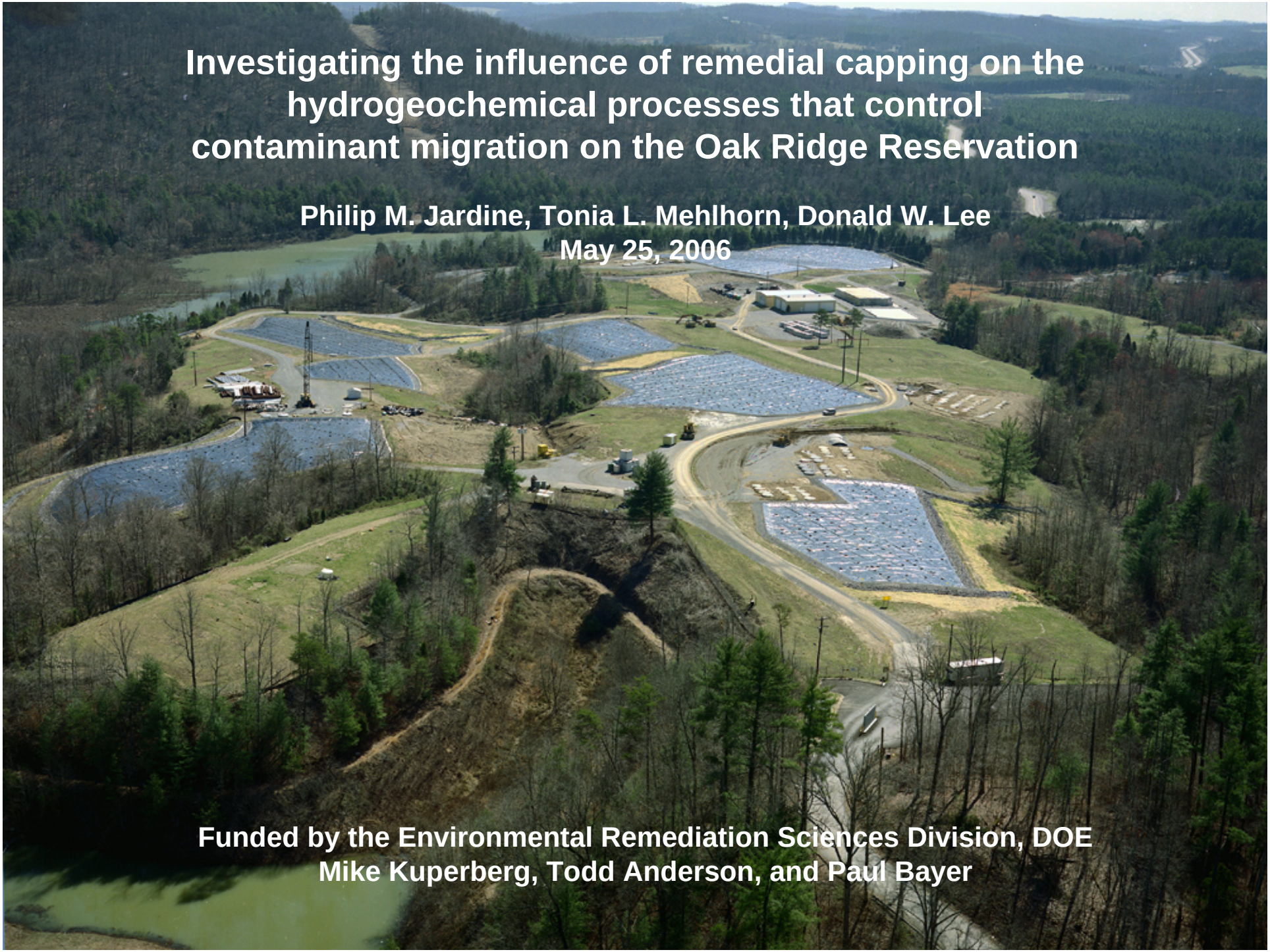

Investigating the influence of remedial capping on the hydrogeochemical processes that control contaminant migration on the Oak Ridge Reservation

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Mike Kuperberg, Todd Anderson, and Paul Bayer

Presentation outline

- Contaminant fate and transport issues at Oak Ridge and historical capping endeavors

- Current remedial action

- Evaluating system responses

Example problem: Pits and trenches on the Oak Ridge Reservation

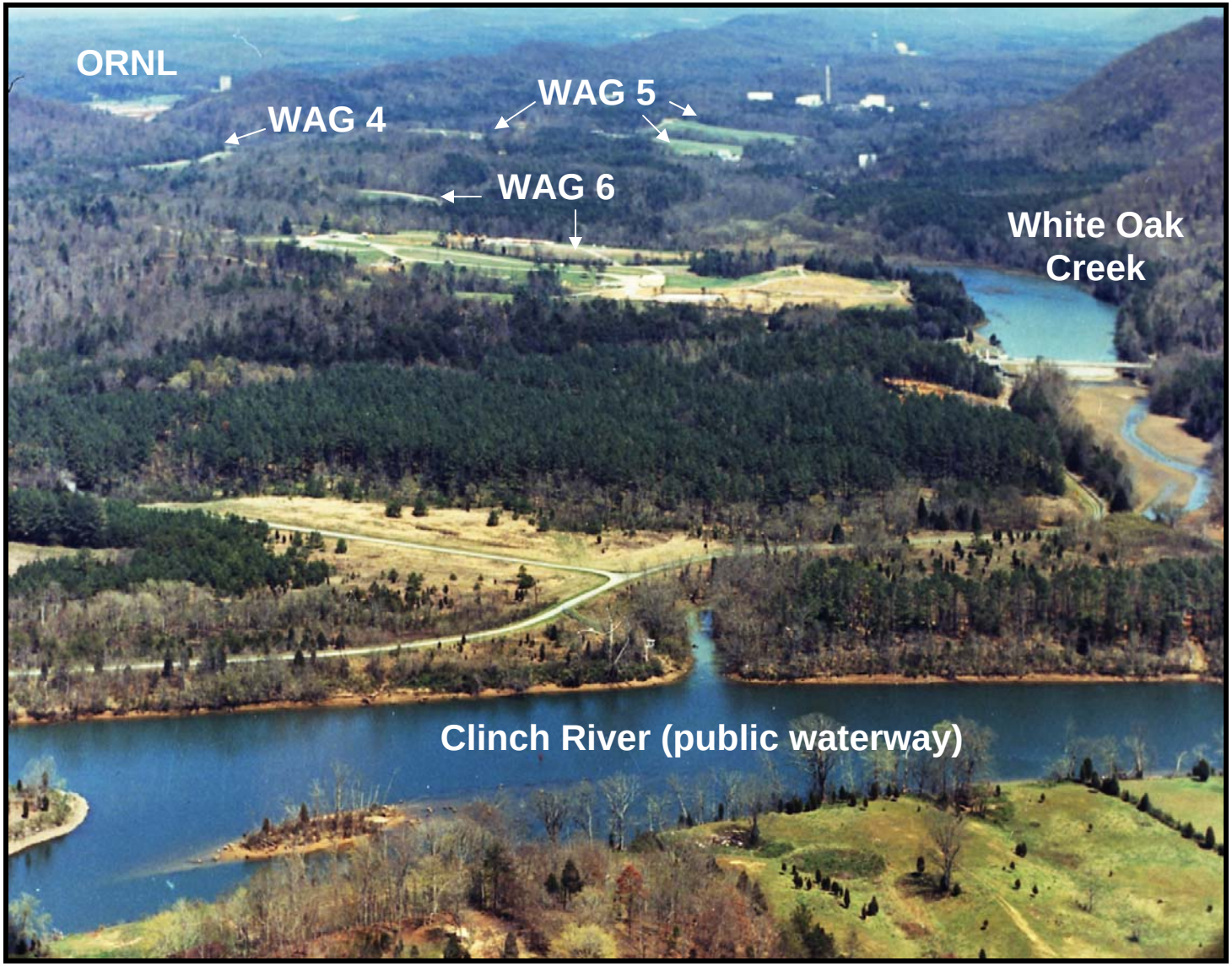
Thousands of unlined pits and trenches filled with low- and high-level radioactive waste.

Large annual rainfall inputs (1400 mm/y) with recharge rates as high as 50%.

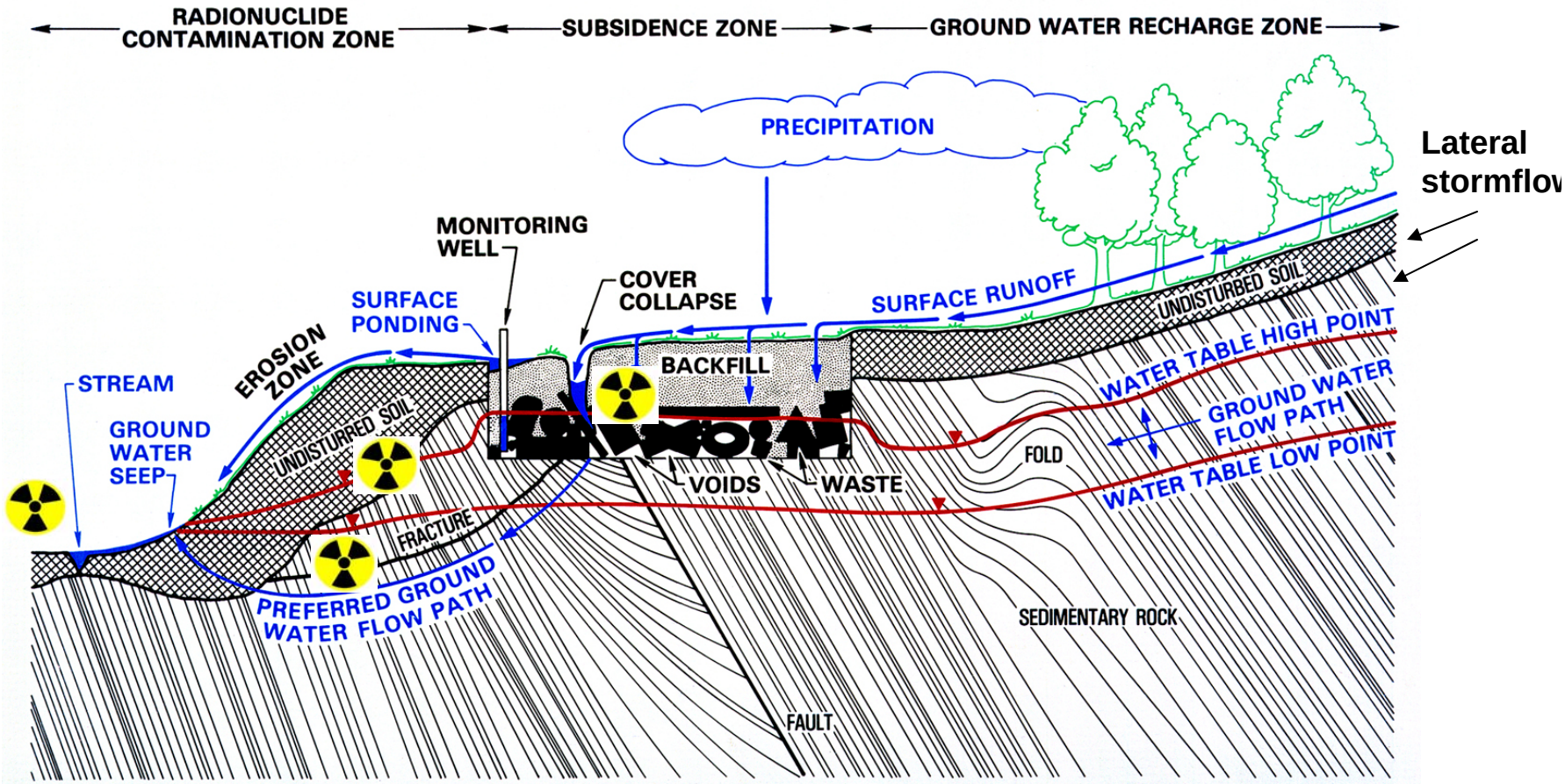
Secondary contaminant source is massive where radionuclides have been disseminated across vast subsurface environments.

Remediation has historically targeted "hot-spots" with *in situ* and *ex situ* treatment of high-risk exit pathways (e.g. preferential flow zones, seeps). Past capping endeavors have failed.

The scope of the problem is massive



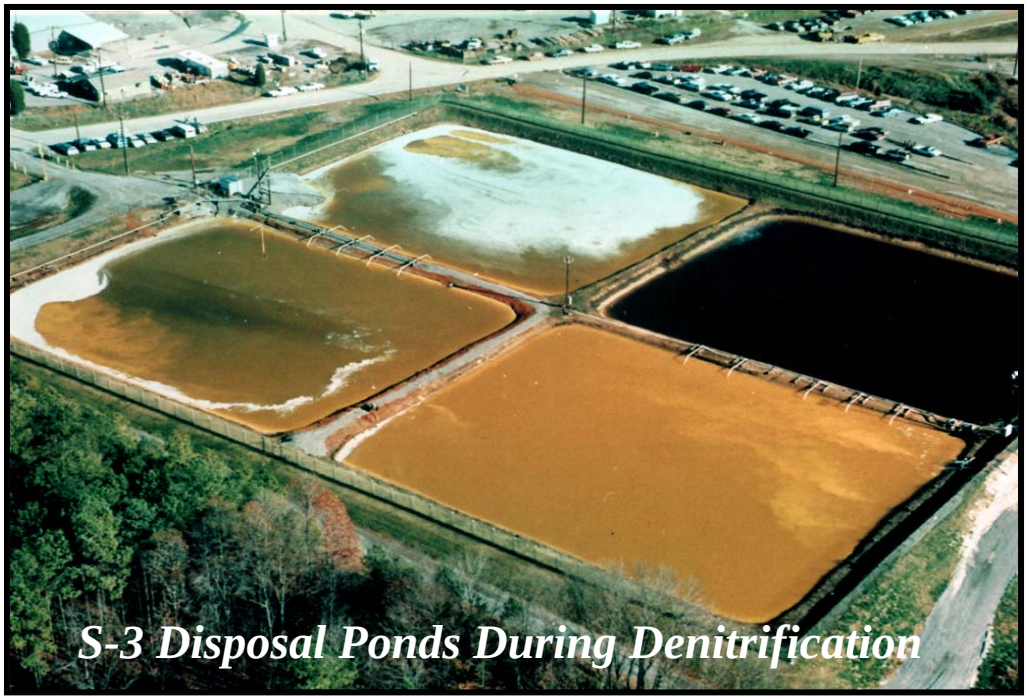
PROBLEMS ENCOUNTERED IN THE SHALLOW LAND BURIAL OF LOW-LEVEL WASTE

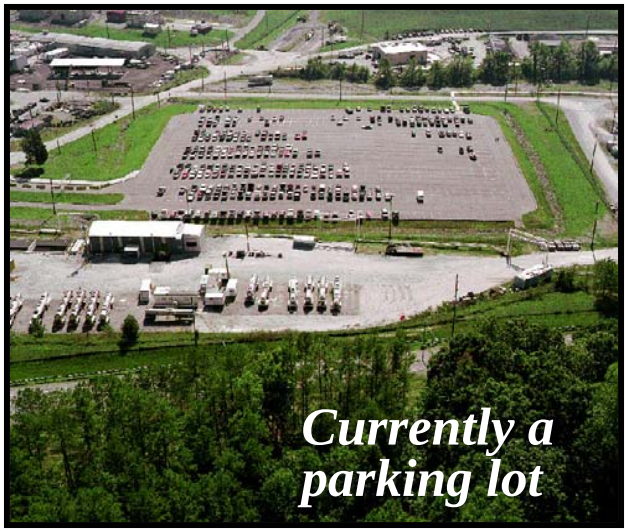


Lateral stormflov

- Lateral storm flow through trenches.
- Elevated groundwater.
- Bathtubbing.
- Direct contact with underlying geology thus preferential flow and upwelling of contaminants at streams.

Example problem: Large volume, long-duration contaminant sources





- **S-3 ponds are located at DOE's NABIR Field Research Center in the Y-12 complex of Oak Ridge, Tennessee.**

- **Unlined surface impoundments received acidic nitrate and U-bearing waste at a rate of 10 million liters / year for 32 y.**

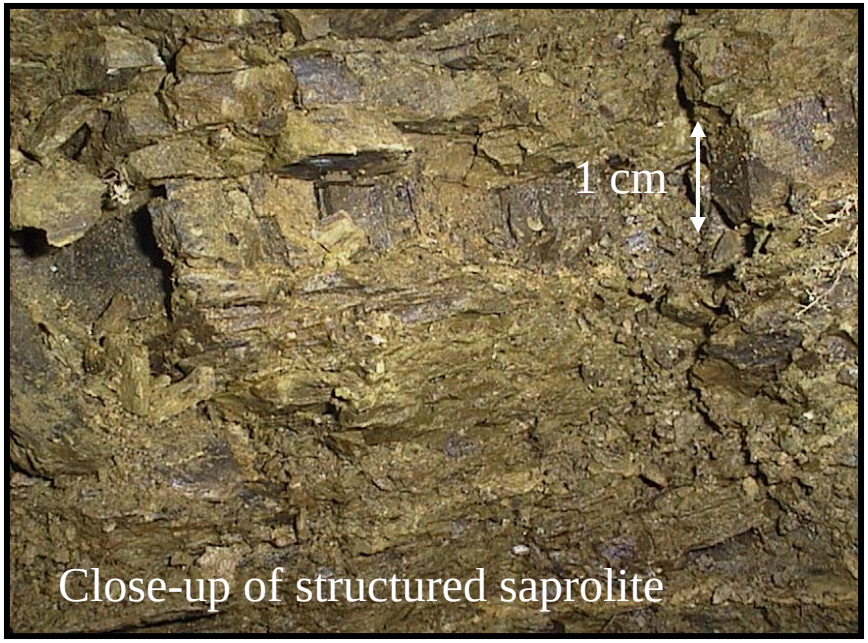
- **Attempts were made to neutralize and denitrify the ponds in 1984, followed by subsequent capping as an asphalt parking lot in 1984.**

- **Long-term infiltration has resulted in a contaminated area of 98 ha. Groundwater nitrate still as high as 40,000 ppm, U at 60 ppm, pH at less than 3.5 and highly buffered.**

Oak Ridge media consisting of interbedded fractured weathered shales and limestone

Overlying Saprolites

Underlying Bedrock



Close-up of structured saprolite

Fractures

Constitute < 5 –10 % of total porosity, yet are able to carry > 95% of saturated groundwater flux.

Serve as conduits for preferential contaminant migration.

Matrix

Contain > 90-95% of total porosity; however, permeability is orders of magnitude lower than fracture.

Serve as high capacity source and sinks for contaminants.

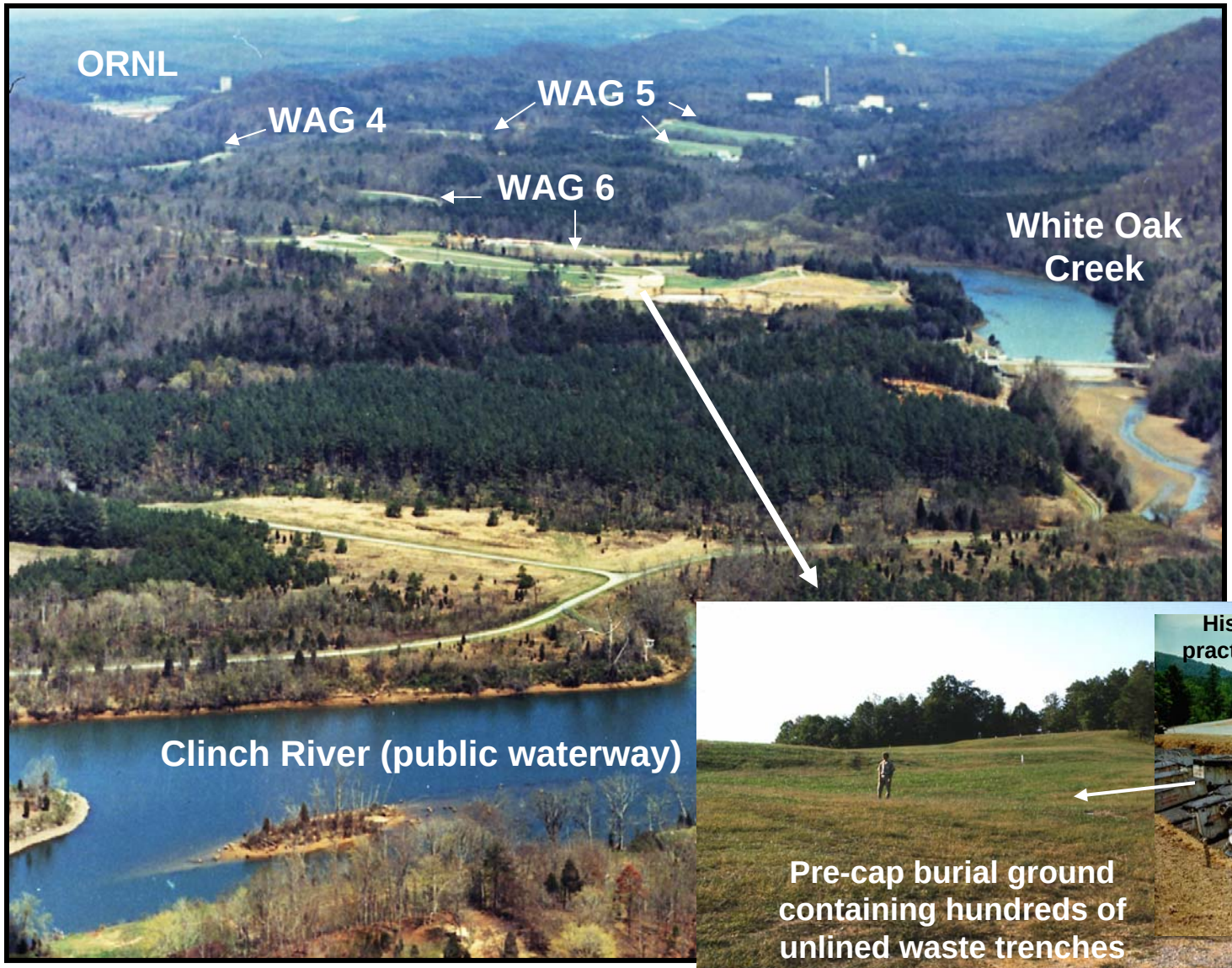
Remediation Dilemma for Secondary Sources

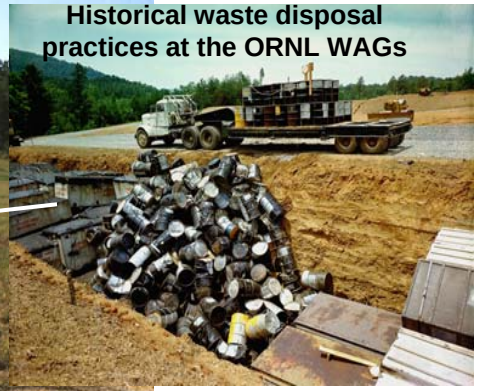
- **In situ treatment of contamination in the soil and rock matrix is not an option due to cost and lack of feasible technologies.**
  - **No feasible removal or immobilization technologies for large volumes of contaminated subsurface saprolites, bedrock, groundwater.**

- **Decision to leave contaminants in-place with aggressive capping, monitoring, and further evaluation of options.**
  - **Stop vertical and lateral storm infiltration into trenches.**
  - **Monitor up gradient and down gradient groundwater wells for contaminant discharge changes.**
  - **Assumption that local scale cap influences on groundwater flow will out weigh regional scale groundwater flow processes.**

Cap Construction Over the Pits and Trenches

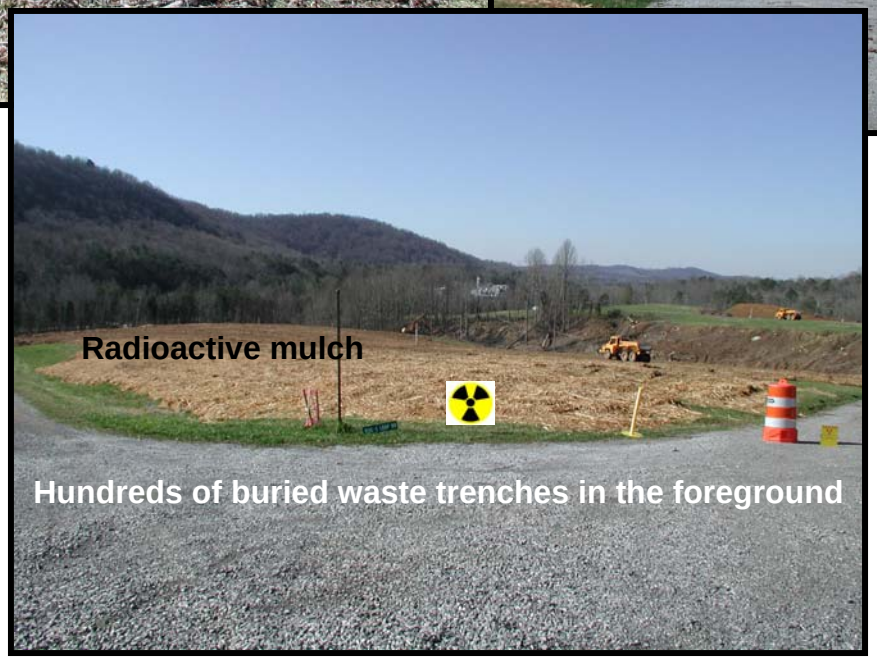
Pre-cap landscape of WAGs 4 through 6





Removing contaminated trees and vegetation downgradient from the WAG 5 waste trenches

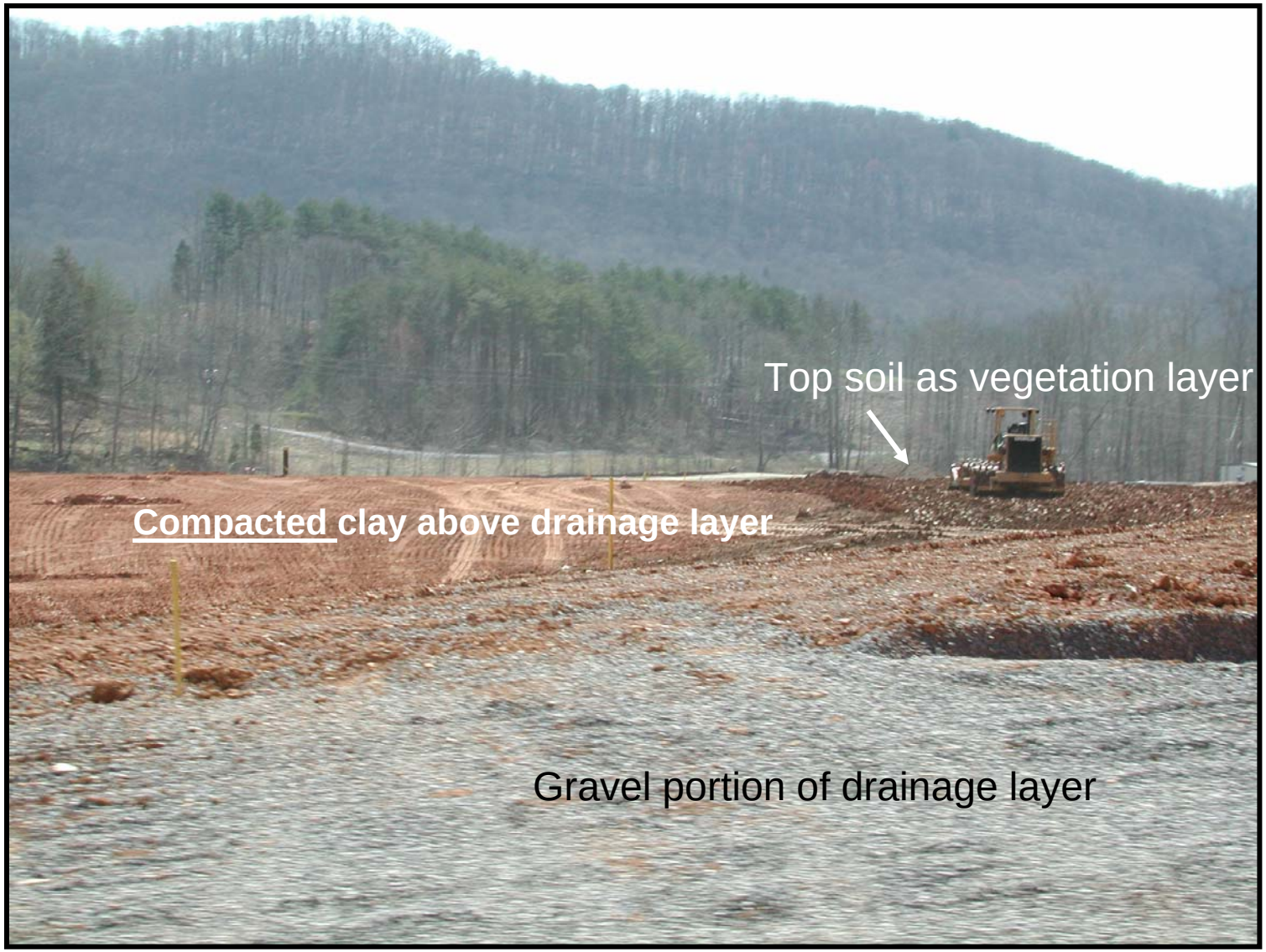
Mulching contaminated trees for burial under the RCRA cap

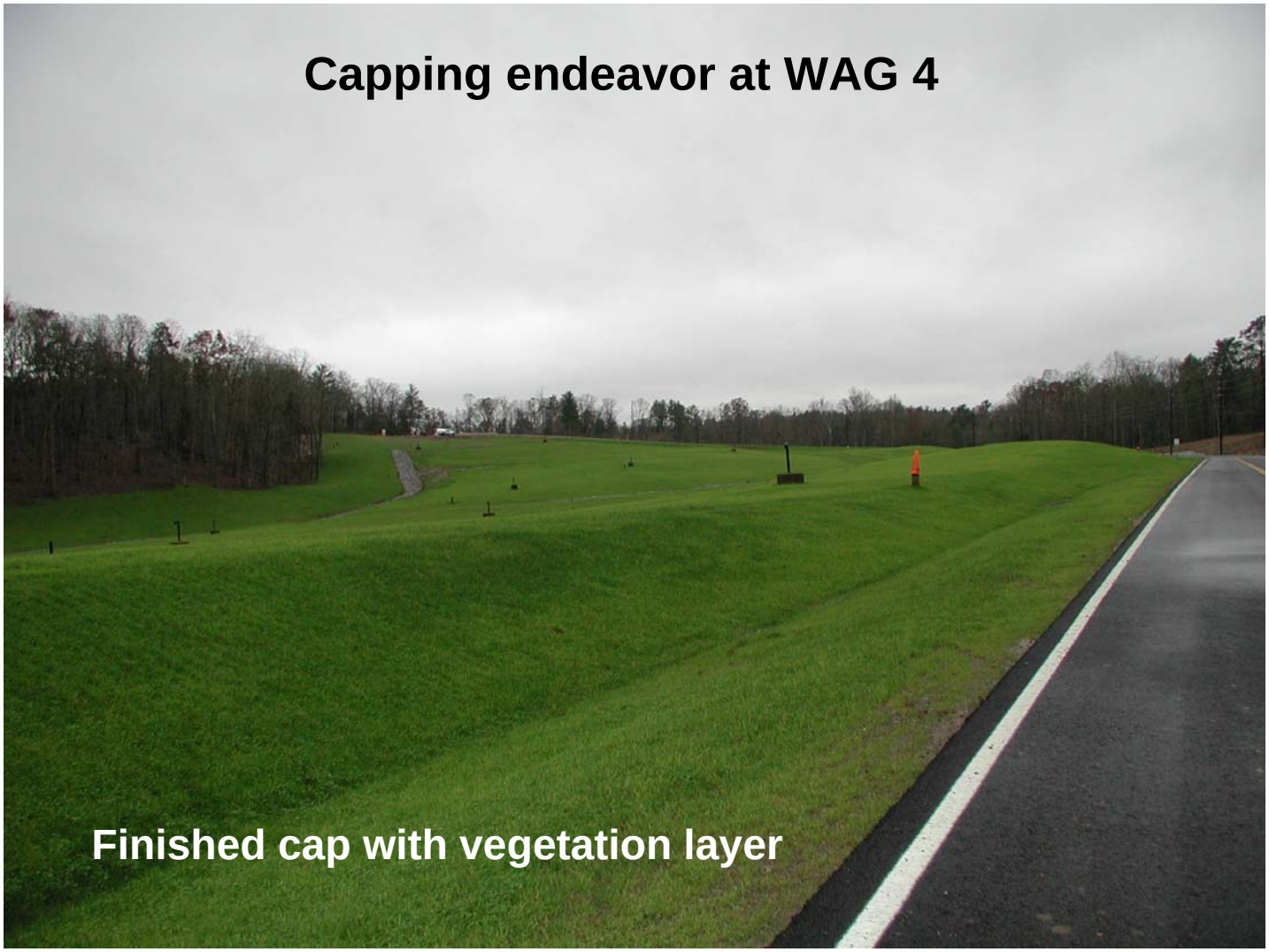


Spreading contaminated mulch above WAG 5 waste trenches

Capping endeavors at WAG 4
(constructing the minimal RCRA cap)

Capping endeavors at WAG 4





How will the new system evolve?

Evaluating system responses to capping

The WAG 5 site now offers a unique scientific opportunity to track the evolution of post-cap processes influencing contaminant migration and immobilization, because we have many years of pre-cap coupled processes information and knowledge.

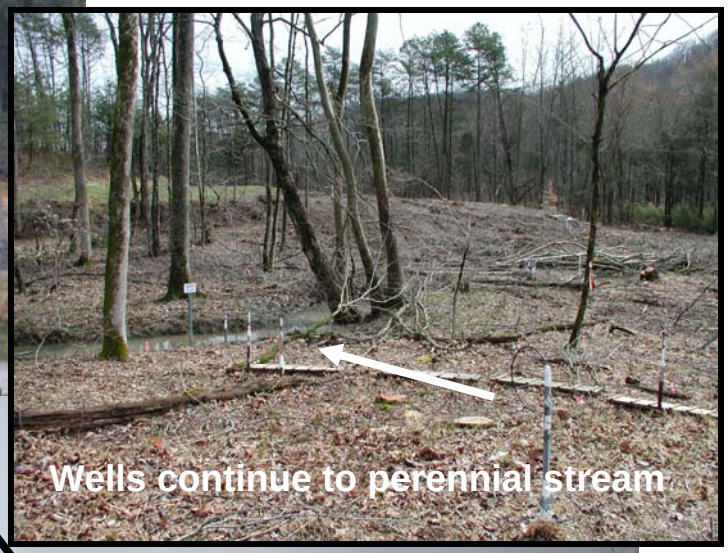
Current efforts are focusing on quantification of the influence of post-cap hydrological, geochemical, and possibly microbial processes on contaminant discharge as a function of scale and time in an effort to assess local-scale cap influences (ha scale) versus un-capped regional-scale groundwater flow influences (km scale) on contaminant discharge.

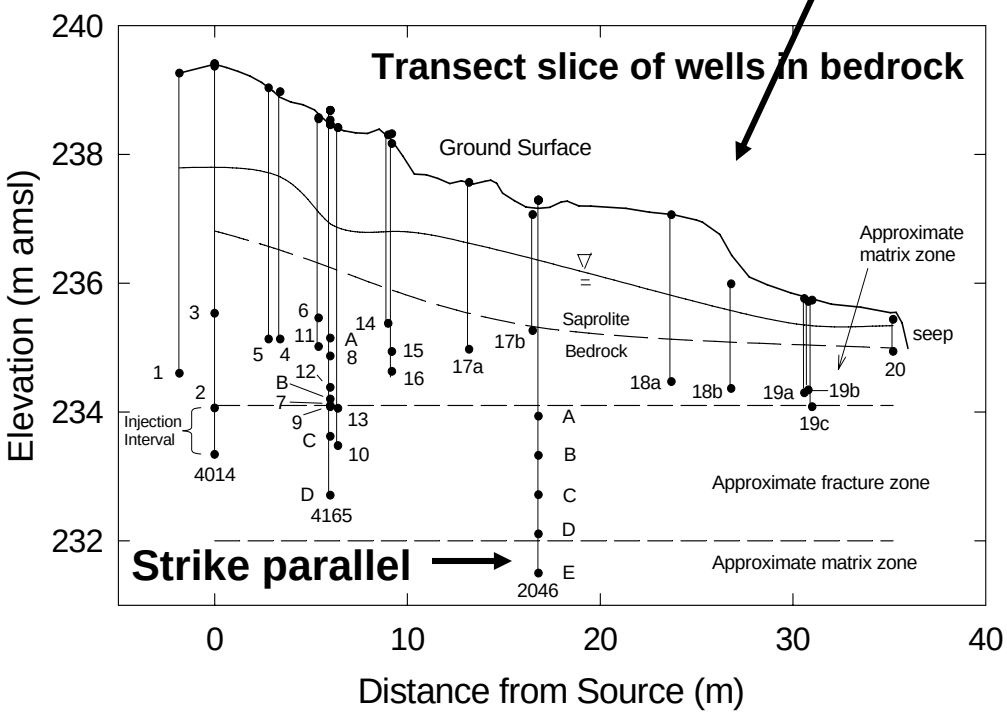
Our rationale is to support the need for a fundamental scientific understanding of the long-term fate, transport, and attenuation of contaminants in the environment as a function of space and time to ensure the effectiveness of remediation and/or natural attenuation processes.

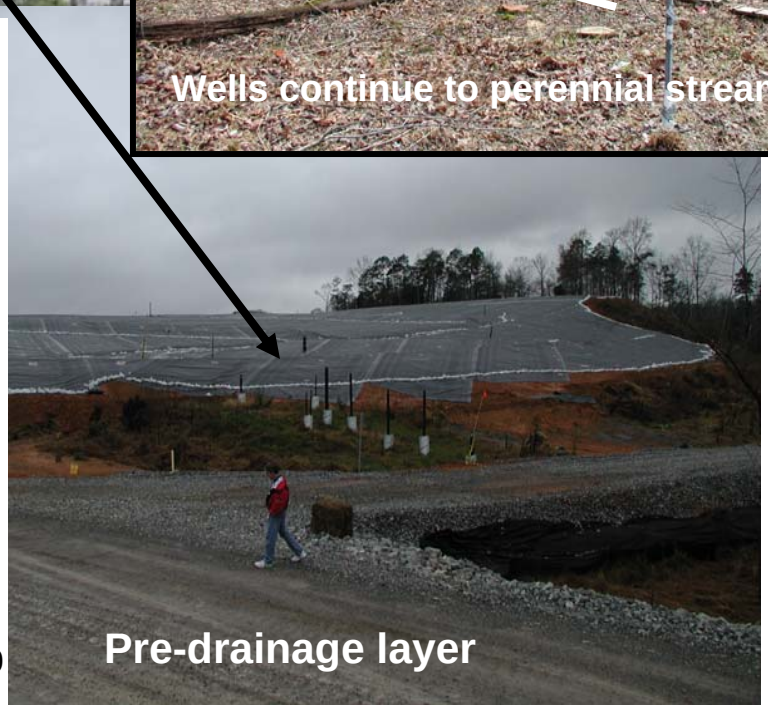
Field facility previously containing 56 multilevel groundwater monitoring wells including certified tracer injection well.

Fourteen (14) wells remain, including two trench wells, for monitoring post-cap system responses.

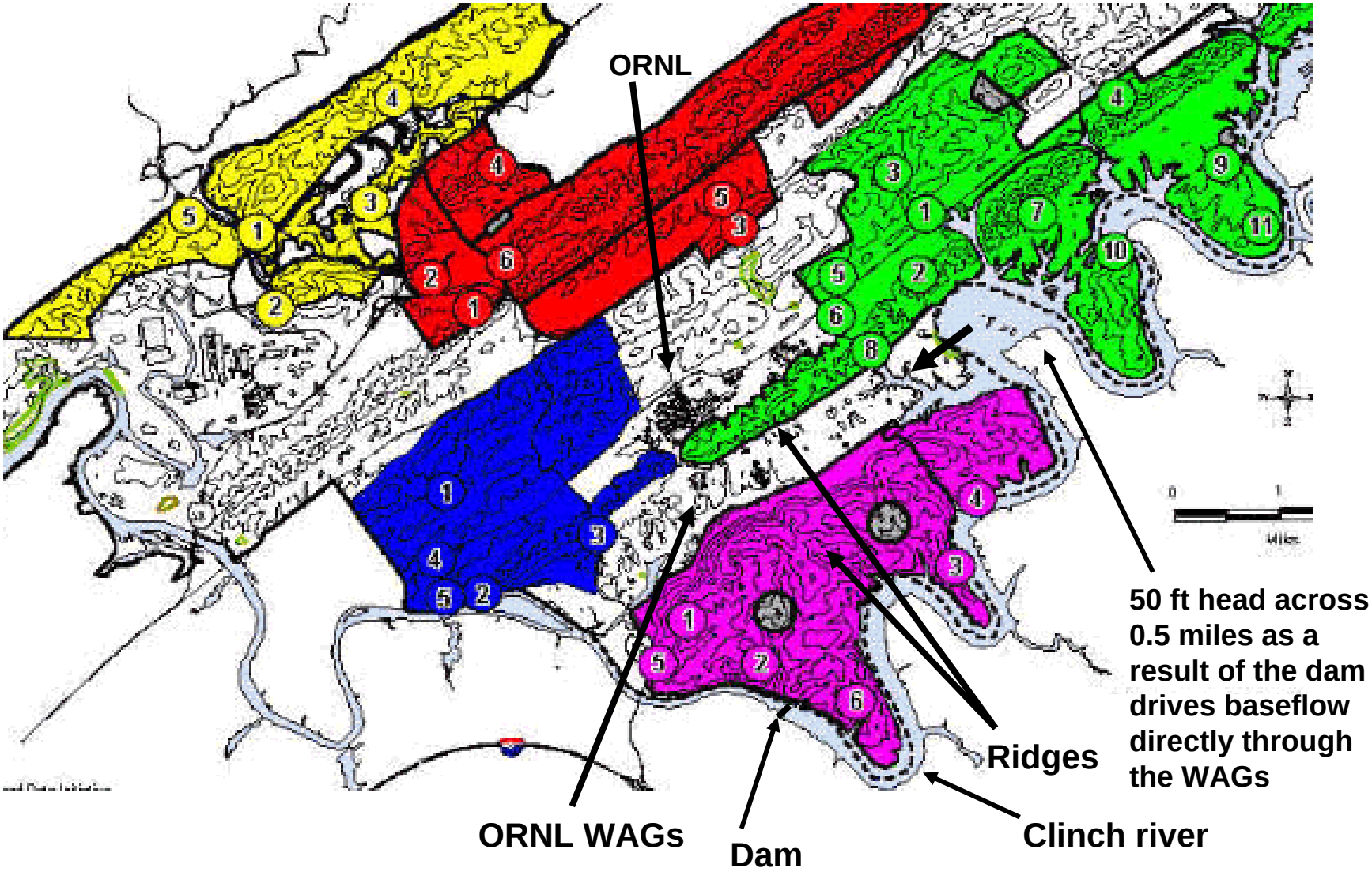
WAG 5 Systems Response Groundwater Monitoring Facility



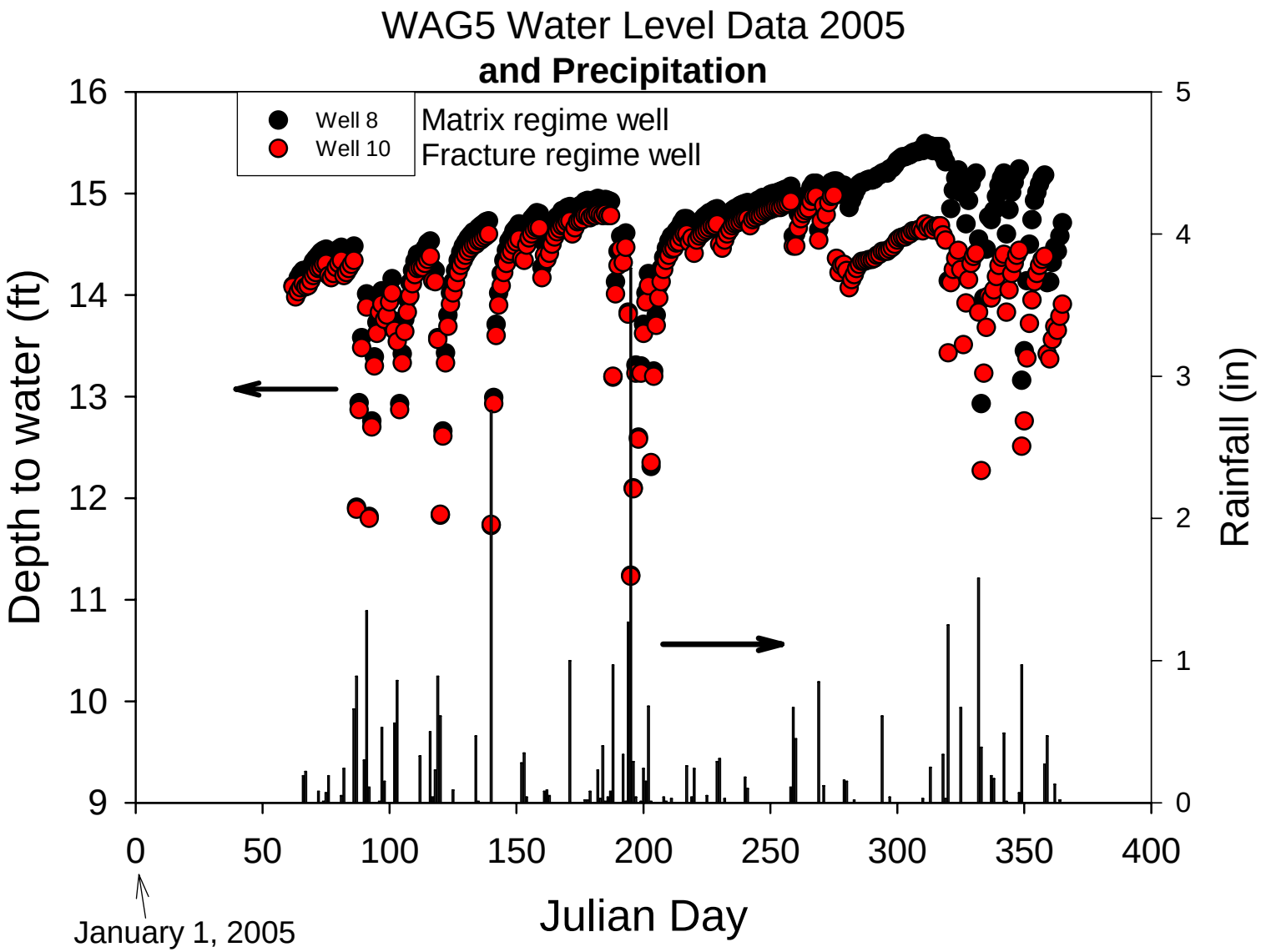




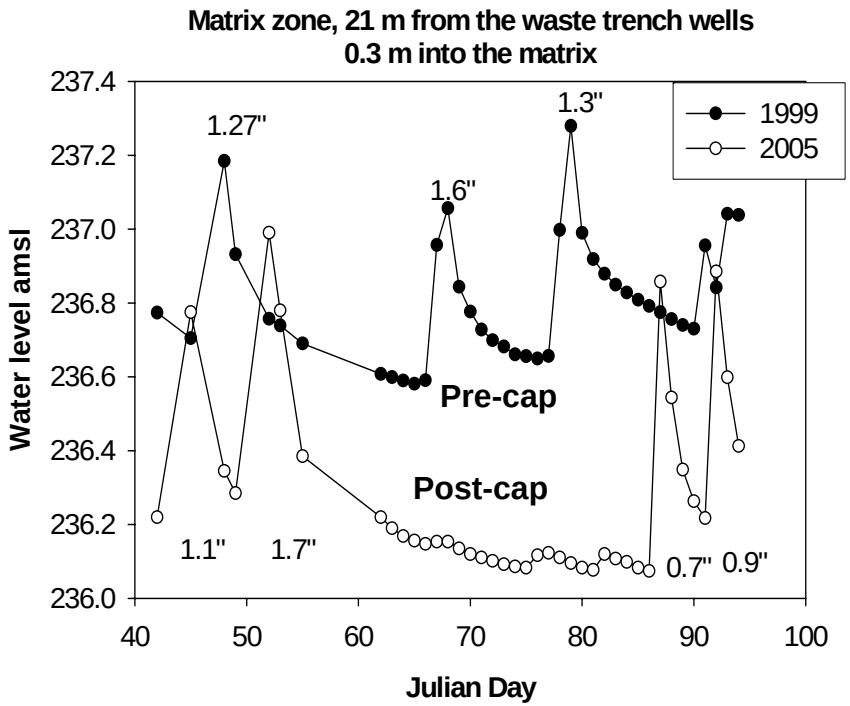
Aerial view of the Oak Ridge Reservation (ORR) and beyond showing the possible influence of regional-scale groundwater flow through the ORR WAG's

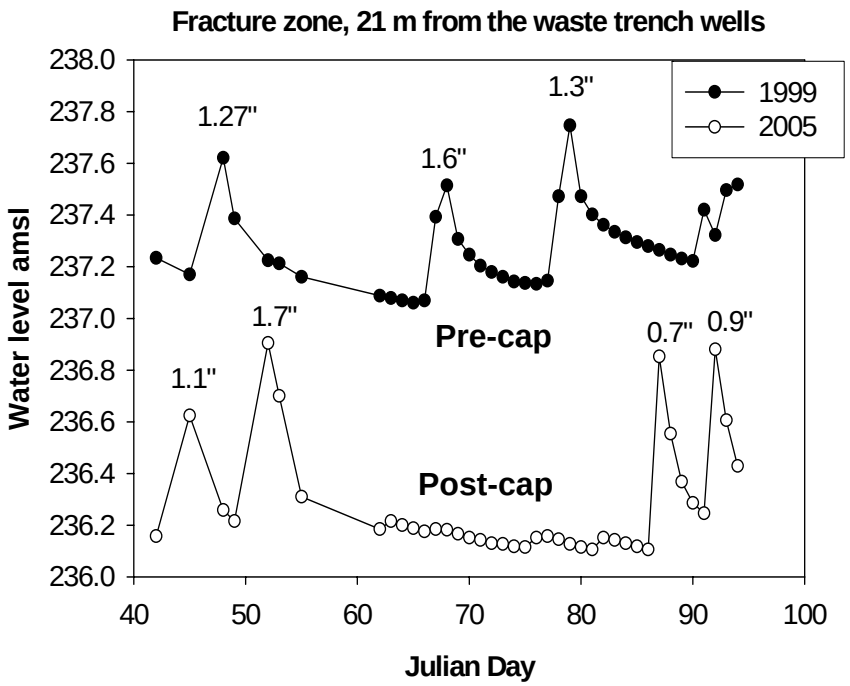


The WAG's are in a hydrologically isolated geologic unit between two ridges of distinct geologic make-up.



Large increases in the water table during storm events despite the presence of a cap. This suggest the continued upward surge of regional scale groundwater. This has traditionally been most problematic during the periods of low ET and high precipitation (winter and early spring).





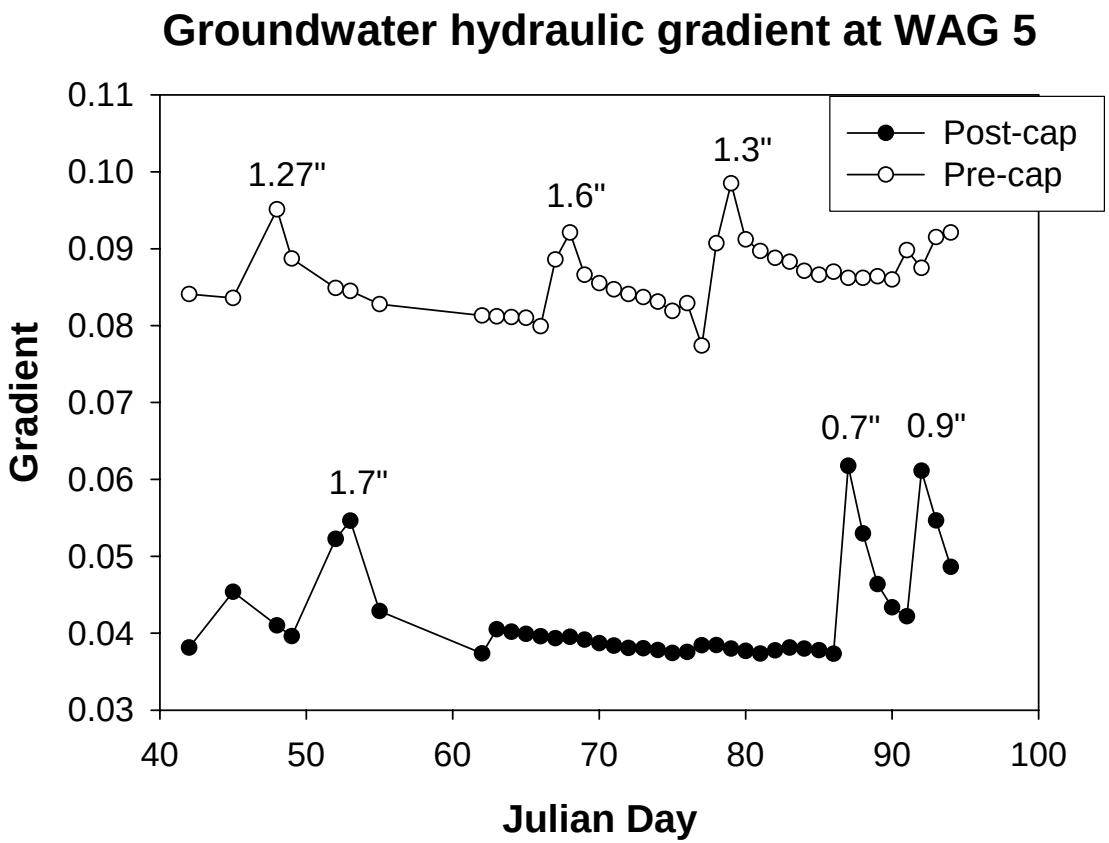
WAG 5 water levels and head responses to storms before and after the cap

Hydraulic head responses to storm events are similar before and after capping suggesting the regional scale influence of groundwater flow.

Fortunately, local-scale capping has dropped the water table 0.5 to 1.0 m.

With longer term monitoring, we will be able to assess whether groundwater is continuing to rise into waste trenches, as historically observed, despite the presence of the cap.

WAG 5 groundwater hydraulic gradient before and after the cap

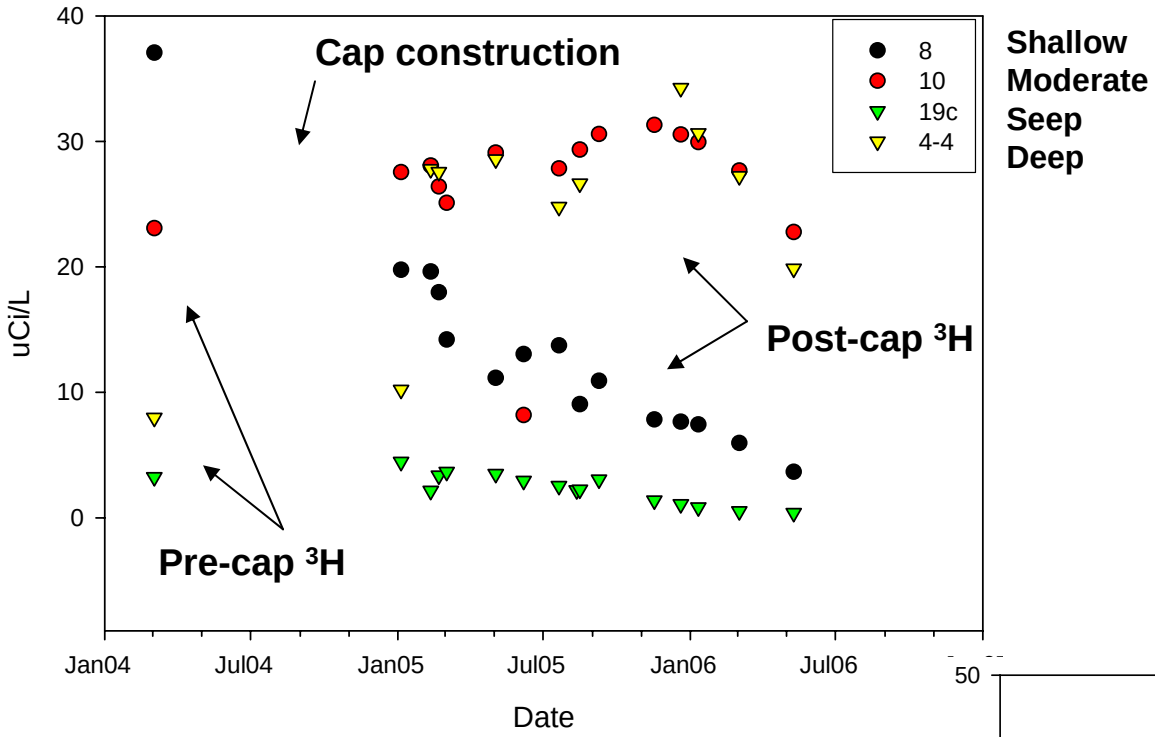


The site hydraulic gradient has decreased from ~0.8 to ~0.4 for post-cap conditions suggesting a local-scale influence of the cap.

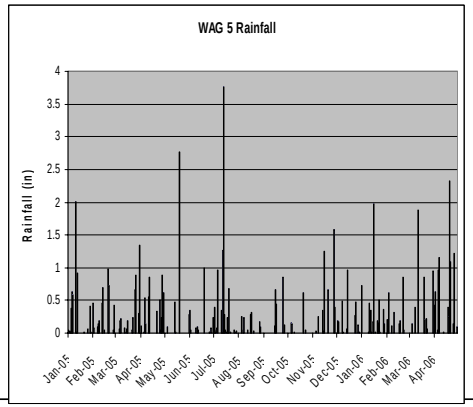
Since two hydraulic drivers at the site, namely lateral storm flow and local-scale groundwater recharge, have been shut off due to the cap, water movement through the site has slowed as suggested by the decrease in hydraulic gradient.

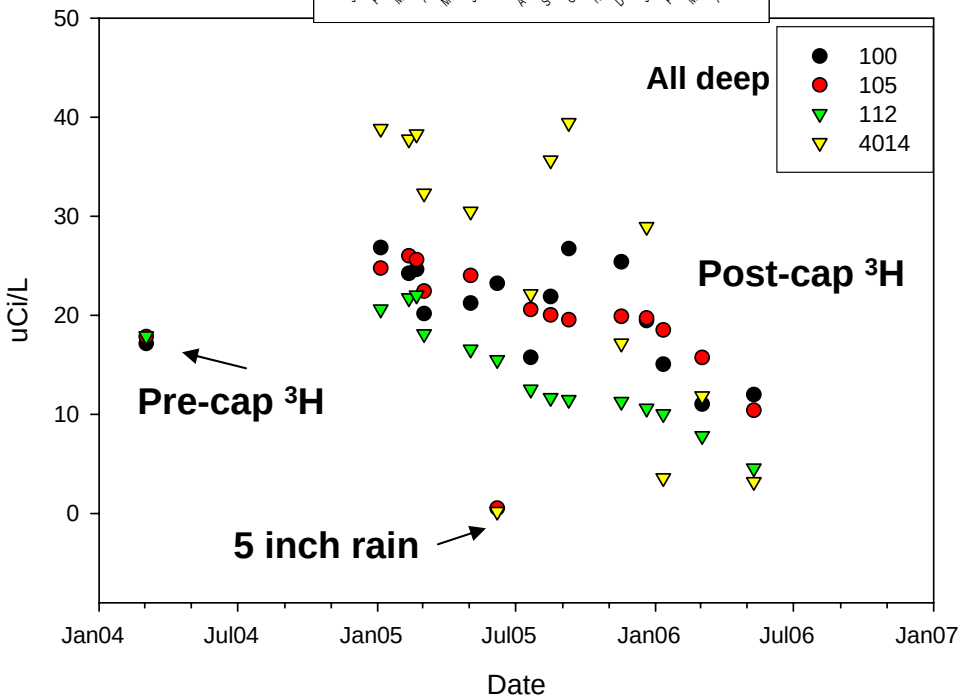
This finding suggests a decrease in contaminant flux and discharge from the site.

WAG 5 groundwater ^3H before and after the cap



Daily rainfall Jan 05 to May 06





Pre- and Post-cap tritium concentration activities for a variety of groundwater wells at the WAG 5 field site.

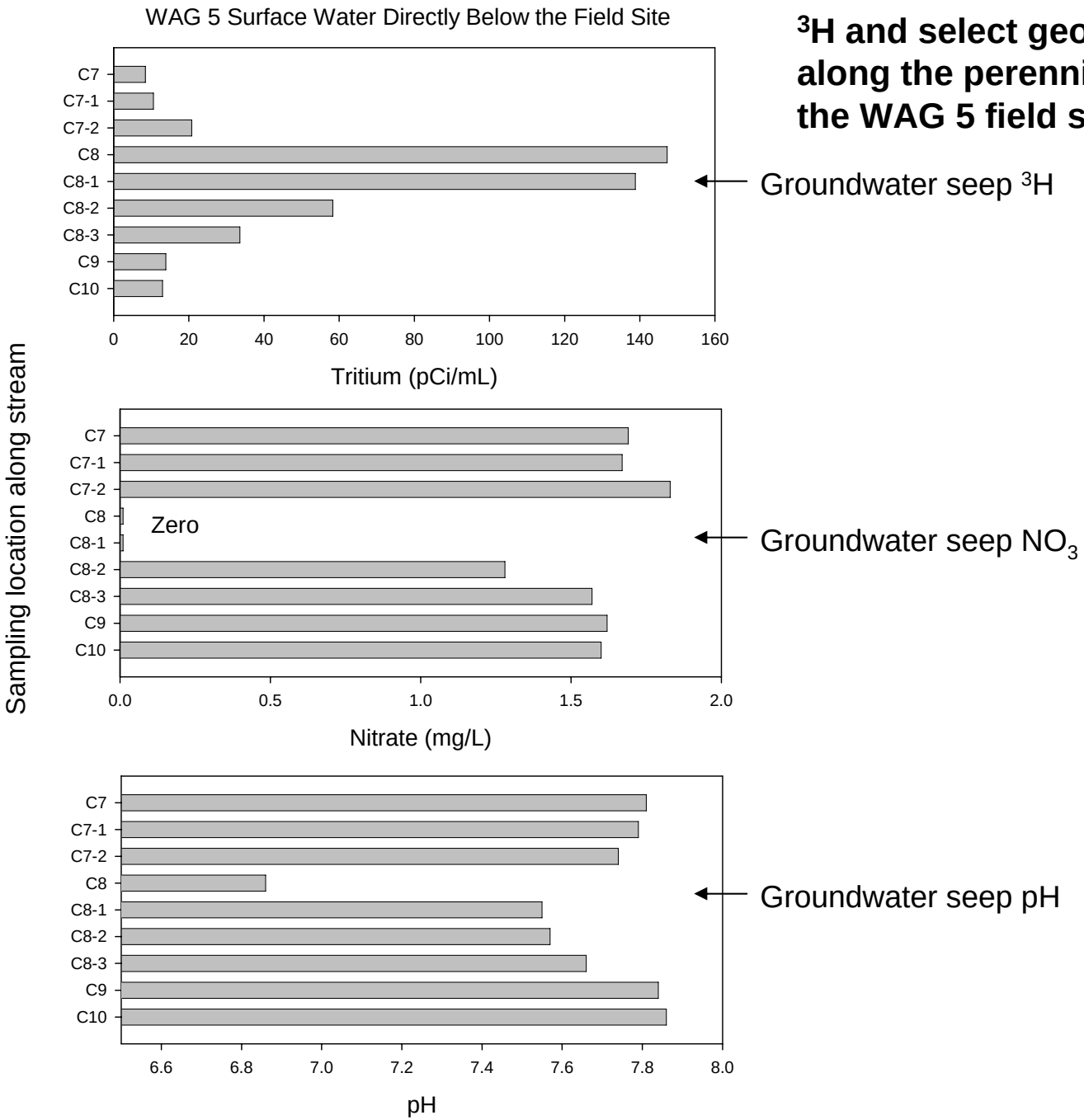
The capping endeavor influenced tritium concentrations in a shallow matrix well (8) most significantly.

Previously observed summer and fall ^3H concentration rebounds did not occur with the presence of the cap.

^3H concentrations plunging in all groundwater wells during the winter and early spring as observed prior to the cap due to the up-surge of regional groundwater at the site.

Will the ^3H concentrations rebound this summer or is the cap doing its job?

^3H and select geochemical measurements along the perennial stream that cross-cuts the WAG 5 field site



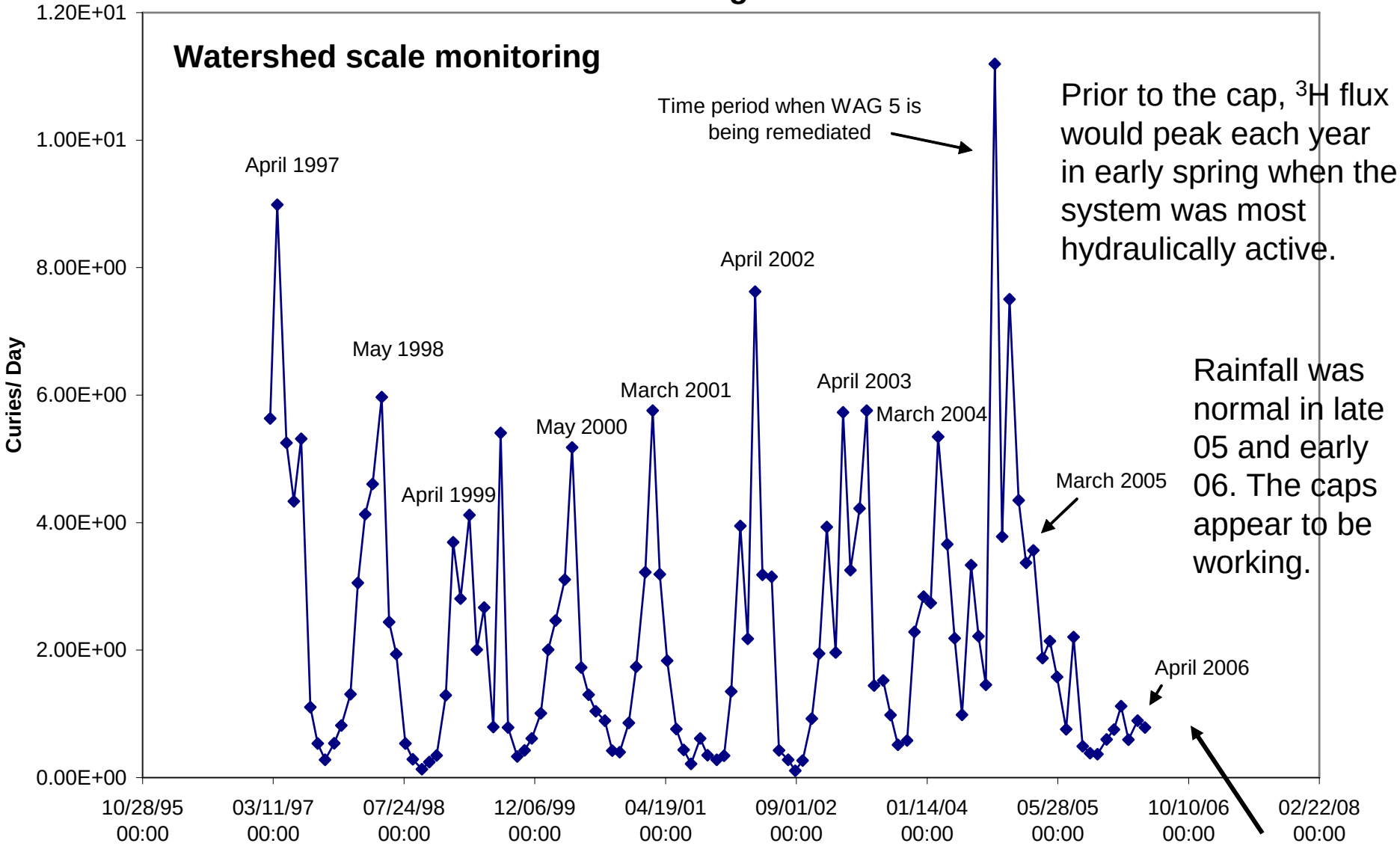
Despite the cap, groundwater contaminated with tritium continues to discharge into the stream.

However, the discharge flux is lower since the gradient is less and it appears as though the ^3H concentrations are dropping as well.

Continued monitoring during a variety of climatic conditions (wet vs. dry vs. average) will assist in quantifying cap effectiveness and need, or lack there of, additional action.

X13 Monthly Tritium Activity Rate of Discharge

Perennial stream downgradient the WAGs



Spring 2006 is the first time the perennial stream ^{3}H flux has not increased during high recharge months for the past 10 y. Influence of remediation or climatic?

Conclusions

The cap appears to have eliminated two hydraulic drivers at the site, namely lateral storm flow and local-scale groundwater recharge, thereby dropping the water table ~0.5 to 1.0 m and decreasing the groundwater hydraulic gradient 50%.

The cap has not influenced regional-scale groundwater flow as storm events continue to cause significant short term increases in water head and dissolved oxygen concentrations regardless of the cap presence.

Disruption of normally observed seasonal variations in ^{3}H discharge at both the local and watershed scale suggest the cap is working.

Continued monitoring during a variety of climatic conditions (wet vs. dry vs. average) will assist in quantifying cap effectiveness and need, or lack there of, additional action.

This research supports the need for a fundamental scientific understanding of the long-term fate, transport, and attenuation of contaminants in remediated environments as a function of space and time to ensure the effectiveness of remediation and/or natural attenuation processes.