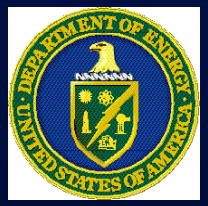
Phytoremediation for Plume Control of Deep Groundwater

M. Cristina Negri*, John Quinn*,
Casey Hamilton*, and Edward G. Gatliff§

*Argonne National Laboratory

§Applied Natural Sciences, Inc.

Contact: (630) 252 9662; negri@anl.gov



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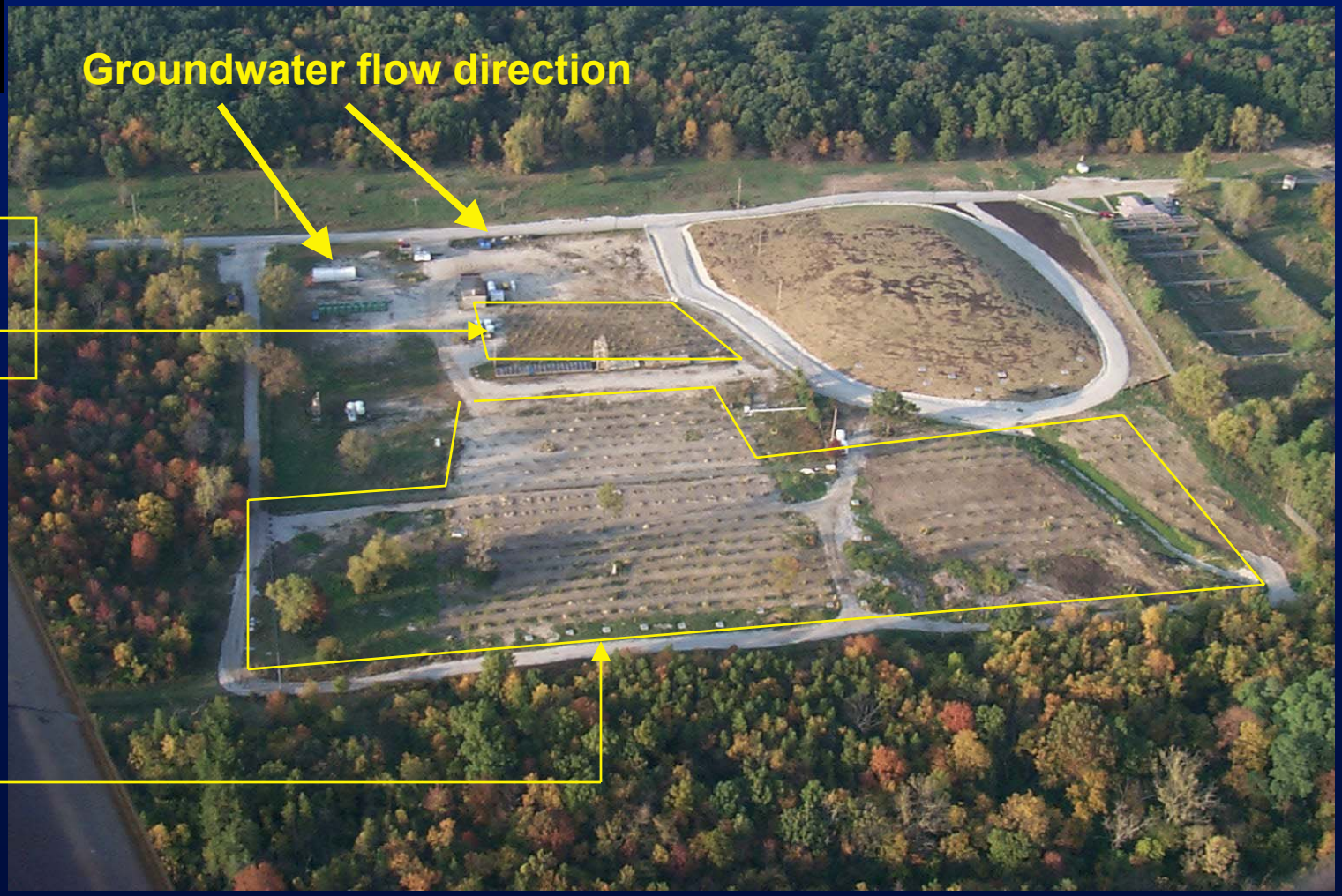
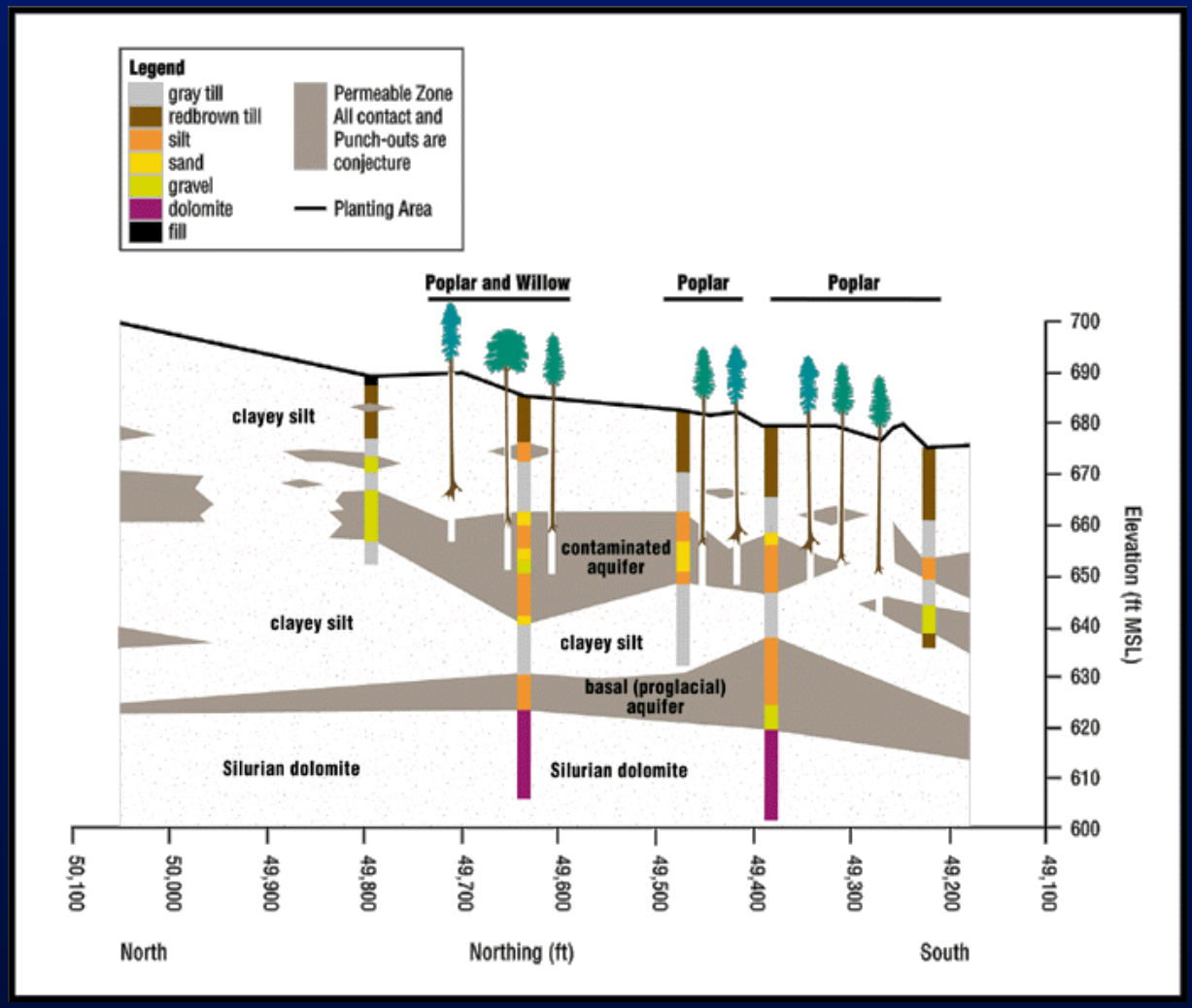
The 317/319 Area



The Subsoil at 317/319 Area

- Complex stratigraphy within glacial sediments forms a heterogeneous hydrologic system
- Water bearing intervals are in interconnected sand and gravel zones
- Hydrologic system is altered by perched or seasonally wet zones and by fracturing of confining clays by desiccation.



Roots can grow deep if conditions allow:

- *Water*
- *Nutrient*
- *Oxygen*
- *Mechanical impedance*

Elongated Root Systems

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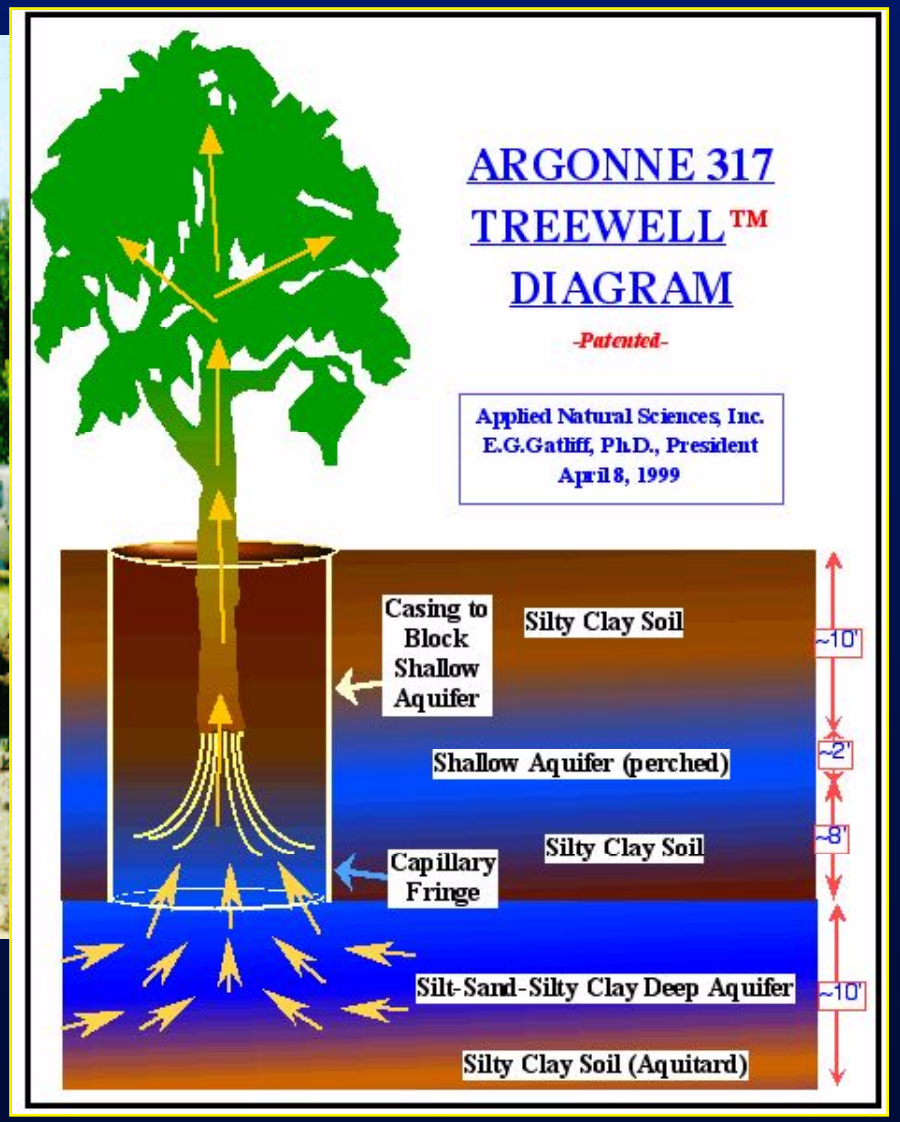
Patented System

Planting Layout

VOC source area FD

Hydraulic control area HC

Deployment construction at ANL-E



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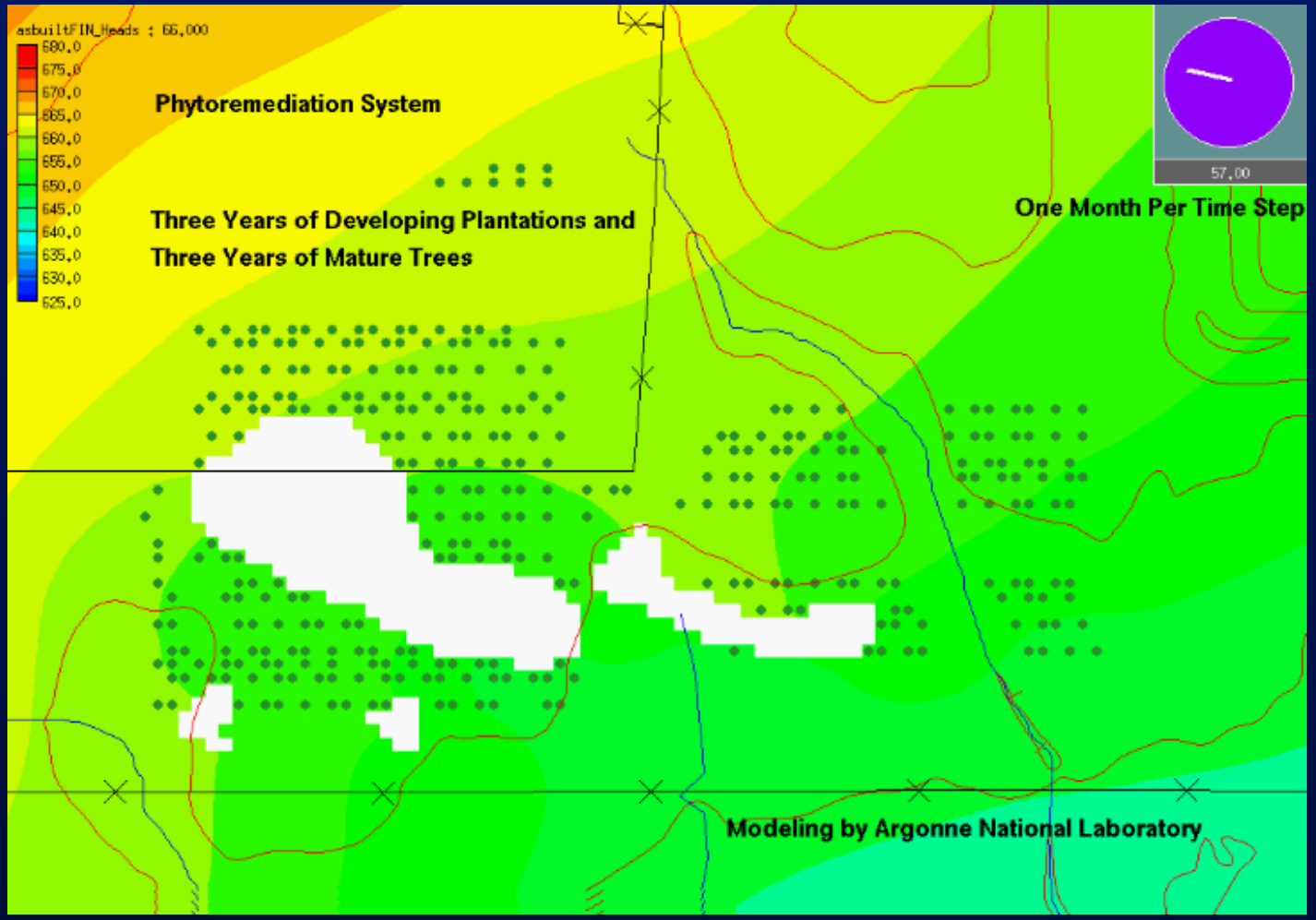
Modeling the Effect of the Phytoremediation System on Groundwater Flow

- Focus on aquifer of interest
- Ignore shallower perched system
- Calibrate initial transient model to the pre-phytoremediation flow field
- Account for plume velocity and winter dormancy

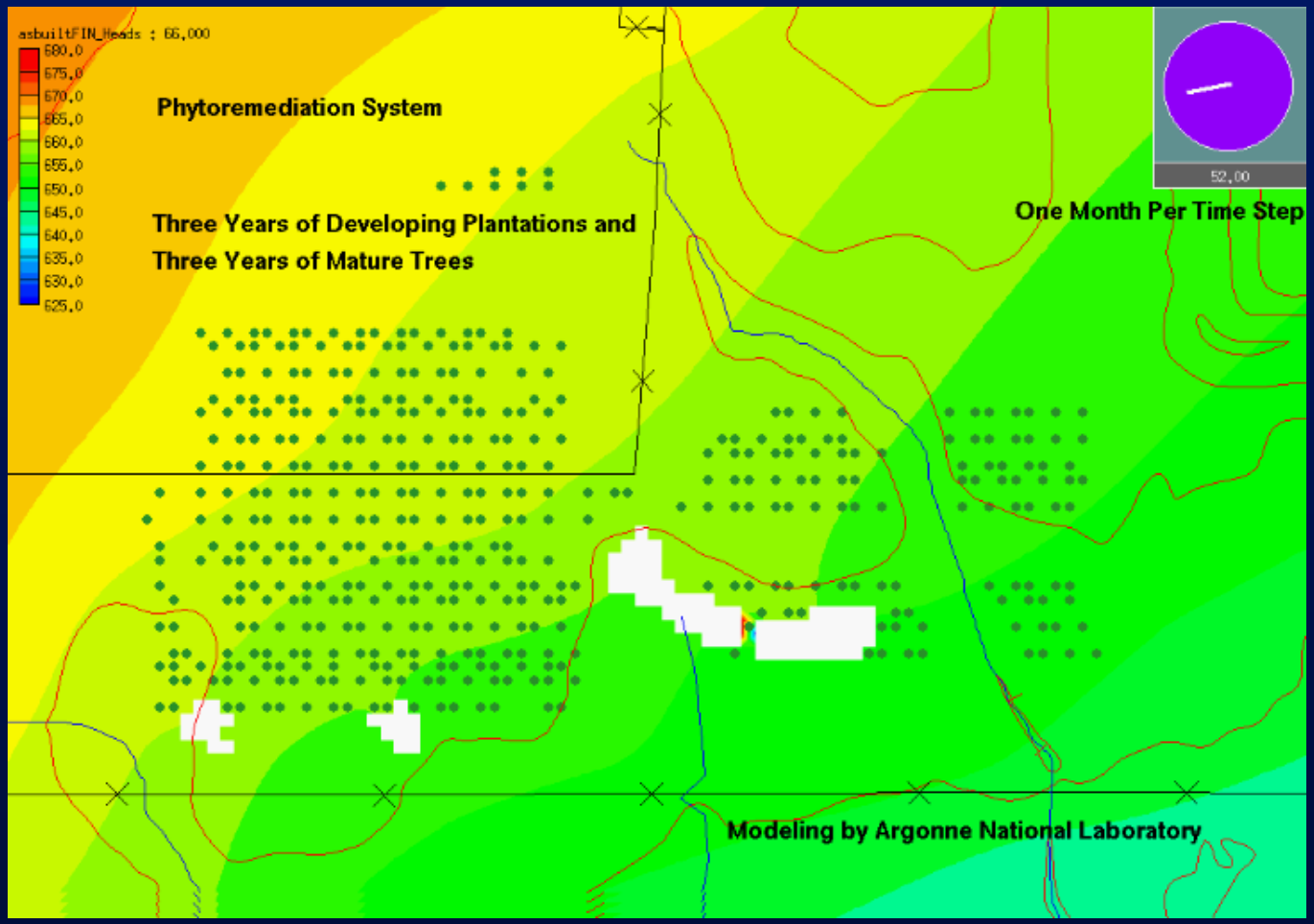
Simulated Low Heads from Phytoremediation: September of fourth year

White areas are dewatered portions of the aquifer



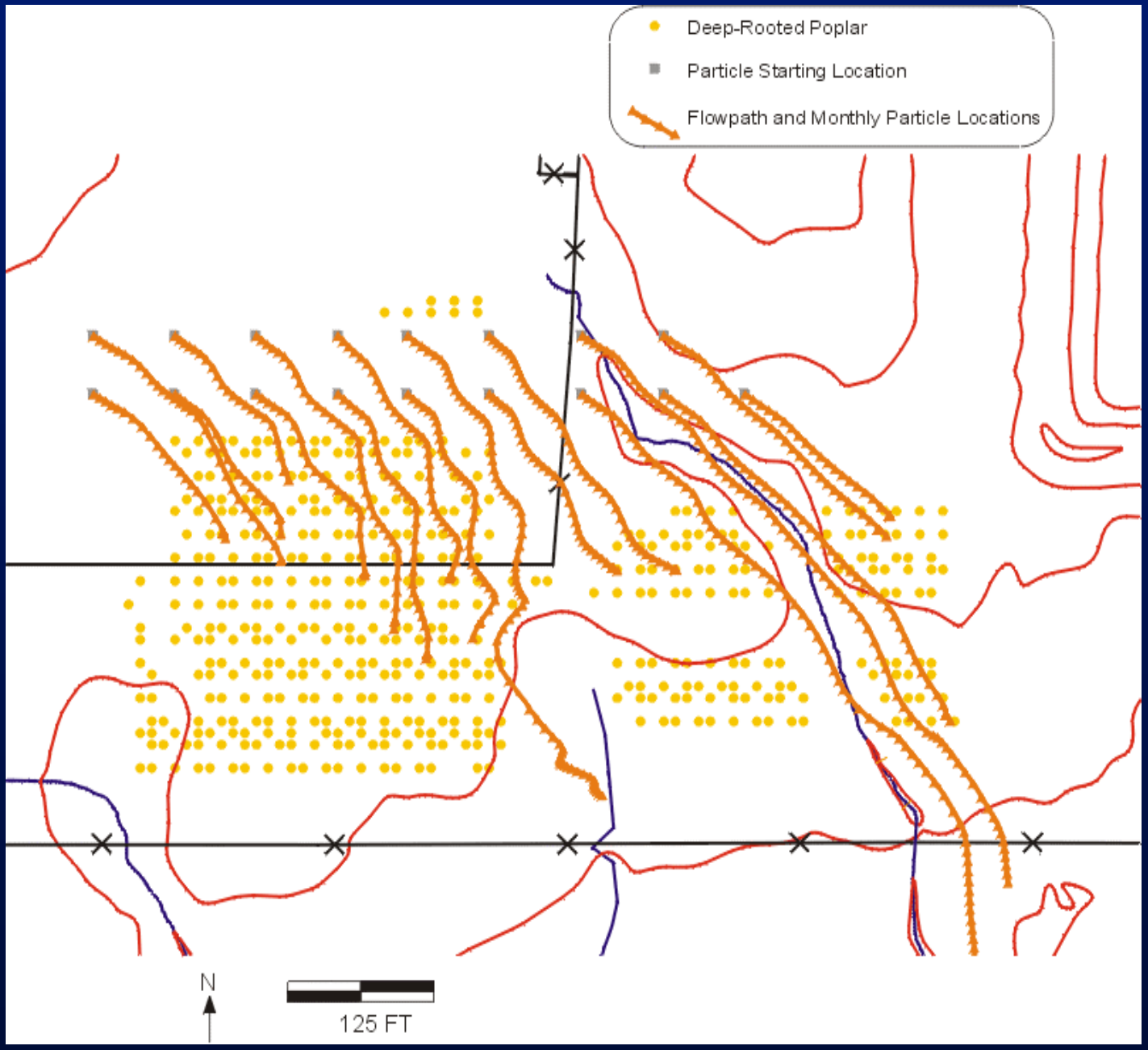
Simulated High Heads from Phytoremediation: April of fifth year

White areas are dewatered portions of the aquifer



Particle Tracking Results

(particles start in January 2000)



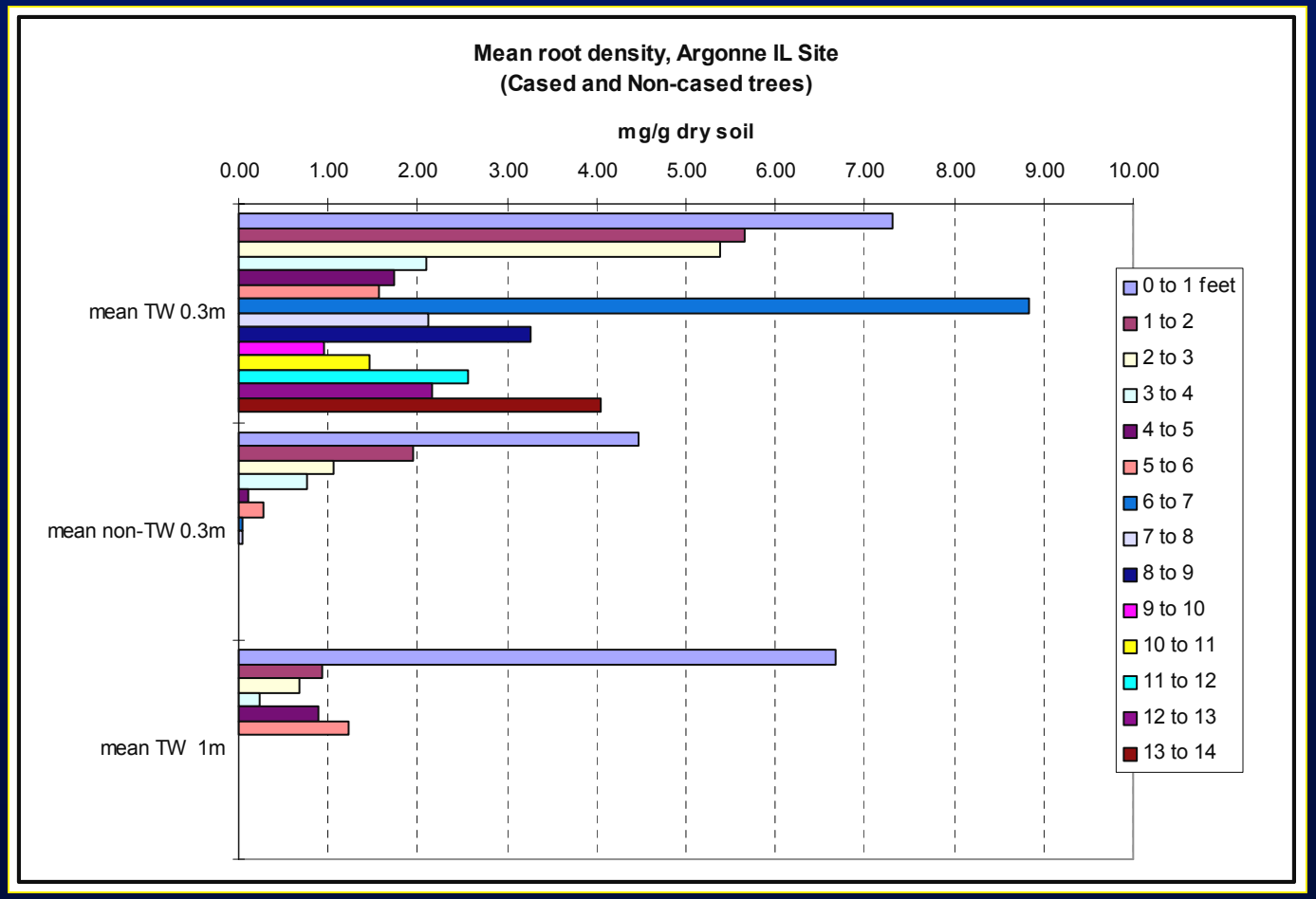
Effect of Phytoremediation on the Groundwater Flow Field

- **Best-estimate predictive modeling suggests**
  - containment of groundwater by mature plantation, even during dormant winter months
  - interim extraction well system phase out
  - residence time of groundwater in geochemically altered rhizosphere of 5-17 months

Is the system working? Monitoring Objectives

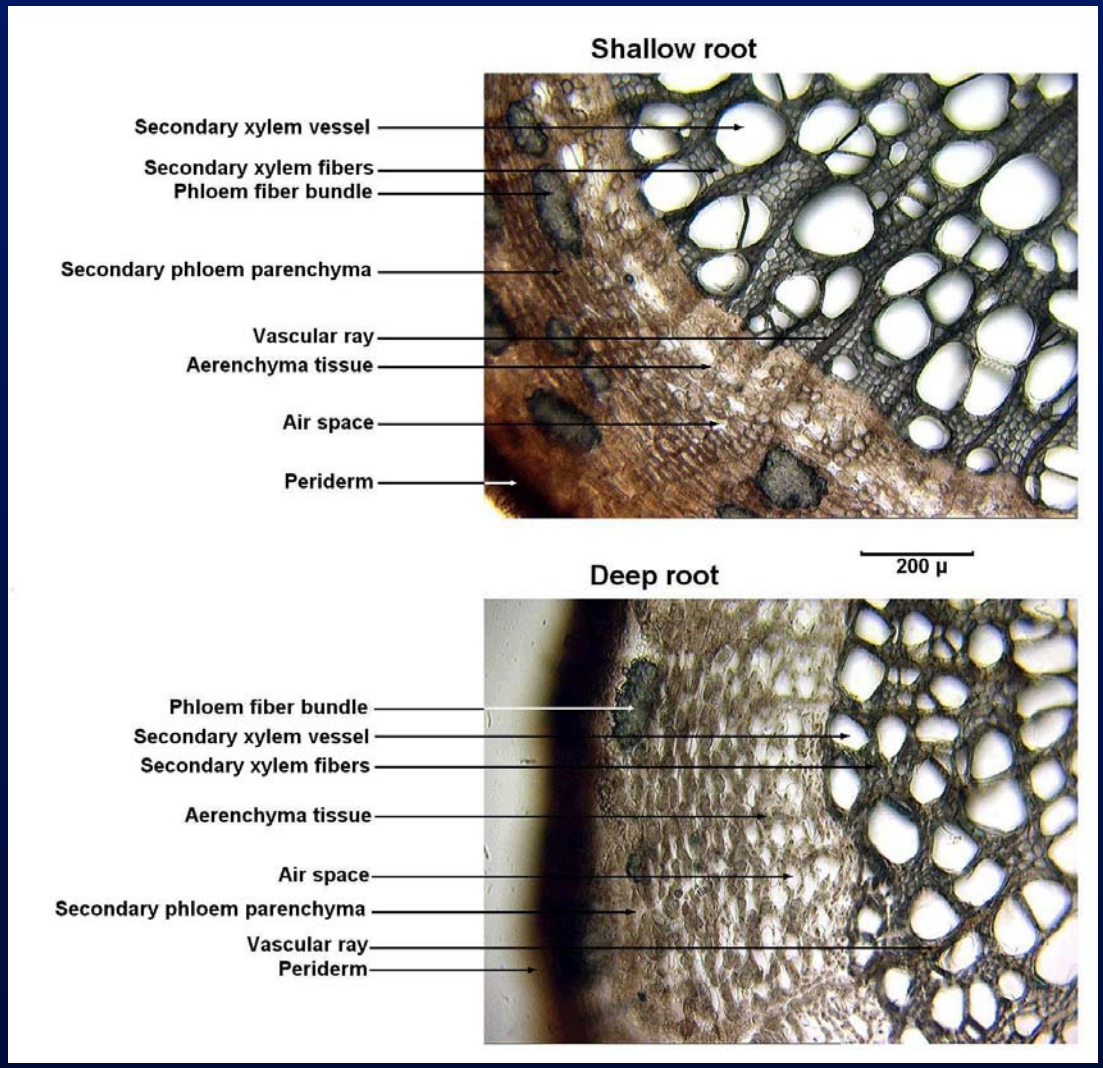
- Determine contact with groundwater (HC)
- Determine effect on groundwater elevation, groundwater use
- Determine contaminant removal rates and contaminant fate (in the source area)

Roots were found in TreeWell® cores to all investigated depths (up to 4+ m)



Morphological Changes in Deep (4m) vs Surface Poplar Roots

- Large porous aerenchyma found in deep root and not in surface root to adapt to poor oxygen conditions
- Implications for Carbon balance?



Contaminant Traces are found in the HC Area

(a control panel lighting up……)

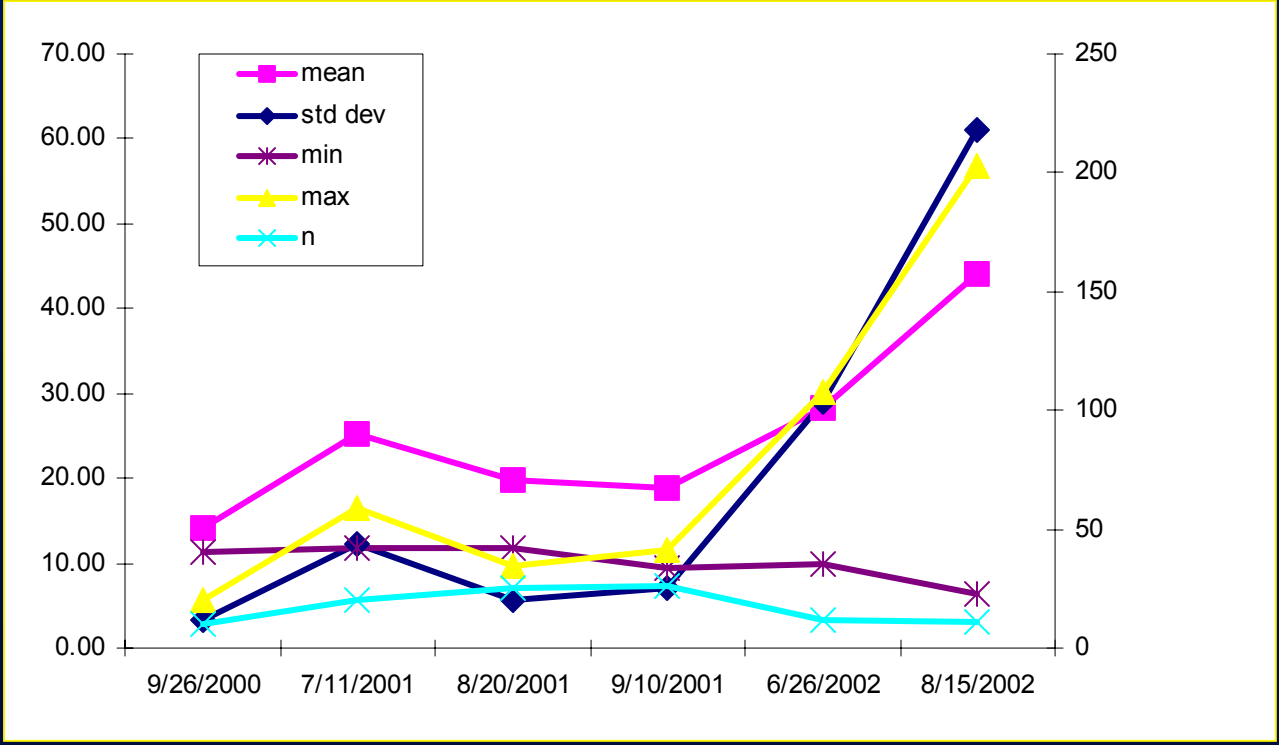
Tritium in Transpirate

- Tritium is best sampled by collecting condensed transpirate in plastic bag
- Condensed transpirate was periodically sampled from poplars at HC every summer
- Tritium concentrations above background would indicate trees are using contaminated groundwater

Traces of contaminants increasingly found in poplar tissue

- **September 2001**
  - 16% trees sampled showed traces of VOCs
  - 2% trees sampled showed tritium slightly above background
- **September 2002**
  - 28% trees sampled showed traces of VOCs
  - 36% trees sampled showed tritium definitely above background

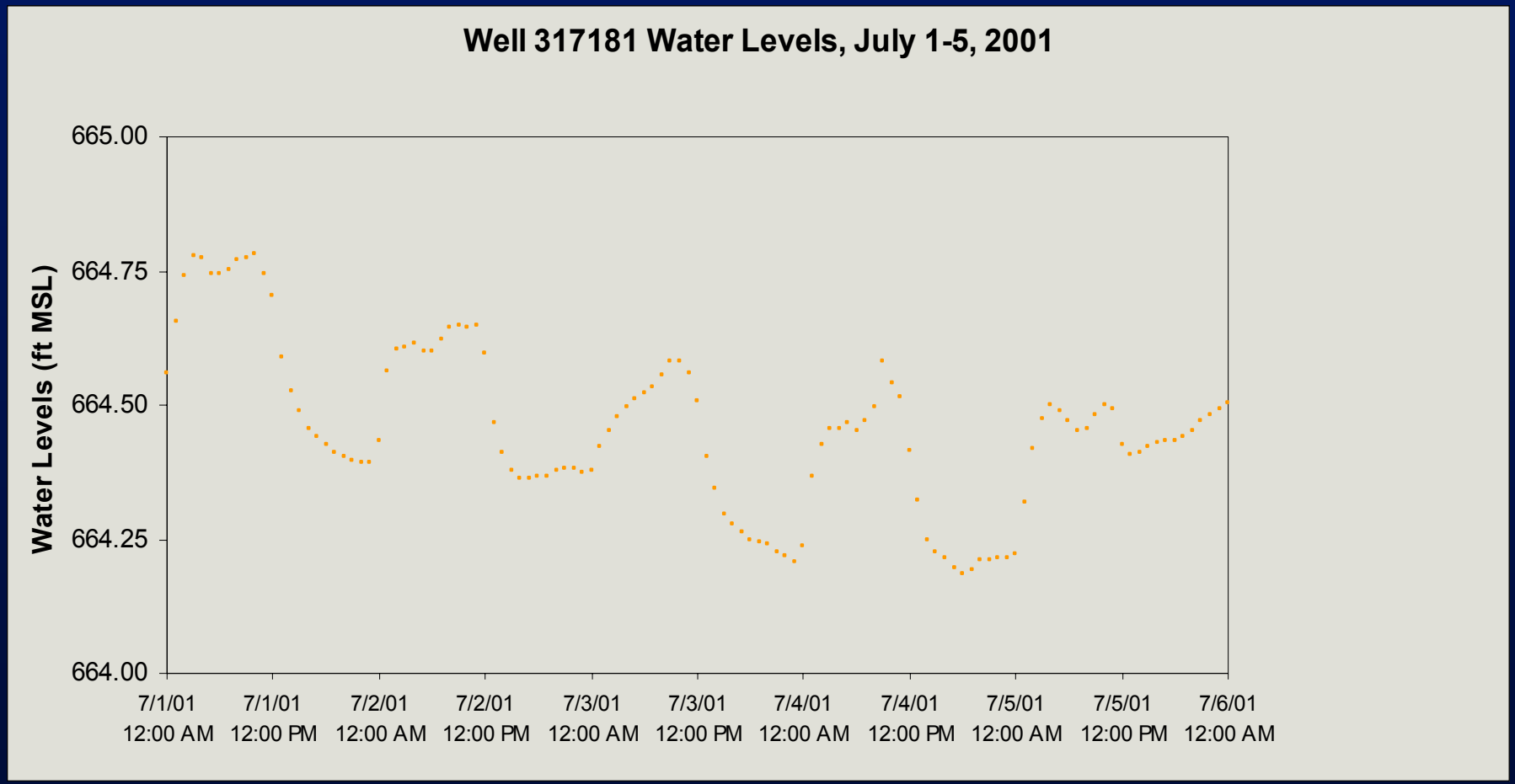
Tritium in Transpirate – HC Area
(TU)



Continuous Water level Measurements-

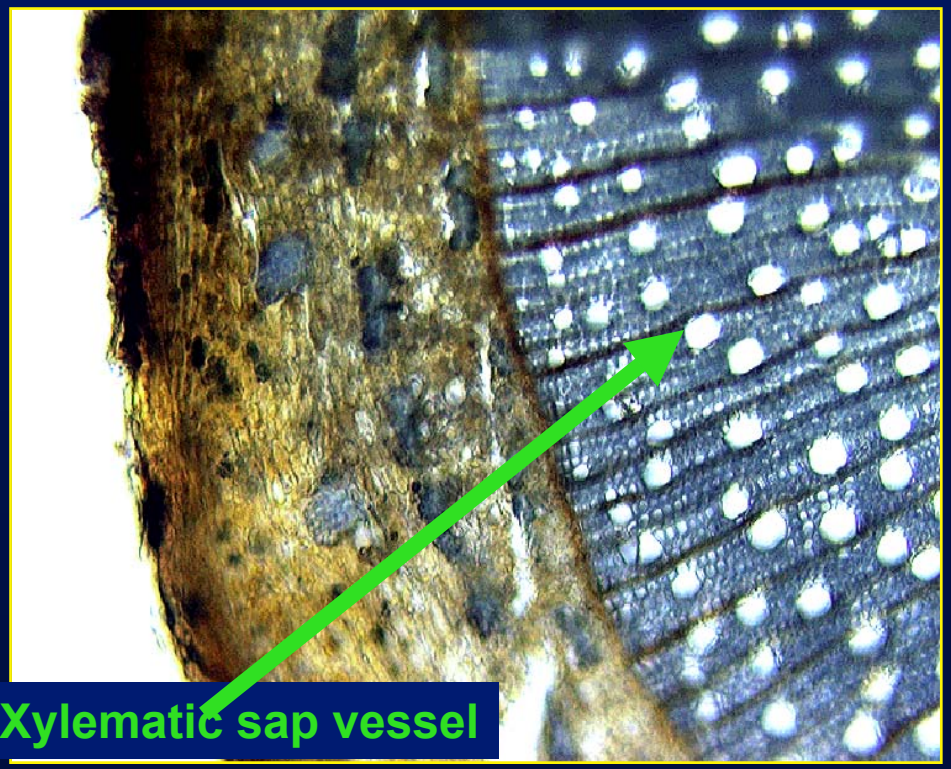
- Hydraulic heads rise within one hour of the onset of precipitation, to be considered in measurements.
- Diurnal fluctuations beginning in warm period of September 2000, continuing in 2001
  - Approximately 8 cm in two wells on sunny days
  - Lesser amplitude at two other wells
- Gradual overall downward trend during dry periods in 2001 at well 317181

Downward Trend during Growing Season in Absence of Rain

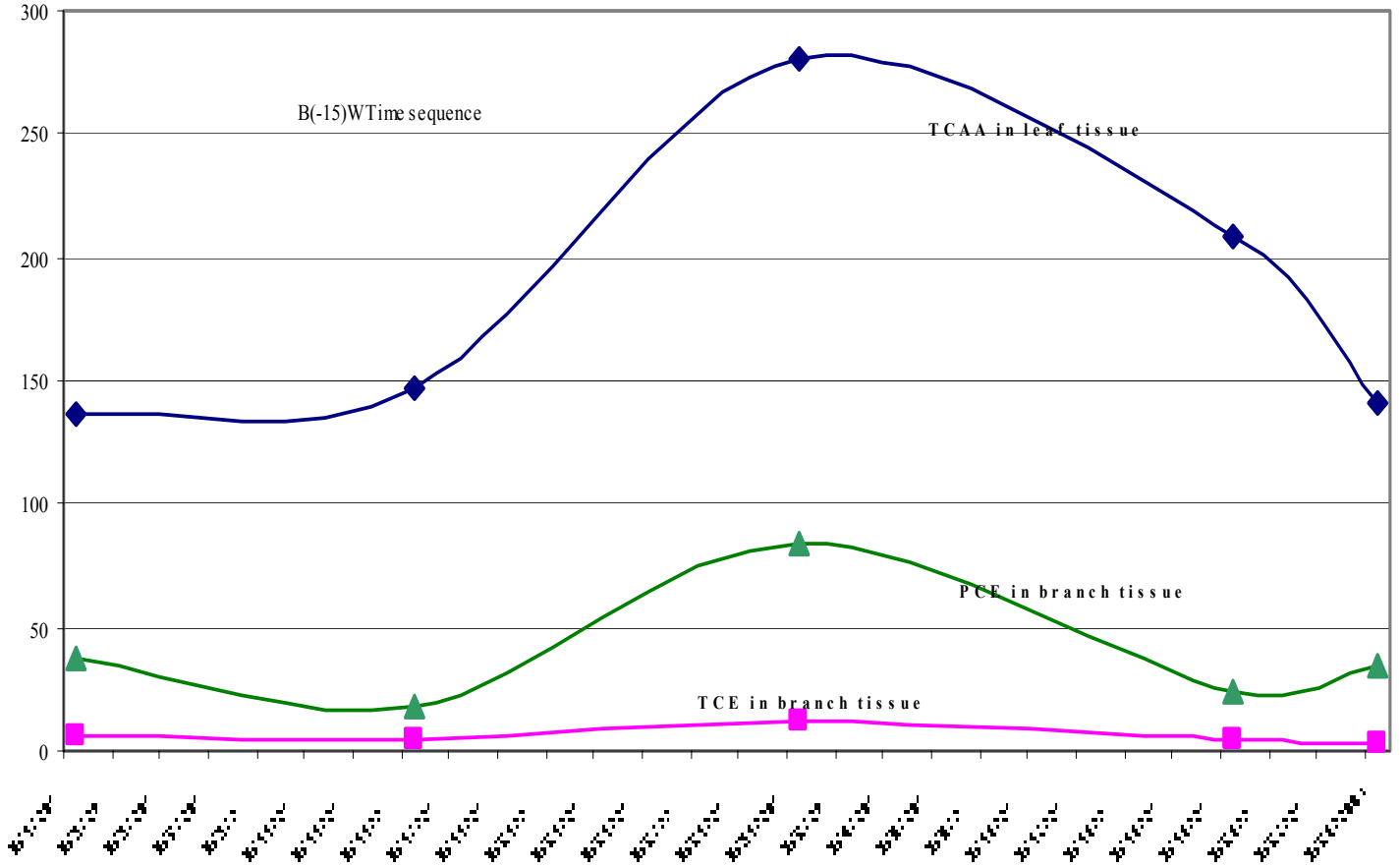


Source Area Reduction: Monitoring VOC Uptake and Degradation by Trees

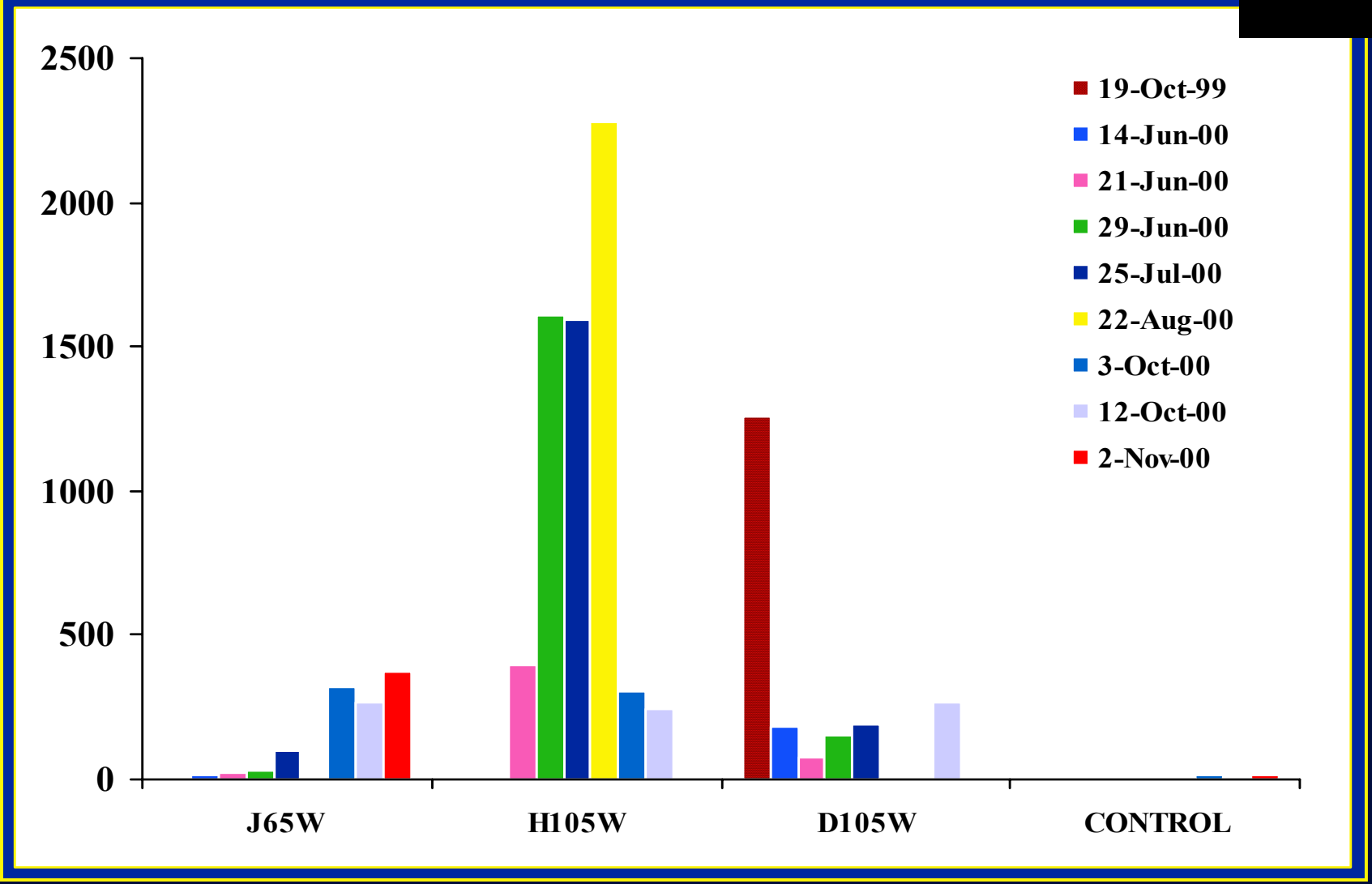
- Trees take up TCE and PCE into their xylematic sap, VOCs found in **branch tissue**
- Trichloroacetic acid (TCAA), metabolite, non volatile, accumulated by **leaf tissue**
- A simplified method allows us to detect TCE, PCE, and TCAA in plant tissue
- Knowing concentration of contaminant in sap (ug/L) and knowing sap flow (L/day) we can also estimate daily removal rates



Time sequence in Willow



TCAA Concentration (ng/g dw) in Leaf Tissue Was Specific to Each Individual Plant



Preliminary Conclusions

- **Diurnal changes in groundwater levels observed suggest root contact (even after only 14 months since planting)**
- **Roots were found at least 4 m deep (max depth investigated)**
- **Traces of tritium and VOCs are increasingly found in transpirate and tissue**