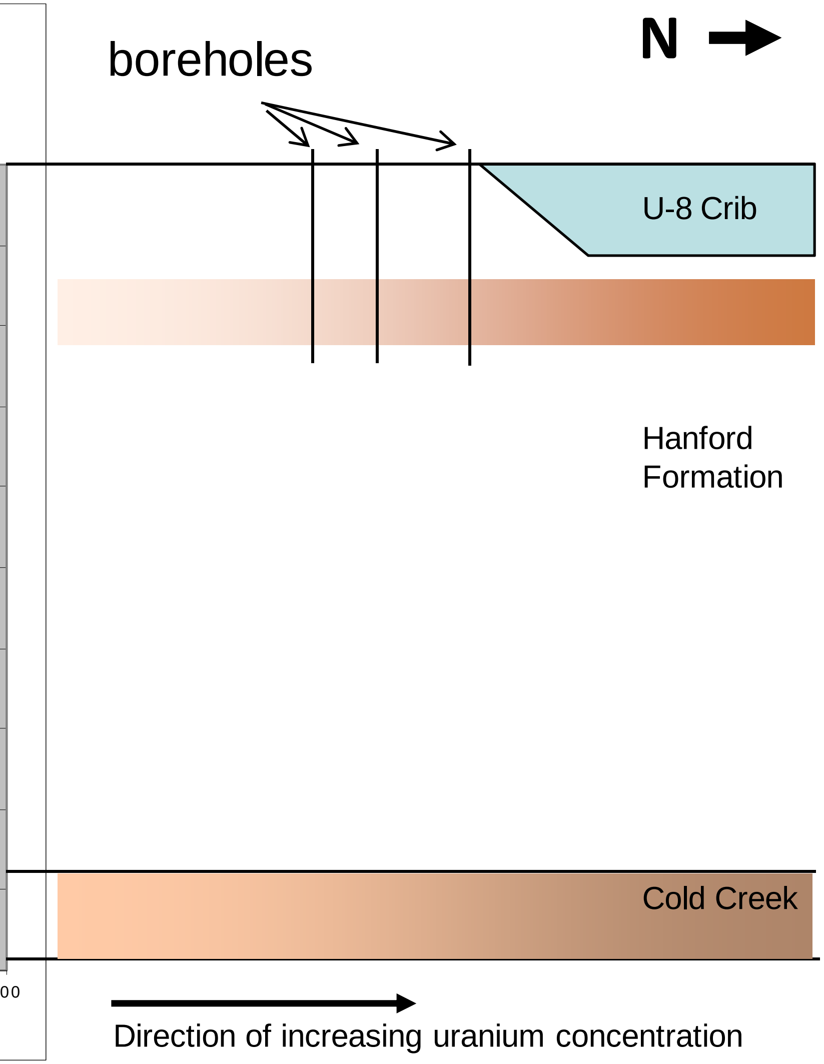
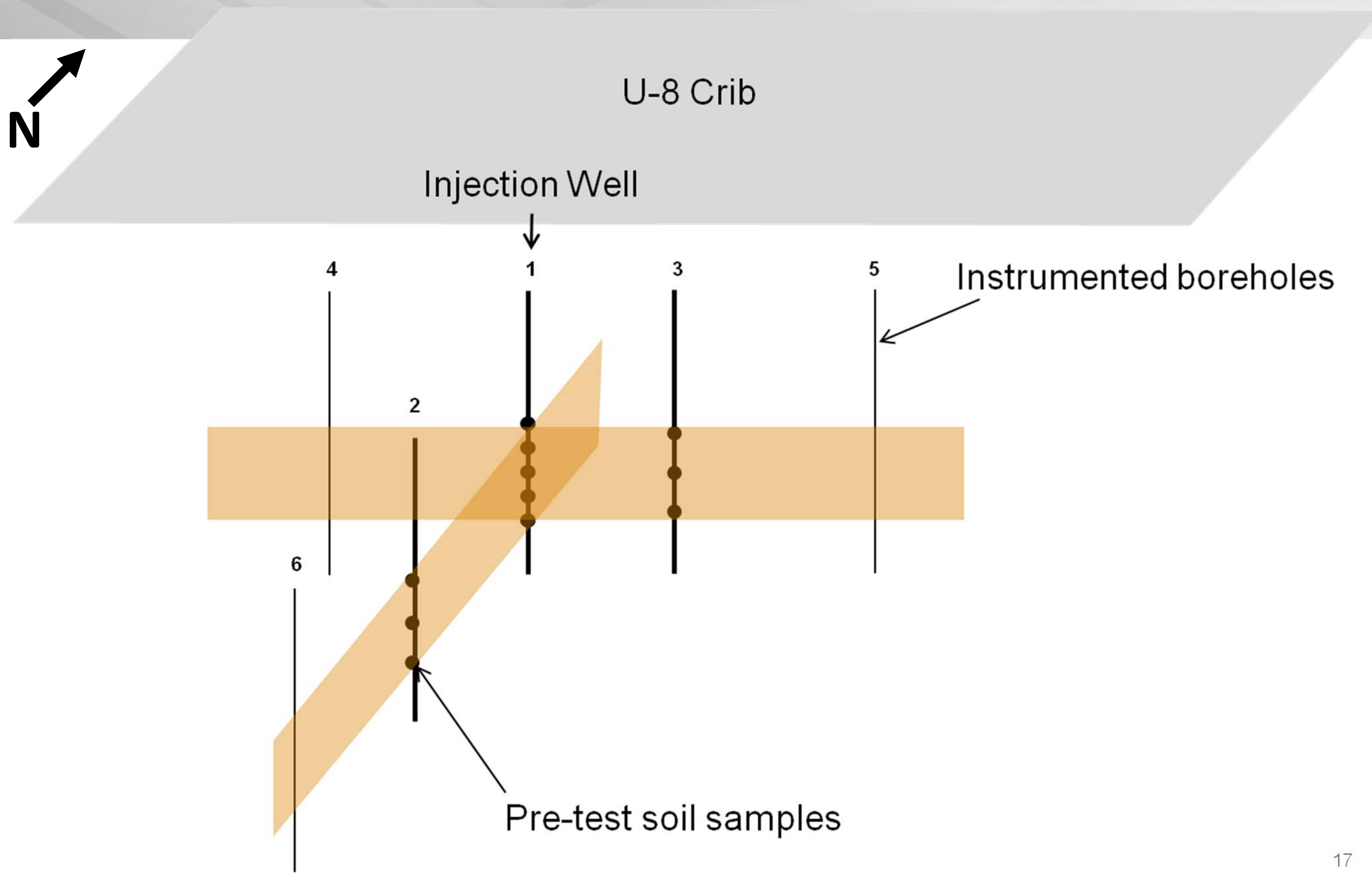


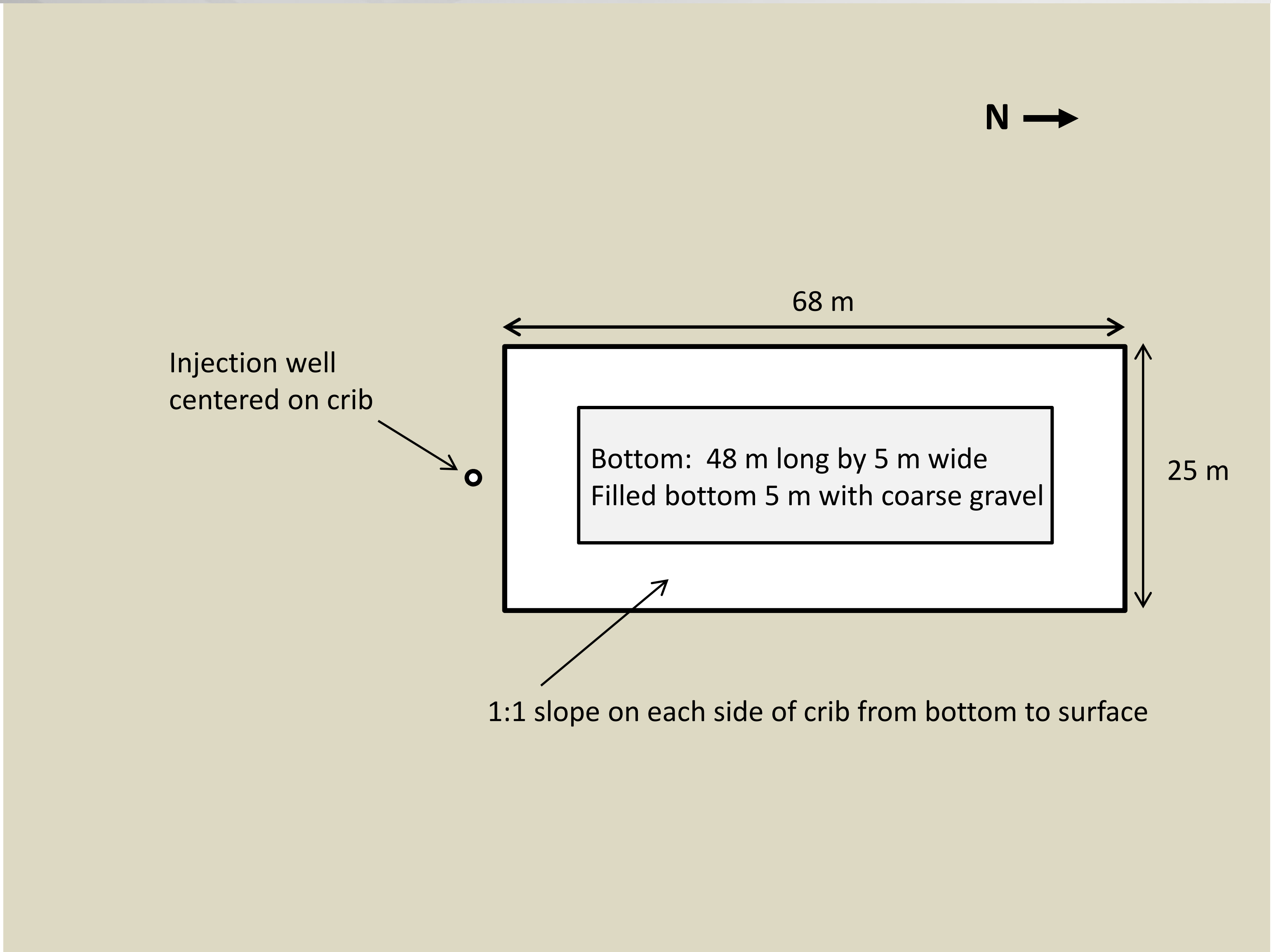



# Site Well/Borehole Layout



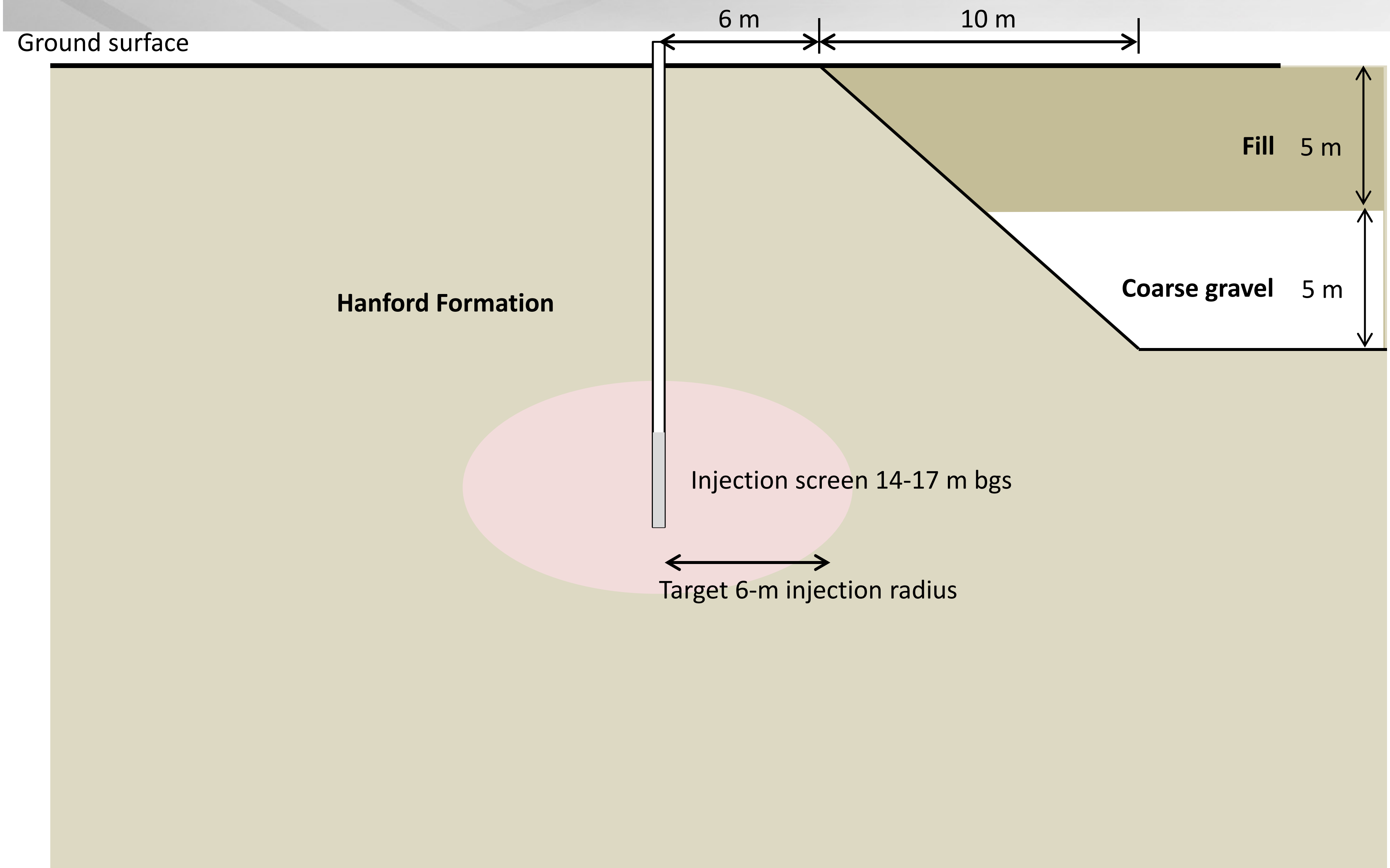


# Plan View

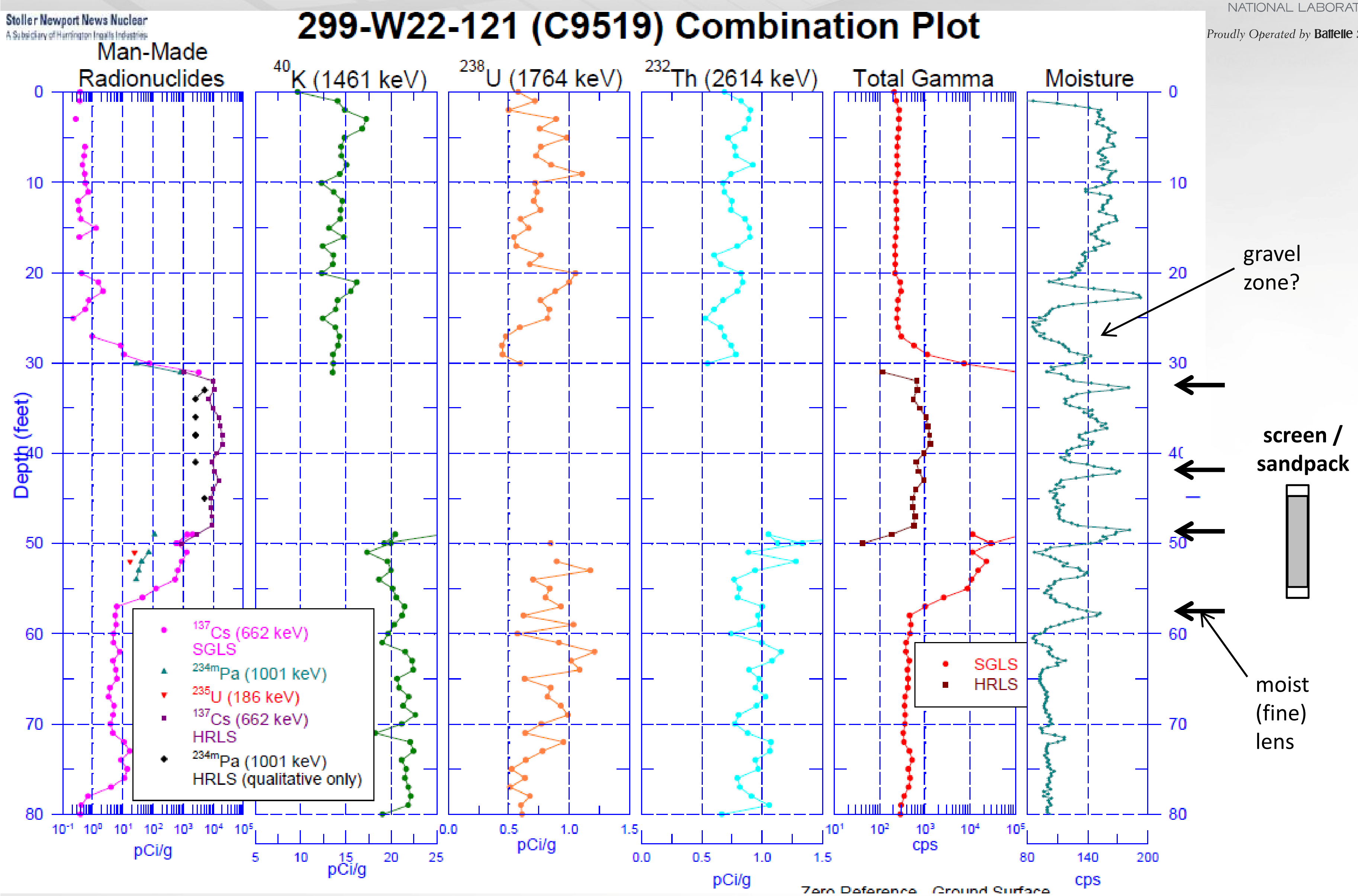

N
68 m
Injection well
centered on crib
Bottom: 48 m long by 5 m wide
Filled bottom 5 m with coarse gravel
25 m
1:1 slope on each side of crib from bottom to surface

# Cross Section





# 299-W22-121 (C9519) Combination Plot



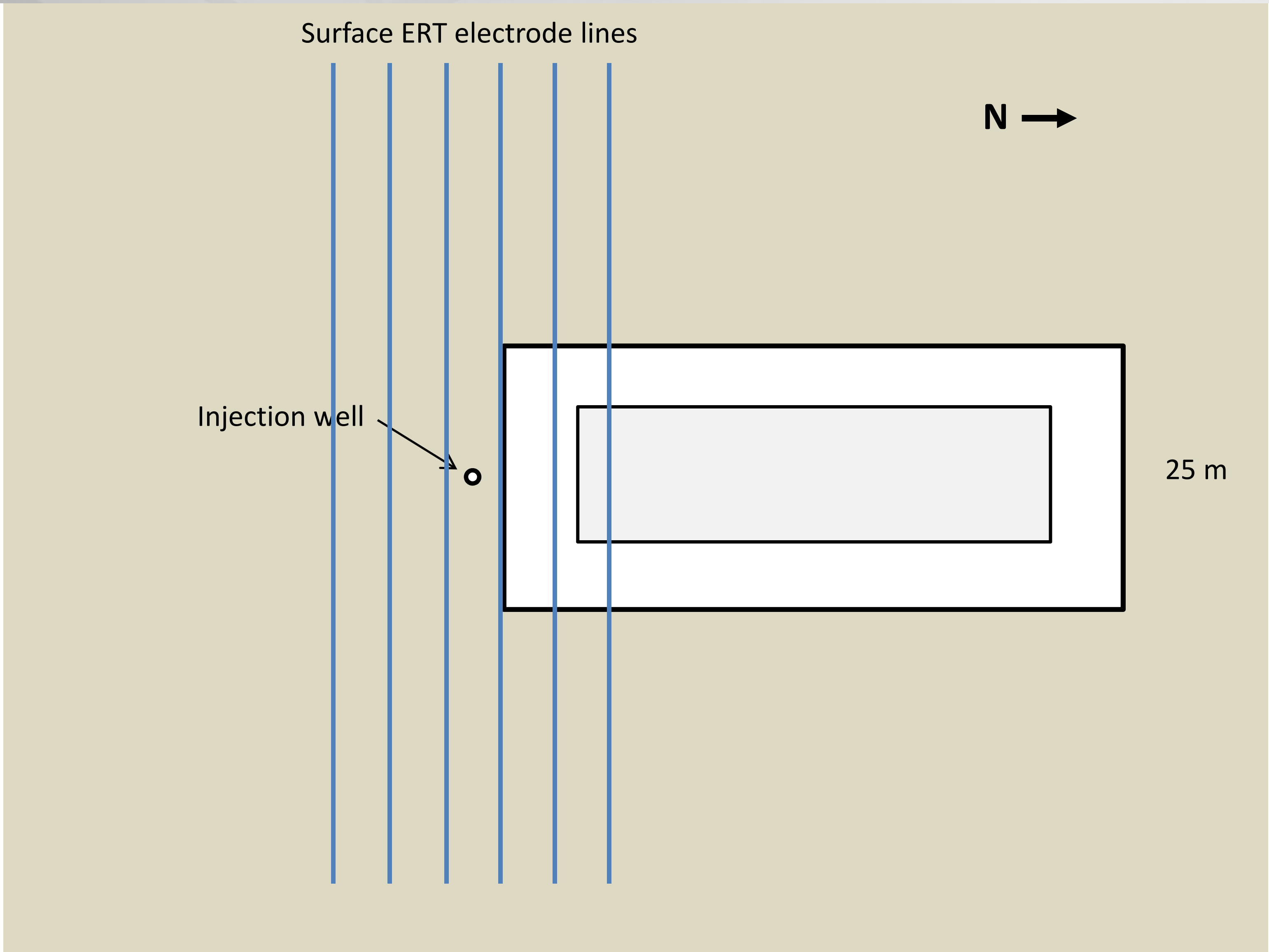
# Site Monitoring



- Ground Surface Ammonia Monitoring
  - Ammonia trailer
  - All piping joints
  - Perimeter/area monitors at ground surface
  - Subsurface gas sampling ports

- Injection Monitoring
  - Electrical Resistivity
  - Temperature
  - Subsurface gas samples

# Surface Electrical Resistivity Tomography



# Subsurface Monitoring

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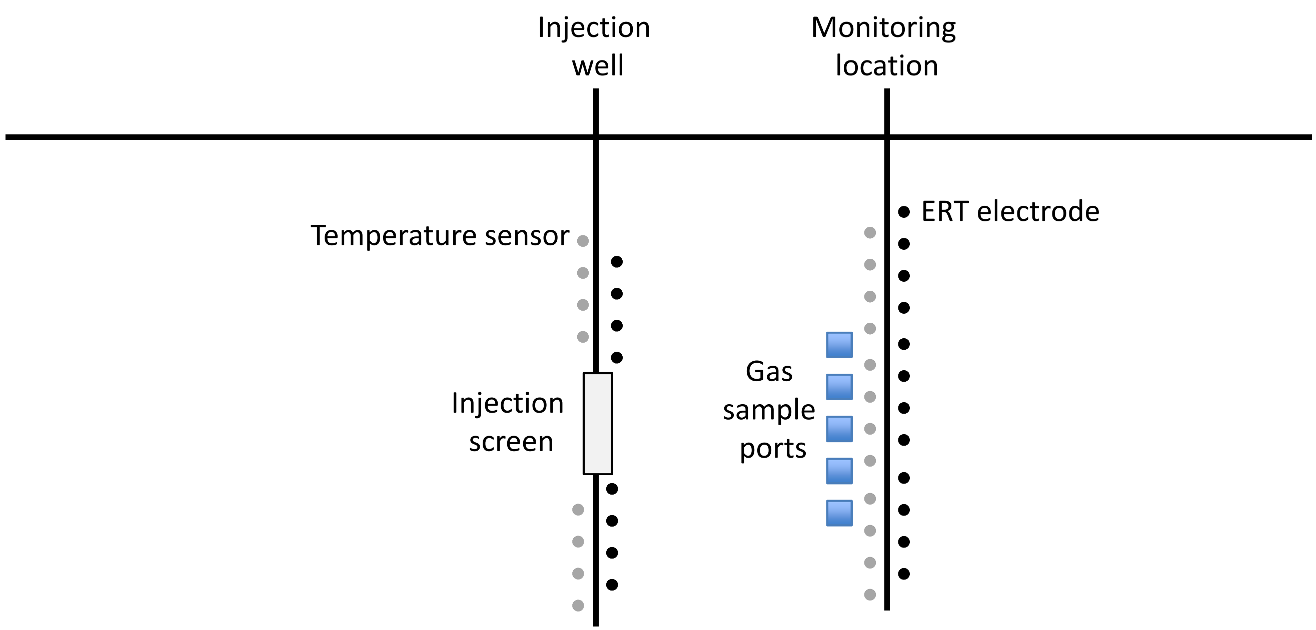
- Cross-hole ERT
- Monitoring for lateral and vertical movement



# Test Objectives



- Determine design and operational parameters
- Demonstrate field-scale treatment
- Demonstrate field-scale equipment
- Collect sufficient information to support consideration of ammonia treatment for a feasibility study

# Test Design Issues



- Ammonia stock is a liquefied gas
  - Pressure depends on temperature (controlled)
  - Cooling with conversion to gas
  - Mass-flow controller for gas-phase mixing with nitrogen gas
- Need anhydrous conditions
  - Ammonia strongly partitions into water
  - Desiccation will occur near injection well
- Ammonia smell recognized well below hazard level
  - Good warning
  - Personnel concerns

# Test Design Issues

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- Equipment compatibility with ammonia
- Ammonia "reaction" time
  - Pore water concentrations drop over first week or so after injection ceases
  - Temporary interruptions of injection
    - Hours to a few days – no impact
    - Week – may "re-treat" areas already treated
  - Full reaction time for precipitation is months to a year with longer as better
    - In vadose zone "reaction time" is not critical because transport rate is slow
- Ammonia will follow carrier gas flow pattern but be slowed and diffuse more due to interaction with water
  - Still need to consider short-circuit flow paths

# Test Status



- Field equipment installed and ready for injection
- Administrative hold to address concerns for use of ammonia
  - Hazards review board
  - Concern for surrounding activities
    - Timing of activity

# Conclusions



- Vadose zone remediation is aimed at decreasing the contaminant flux from the vadose zone to the groundwater
- Geochemical manipulation with ammonia creates low-solubility precipitates that are effective in reducing uranium mobility
  - Not sensitive to re-oxidation
  - Favorable delivery properties for the vadose zone
- Use of ammonia must consider hazards and appropriate controls

# References


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