Modeling Plume Capture at ANL-E

An Analysis of the Effect of the Argonne Phytoremediation System on Groundwater Flow

John J. Quinn

Argonne National Laboratory

Argonne, IL

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Who or what is Phyto??

Potential Phytoremediation Uses

- Phytoaccumulation (metals and inorganics)
- rhizofiltration from water (metals and orgs.)
- phytodegradation (organics)
- phytovolatilization (organics, Hg)
- control of landfill leachate
- microbial stimulation in rhizosphere

Advantages of Phytoremediation

- In situ, passive, solar-driven
- costs less than mechanical systems
- faster than Natural Attenuation
- high aesthetics
- public acceptance
- could be part of treatment train
- stewardship

Limitations of Phytoremediation

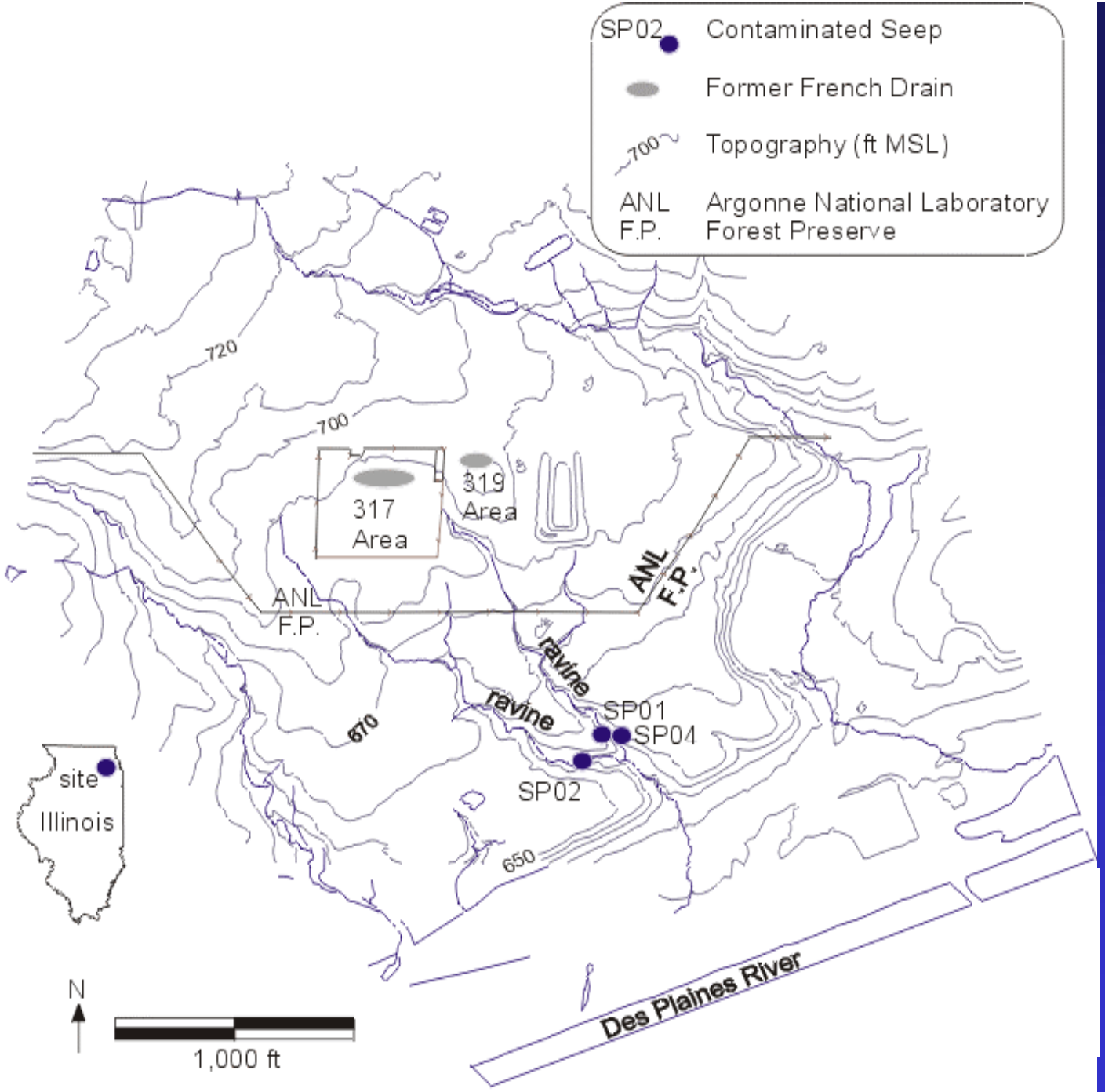
- high concentrations may be toxic to plants
- mass transfer rate limitations
- limited to “shallow” groundwater and soil (?)
- slow in cold weather
- what is really going on?
- a scientific frontier
- new to regulators

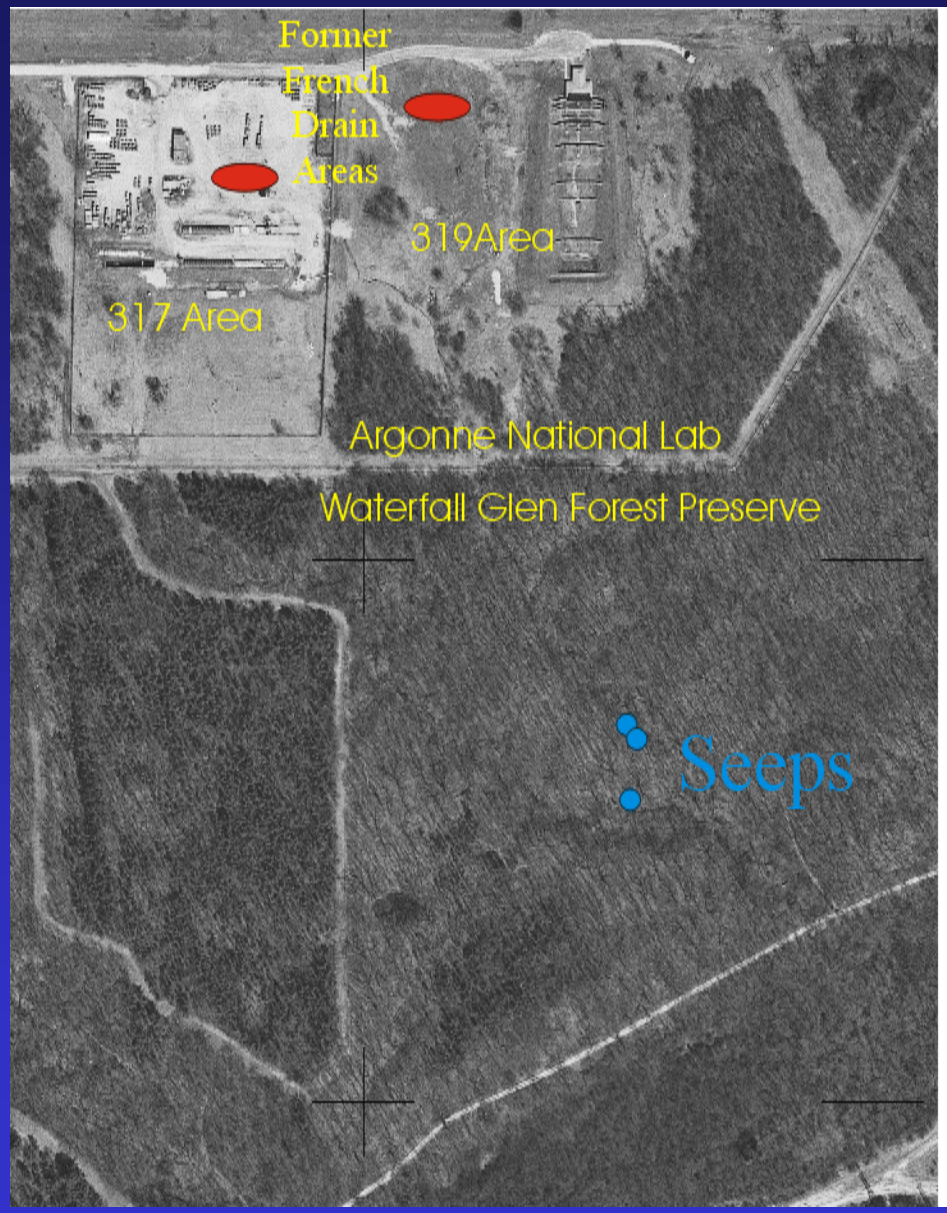
Phreatophytes (poplar and willow) useful in some settings

- Transpire contaminants (VOCs, tritium)
- metabolize VOCs in rhizosphere
- degradation within the plant
- depress water table --> containment

Study Area:
Argonne National Laboratory
317/319 Area

- Prior waste disposal area (french drains, rad waste vaults, landfill)
- contaminants of concern are solvents and tritium

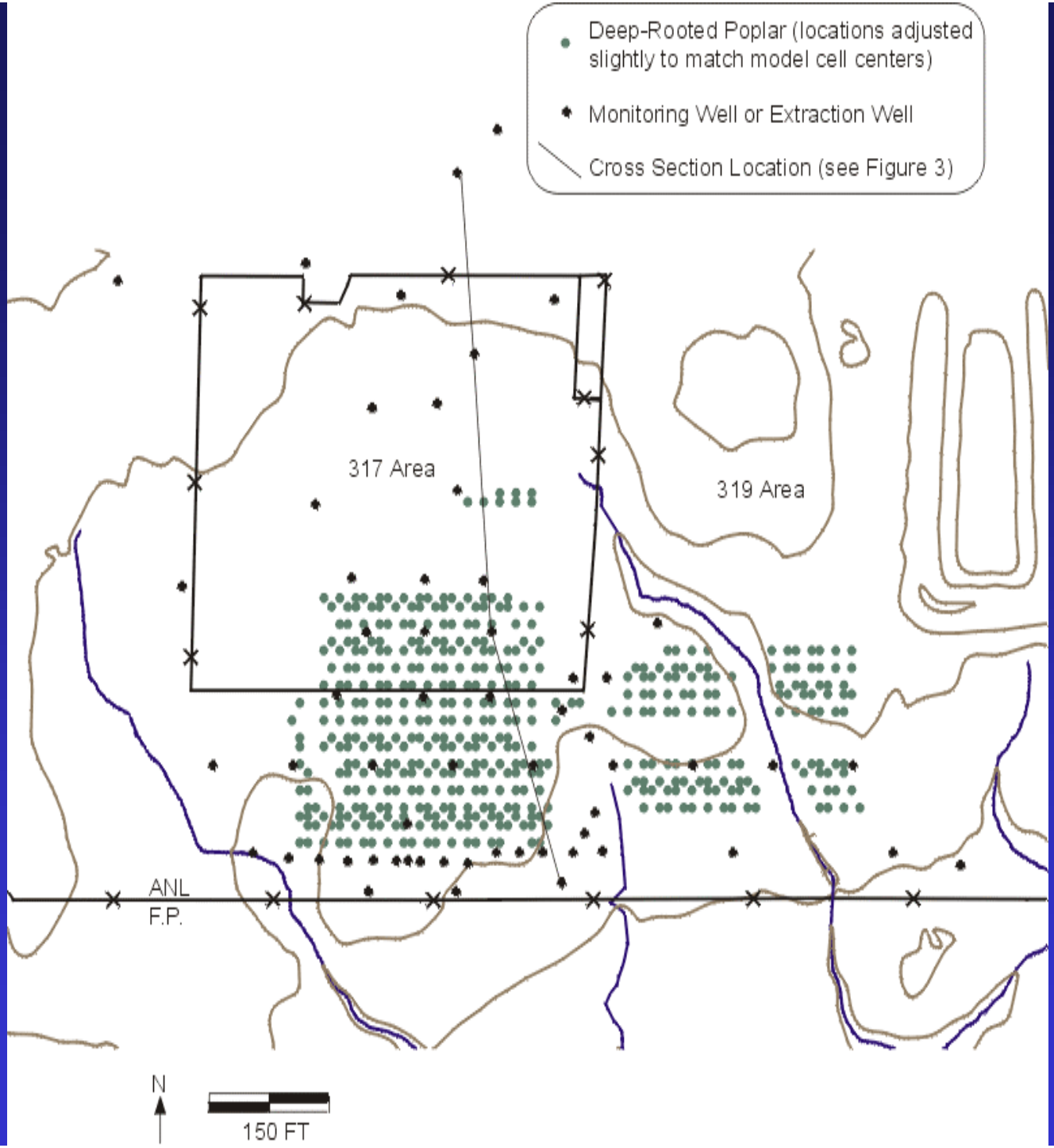

SP02 Contaminated Seep
Former French Drain
700 Topography (ft MSL)
ANL F.P. Argonne National Laboratory Forest Preserve
720
700
317 Area
319 Area
ANL F.P.
ANL F.P.
ravine
ravine
670
SP01
SP04
SP02
650
site
Illinois
N
1,000 ft
Des Plaines River

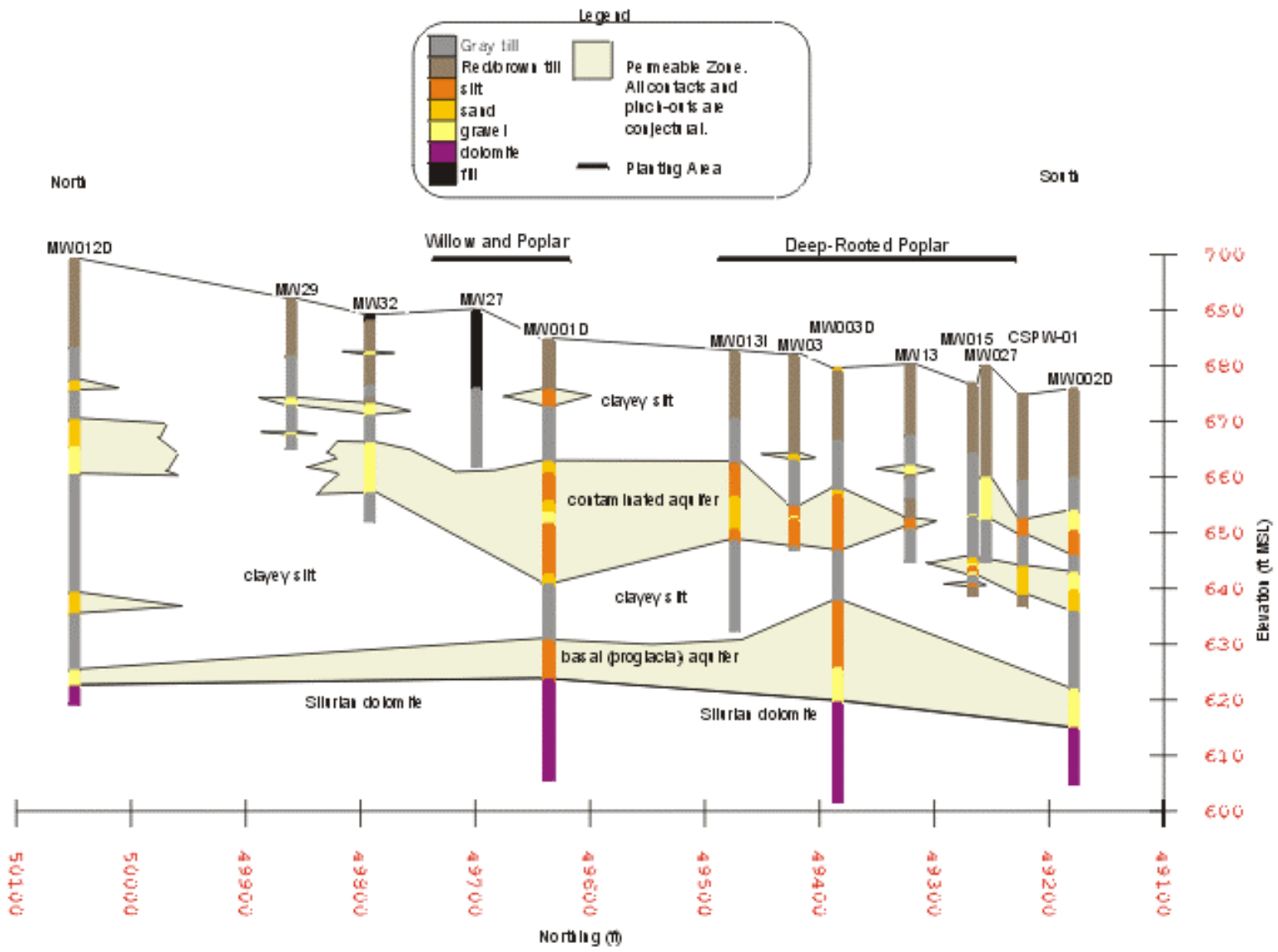

Former
French
Drain
Areas
319Area
317 Area
Argonne National Lab
Waterfall Glen Forest Preserve
Seeps

Soil Mixing

at 317 French Drain

1997


Deep-Rooted Poplar (locations adjusted slightly to match model cell centers)
Monitoring Well or Extraction Well
Cross Section Location (see Figure 3)
317 Area
319 Area
ANL
F.P.
N
150 FT

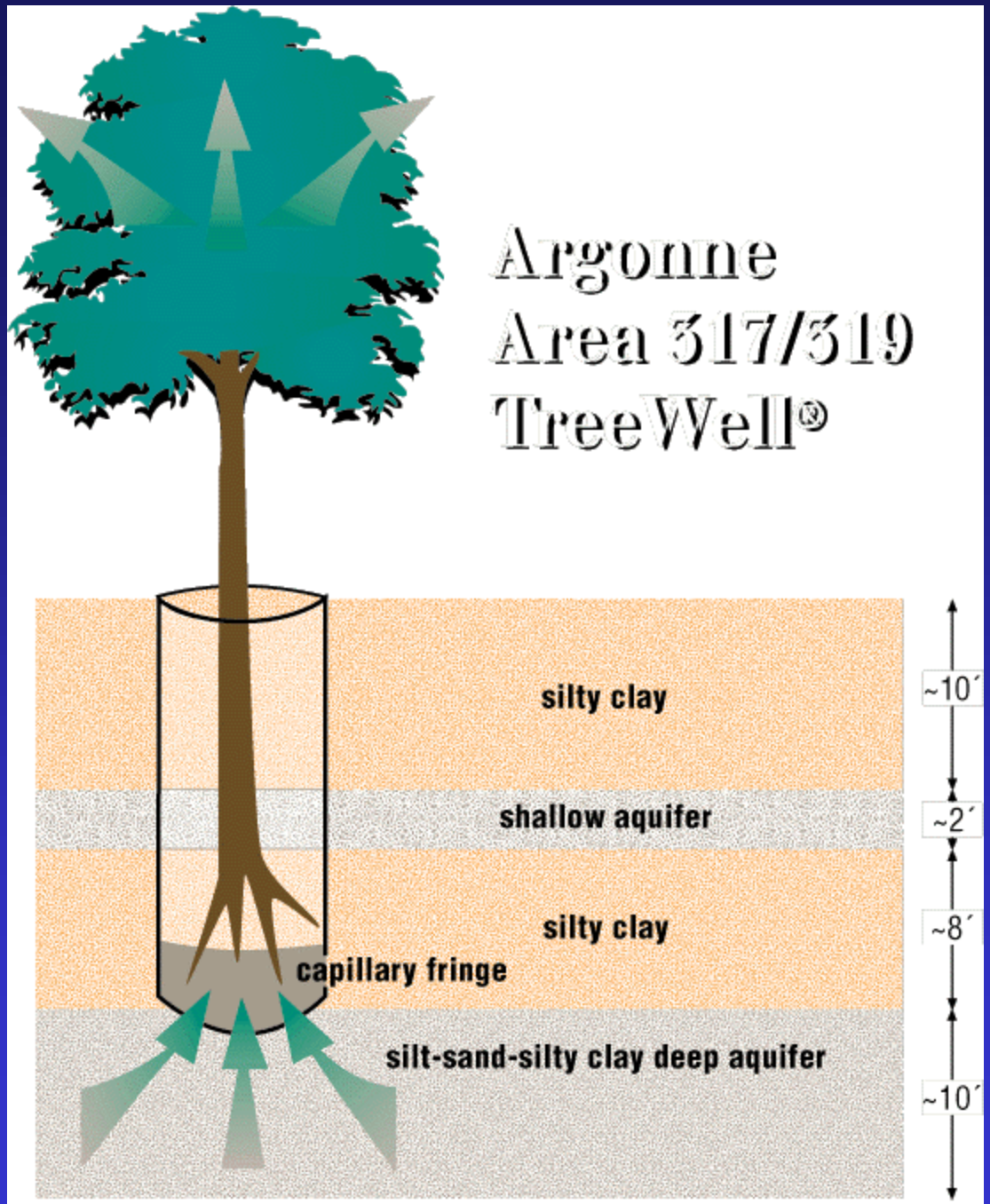

Legend
Gray till
Redbrown till
silt
sand
gravel
dolomite
till
Permeable Zone. All contacts and pinch-outs are conjectural.
Planting Area
North
South
Willow and Poplar
Deep-Rooted Poplar
MW012D
MW29
MW32
MW27
MW001D
MW013I
MW03
MW003D
MW13
MW015
MW027
CSPW-01
MW002D
clayey silt
contaminated aquifer
clayey silt
clayey silt
basal (proglacial) aquifer
Silurian dolomite
Silurian dolomite
700
690
680
670
660
650
640
630
620
610
600
Elevation (ft MSL)
50100
50000
49900
49800
49700
49600
49500
49400
49300
49200
49100
Northing (ft)

Problem: contaminants 30 feet deep

Solution: engineered phytoremediation system

- 389 willows and poplars planted at or near the surface
- 420 specially installed poplars (roots directed to target aquifer)

Argonne Area 317/319 TreeWell®



Applied Natural Sciences, Inc., E.G. Gatliff, Ph.D., President April 8, 1999

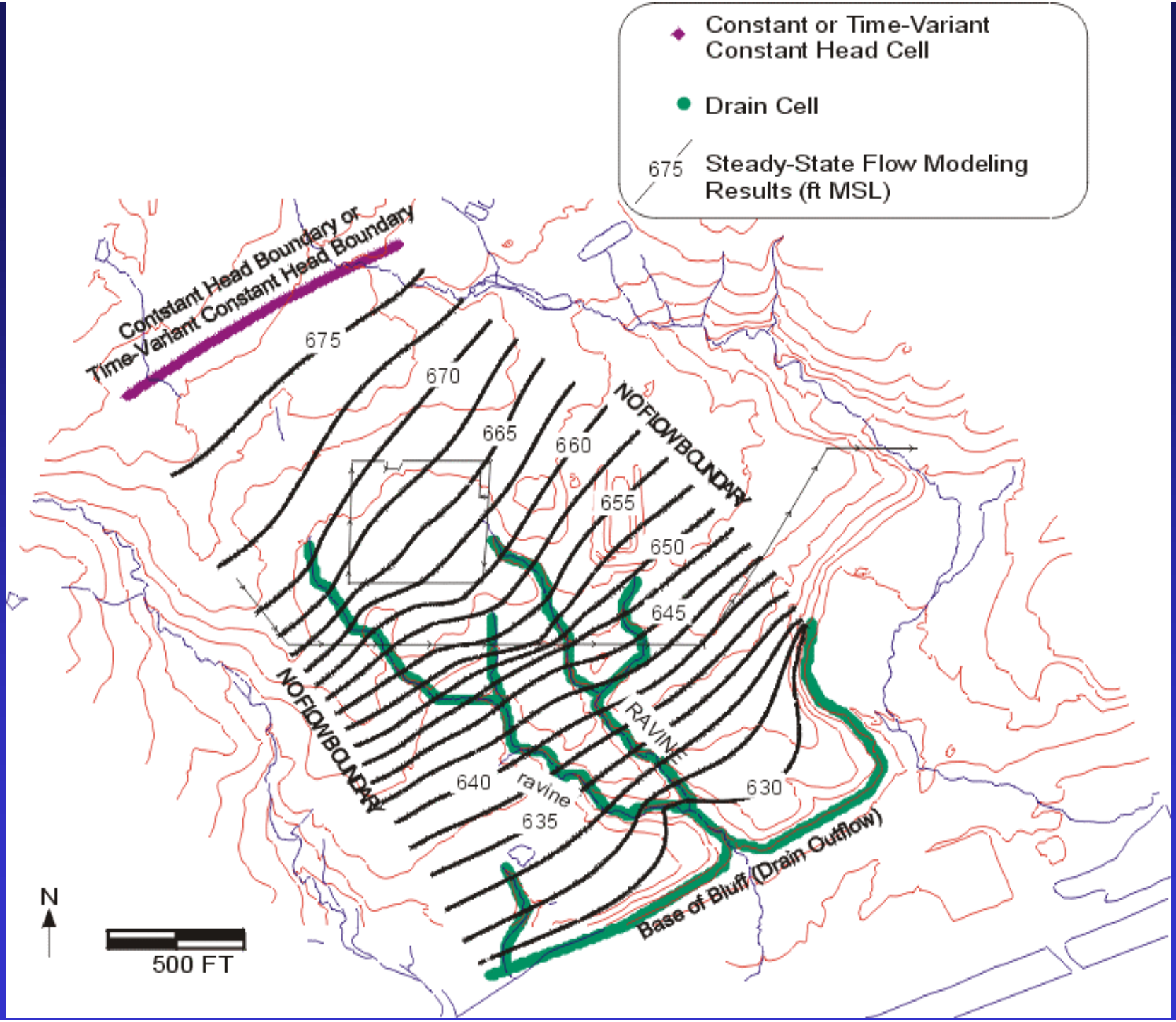
Caisson Rig

2-ft Diameter

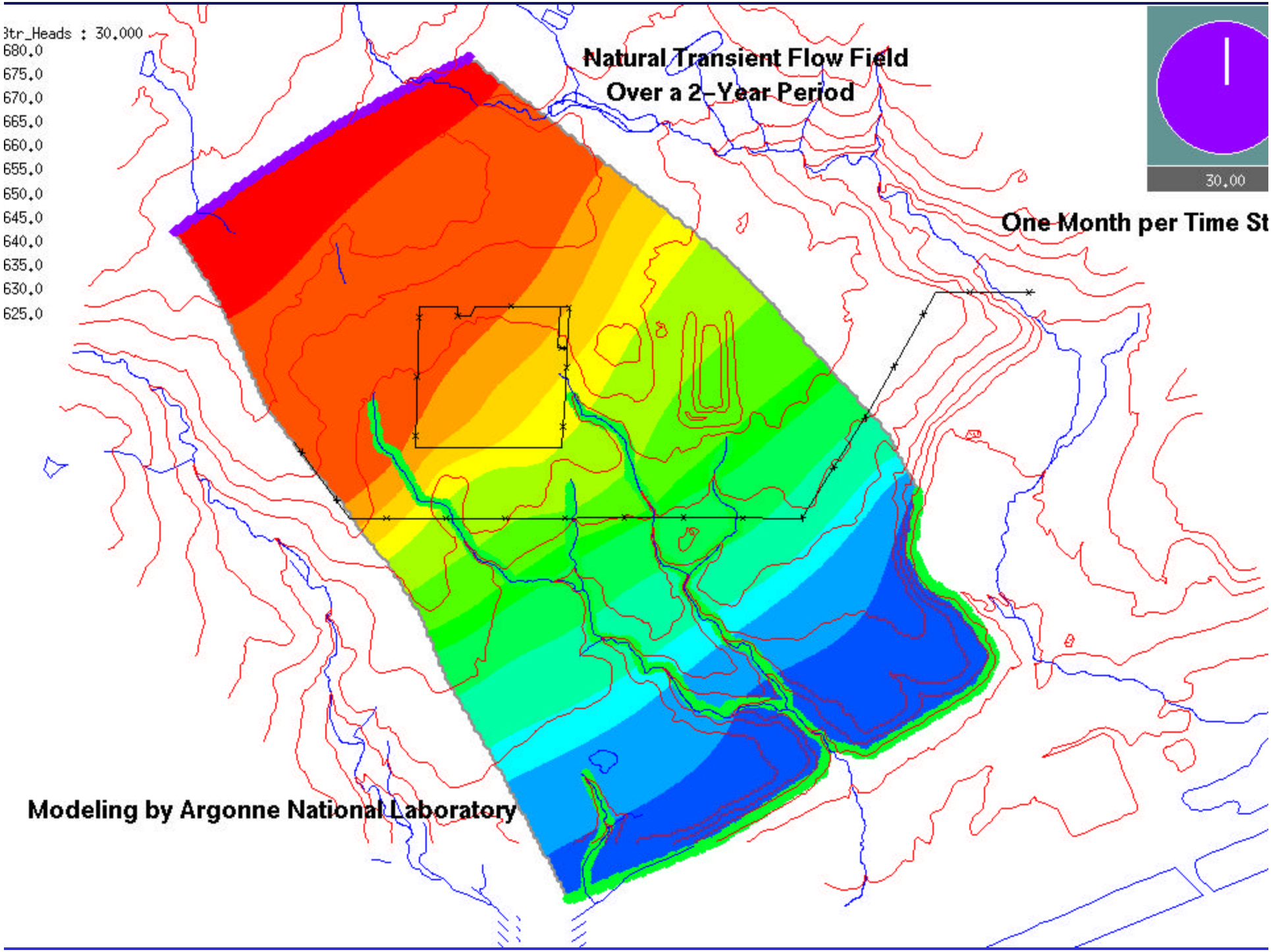
JOHN DEERE
7775

Evaluation of Effect of Phytoremediation System on Groundwater Flow

- focus on aquifer of interest
- ignore shallower perched system
- calibrate initial transient model to the pre-phytoremediation flow field


Constant or Time-Variant Constant Head Cell
Drain Cell
675
Steady-State Flow Modeling Results (ft MSL)
Constant Head Boundary or Time-Variant Constant Head Boundary
675
670
665
660
655
650
645
640
635
630
NO FLOW BOUNDARY
NO FLOW BOUNDARY
RAVINE
ravine
Base of Bluff (Drain Outflow)
N
500 FT

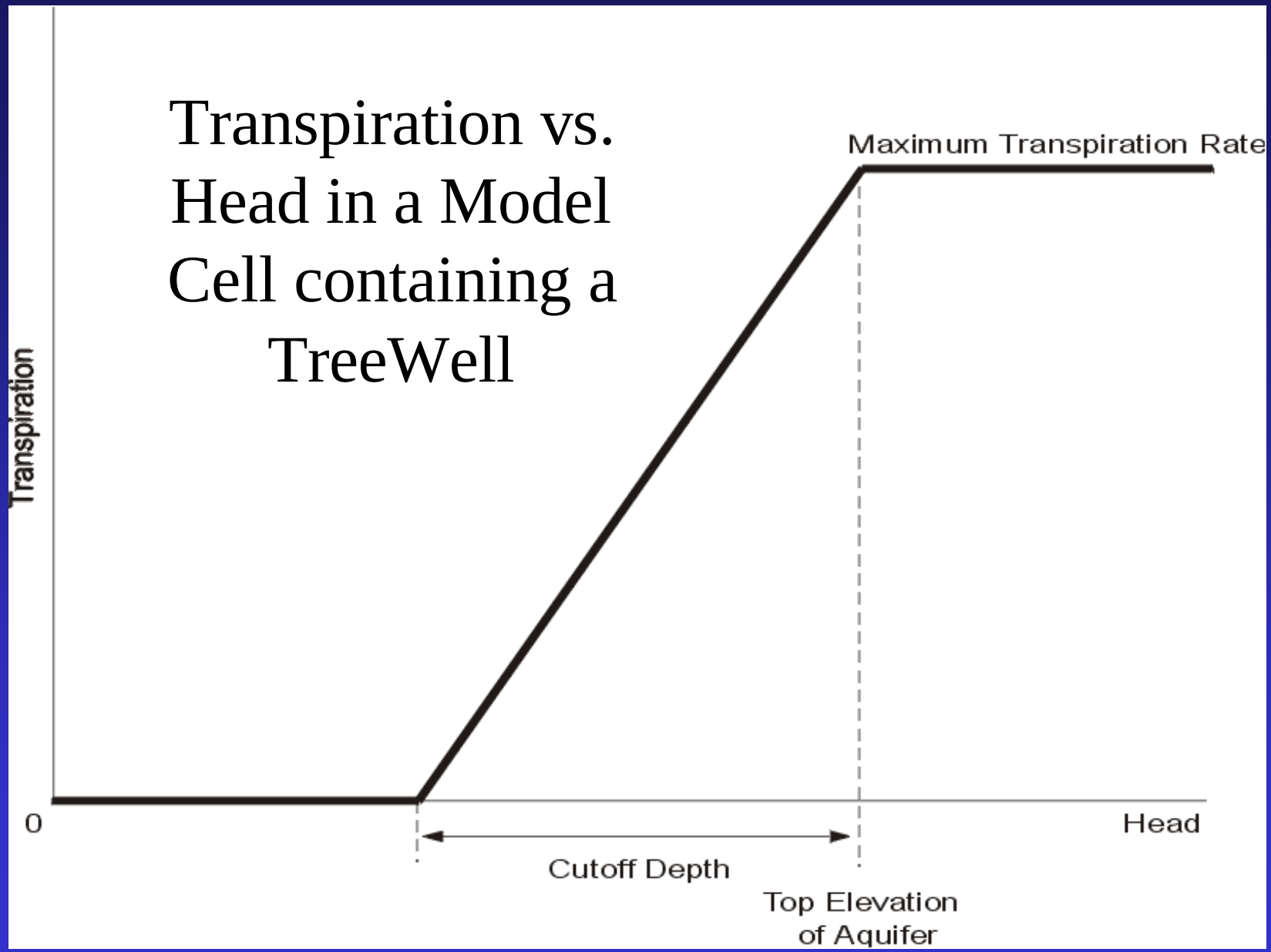
Now switching to animation…


Natural Transient Flow Field
Over a 2-Year Period
3tr_Heads : 30.000
680.0
675.0
670.0
665.0
660.0
655.0
650.0
645.0
640.0
635.0
630.0
625.0
30.00
One Month per Time St
Modeling by Argonne National Laboratory

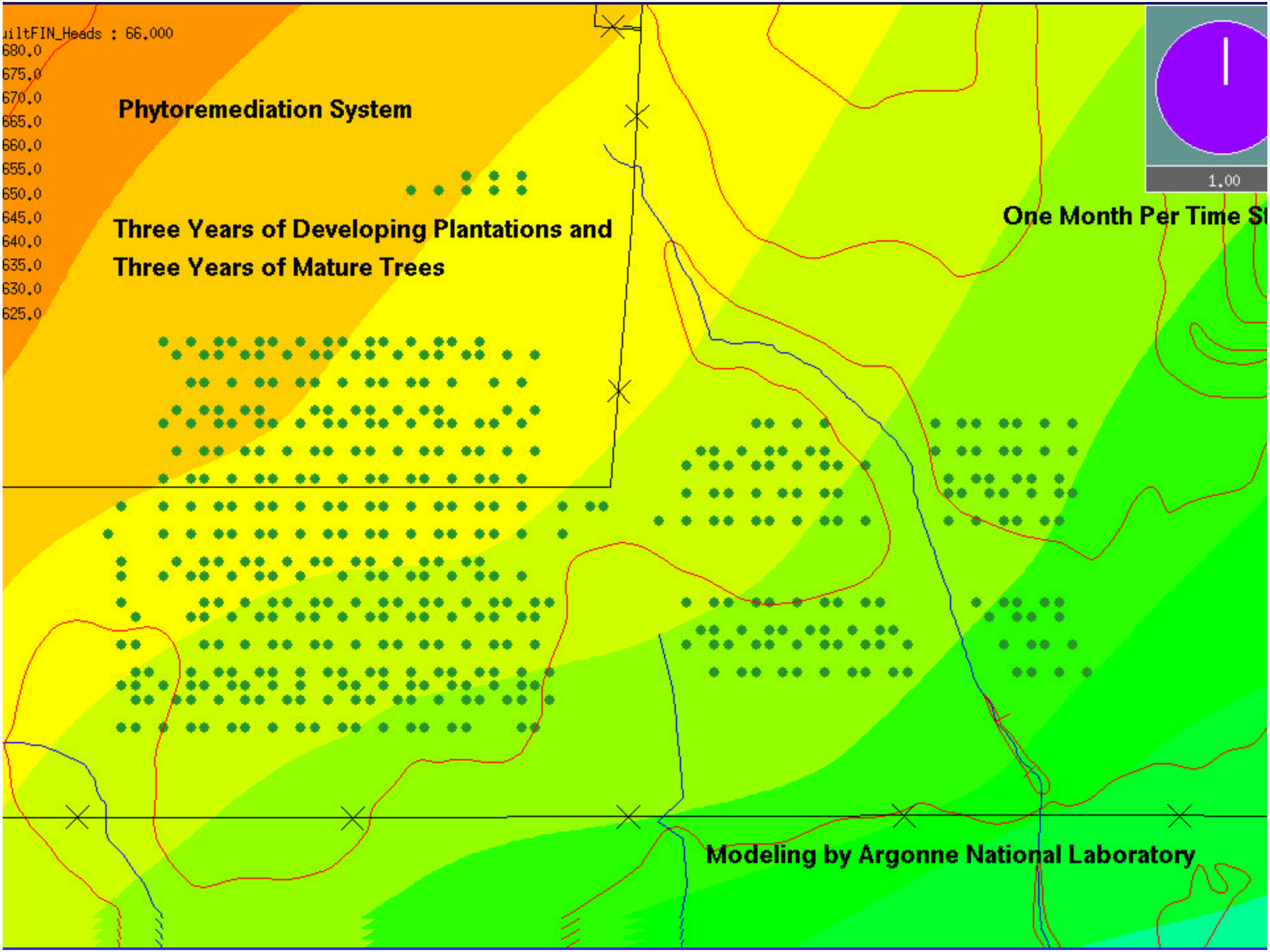
Estimated Water Use for Developing Plantation

	ANL tree water use rates (at 174 trees/acre)											
	jan	feb	mar	apr	may	june	july	aug	sept	oct	nov	dec
year 0 (1999)	0	0	0	0	0	0	2	3	2	1	0	0
year 1 (2000)	0	0	0	0	2	8.75	12.5	12.5	8.75	2	0	0
year 2 (2001)	0	0	0	0	5	17.5	25	25	17.5	5	0	0
year 3 (2002)	0	0	0	0	7	24.5	37.5	37.5	24.5	7	0	0
year 4 (2003) and beyond	0	0	0	0	10	35	50	50	35	10	0	0
All values are conservative average gallons per day per tree per month												

Transpiration vs. Head in a Model Cell containing a TreeWell

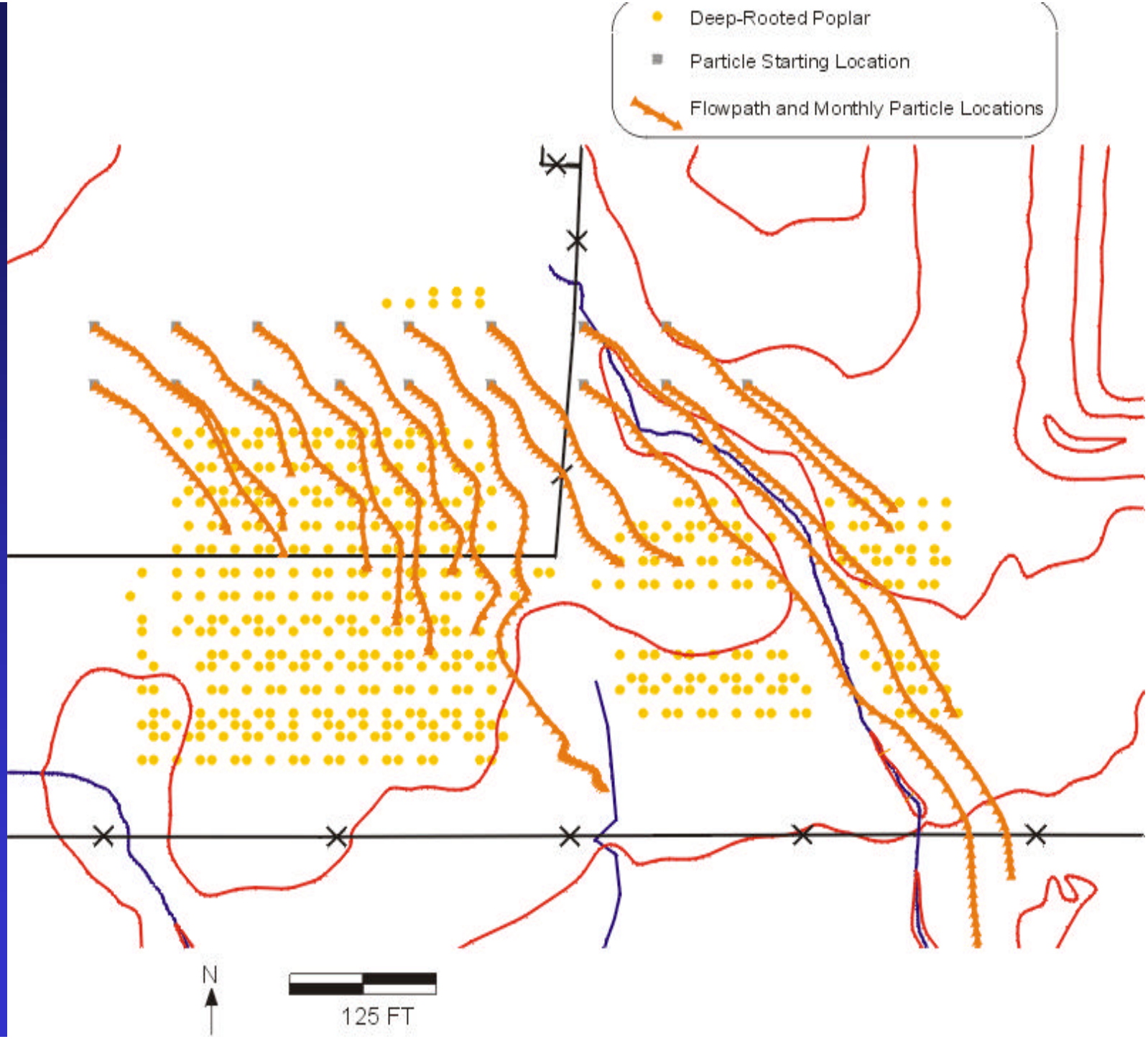


Now switching to animation…


iltFIN_Heads : 66.000
680.0
675.0
670.0
665.0
660.0
655.0
650.0
645.0
640.0
635.0
630.0
625.0
Phytoremediation System
Three Years of Developing Plantations and
Three Years of Mature Trees
1.00
One Month Per Time St
Modeling by Argonne National Laboratory

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 microbially active rhizosphere of 5-17 months

... and vice versa…
The Effect of the Groundwater Flow Field on the Phytoremediation System

- Dewatering of aquifer of interest could stress the poplars
  - future thinning of tree density

What Next?

- Groundwater sampling
- Water level measurements
- Weather data
- Tissue sampling
- Transpirate sampling
- Rhizosphere soil sampling
- Viewing tubes

For your viewing pleasure…

- web.ead.anl.gov/phyto
  - animated visualization of transient flow field under pre- and post-phytoremediation conditions