

Phytoremediation and Biomass with Trees

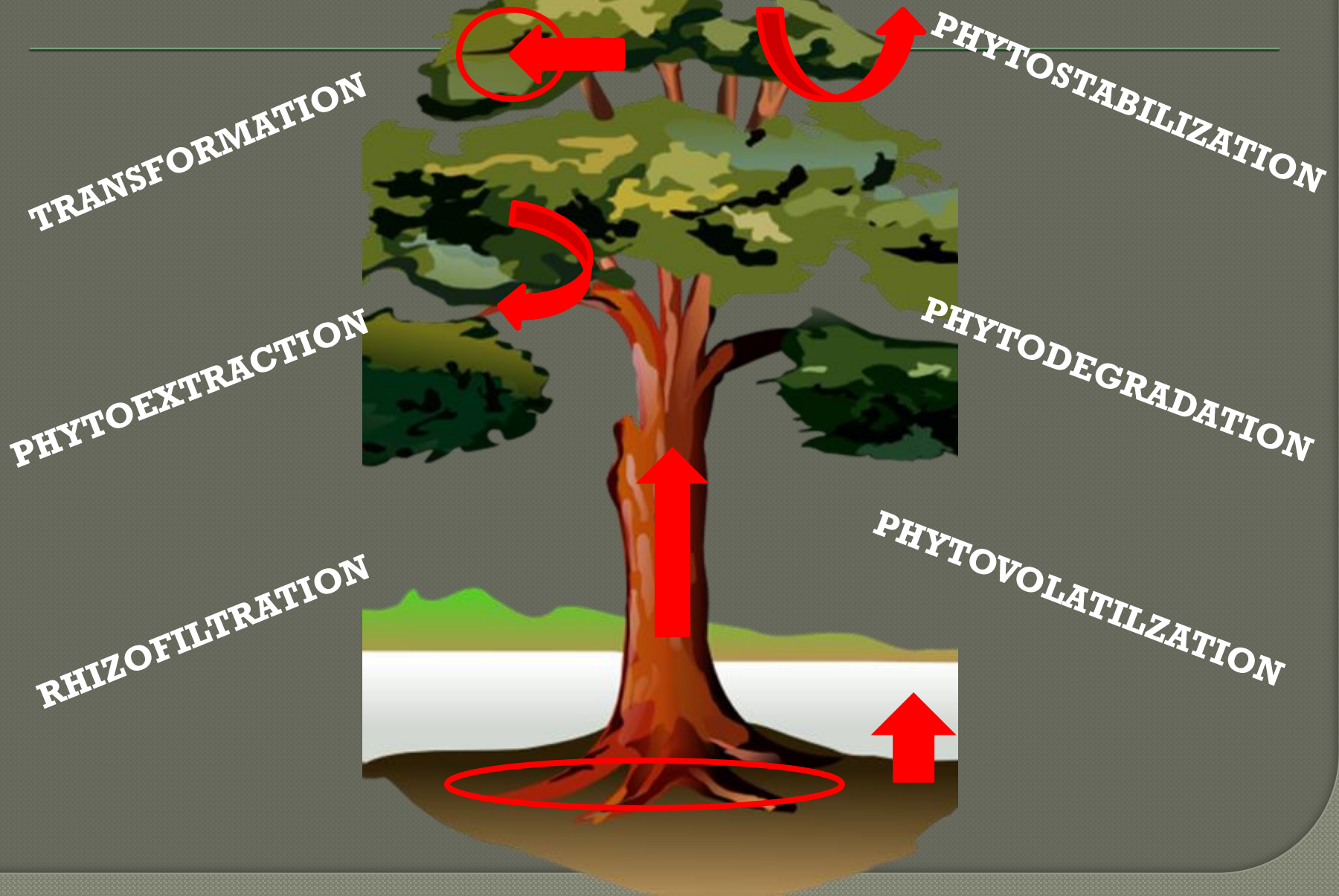
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KANSAS STATE

U N I V E R S I T Y



Phytoremediation



Benefits and Limitations

- ☐ Cost
- ☐ Aesthetics
- ☐ Improvement of soil characteristics
- ☐ Proven for many contaminants
- ☐ Becomes more effective with time

- ☐ Deep aquifers or bound by impervious layers
- ☐ Urban areas
- ☐ Seasonal
- ☐ Time to maturity
- ☐ Growth limited by environment

Woody Biomass Potential

- ◉ As a solid fuel, near C-neutral.
- ◉ As a building material, much smaller energy or C-footprint than other materials.
- ◉ Liquid biofuels are becoming feasible.

Advantages of woody crops

- ◉ Woody crops can be productive on marginal land.
- ◉ Once established, very low inputs for fertilizer, herbicides, irrigation.
- ◉ Plant once, harvest many times.
- ◉ Already dense, pelletizing not needed.
- ◉ Minimal processing needed for use as solid fuel.

Advantages of woody crops

- Can delay harvest by months or years until needed.
- Stores well in the field

9 year old black locust re-sprouts



Populus spp.

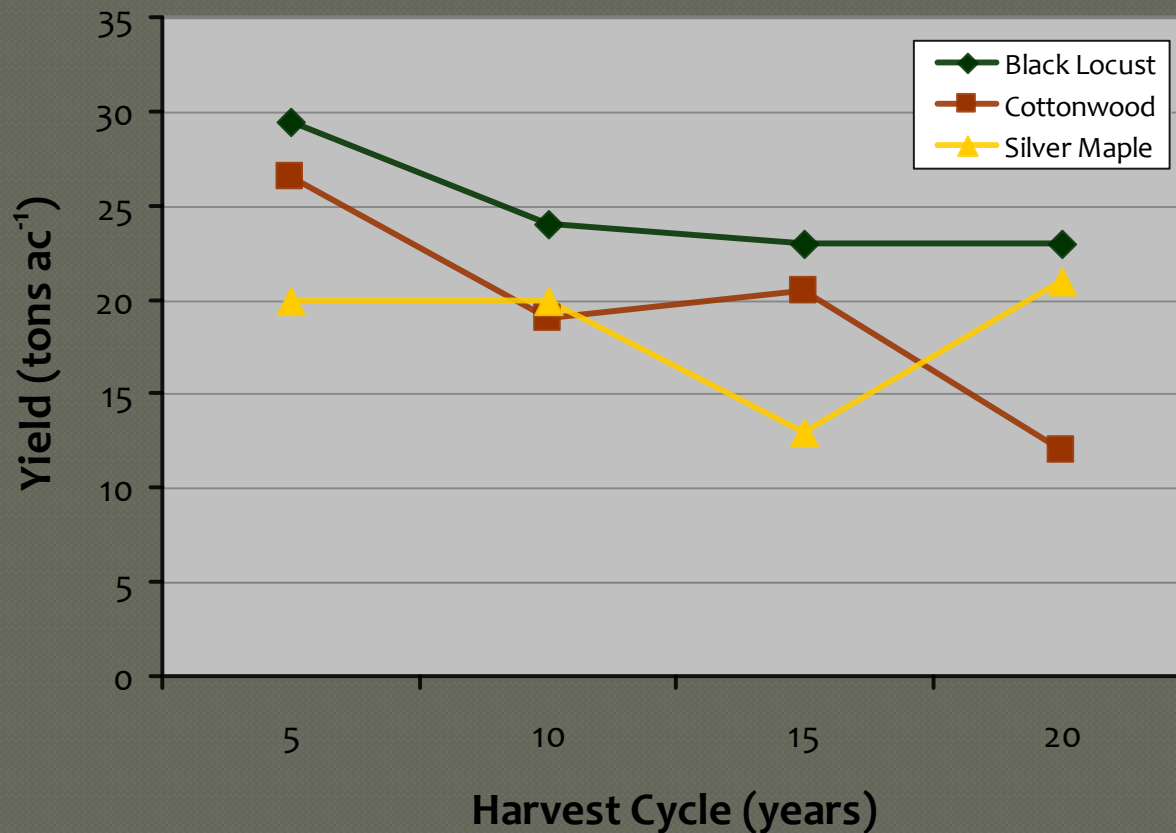
- ◉ Rapid growth
- ◉ High nutrient demand
- ◉ High water use rates
- ◉ Extensive root systems
- ◉ Easy to grow
- ◉ INEXPENSIVE



Phytoremediation with trees

- Usually begins and ends with species and hybrids of *Populus*.
- But there are lots of other species available, each with there own unique set of attributes.

Air-dry yield, 5 year cutting cycle



Black locust *Robinia pseudoacacia*

- Used to remediate mine spoil sites
- Tolerates low pH
- Co-benefits, fixes N, stores C above and below ground, nectar and honey production.
- Compare to miscanthus?



Woodland Ecosystem Services

- ◉ Sequester carbon
- ◉ Prevent erosion
- ◉ Stabilize streambanks
- ◉ Native woodlands provide habitat for native species of flora and fauna
- ◉ Aesthetically-pleasing landscape

Case Studies in Manhattan, KS

Case Study 1: Manhattan Biosolids Farm



Case Study 2: KSU Old Chemical Waste Landfill





City of Manhattan Biosolids Farm Management Areas



0 500 1,000 1,500 2,000 2,500 Feet



Biosolids Pipeline
Wastewater Outfall



Sections
City owned land



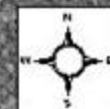
Leased land (Star A, Inc.)



Leased land (Sneegas family)

Manhattan, KS Biosolids Farm

- In the late 1990's KDHE realized it was over applying biosolids to a limited area of 160 acres.
- A nitrate-rich plume was detected in the groundwater and moving to the Kansas River.
- 16 monitoring wells were installed throughout the farm.
- Worst wells averaged 40-70 ppm-N.



600 0 600 1200 Feet

City of Manhattan Biosolids Farm Management Areas
Groundwater Test Wells

Remediation Efforts

- Cease applying biosolids to the original 160 acres
- Grow alfalfa on that field
- Applied 2T/acre/year over a broader area
- Establish tree buffer near Kansas River, CH2M Hill recommended hybrid poplar



Tree Planting 2004

- Cottonwood seedlings and unrooted cuttings, sycamore, willow, and Siberian elm
- Trees planted in the sandiest area did not establish



End of second summer growth

Objectives

- Determining the most effective way of establishing trees in sandy coarse soils.
- Using *Populus* spp. and Siberian elm trees to take up and stabilize nitrates from groundwater.



Methods

2006 Trench Study

- ◉ .4m deep by 43m long by 2m across trench
- ◉ KSU dairy cow composted manure
- ◉ Plastic Miracle Tube tree shelters
- ◉ Each tree was irrigated



Trench Study

- Trees planted were rooted cottonwood cuttings from Nebraska and true seedlings from Missouri , and Siberian elm

TREATMENTS

- Untrenched, no compost
- Untrenched with compost
- Trenched no compost
- Trenched with compost
- Shelters no shelters

S elm, MO and NE cottonwood



Trees Measured

- n=24
- Tree height we used a laser hypsometer
- Dbh tape to measure diameter of trees
- Trees were measured in years 2006, 2008, 2010, 2014



Trench preparation and planting



August of second year



Success, plantation is visible on Google earth!



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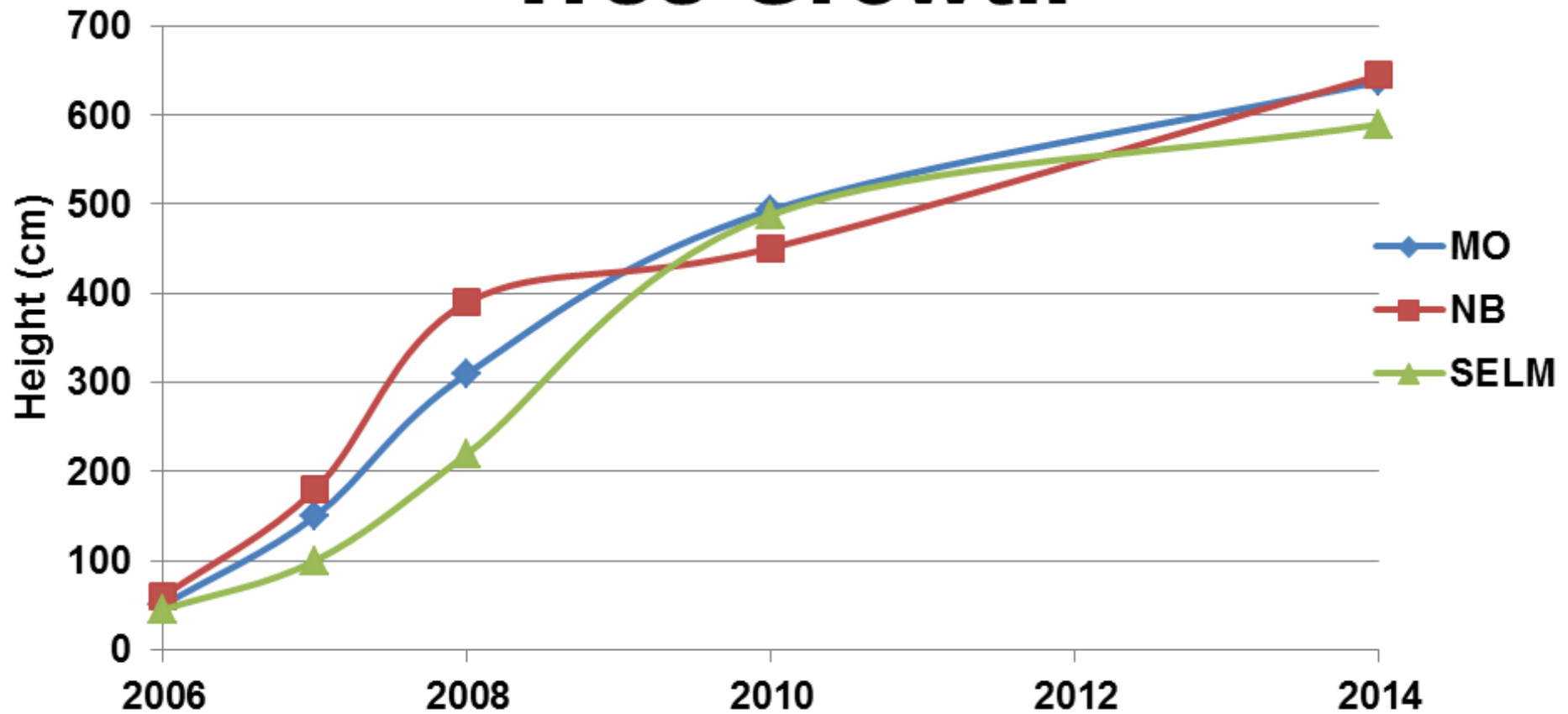


1991

Imagery Date: 9/1/2012 39°11'01.90" N 96°31'44.18" W elev 1006 ft eye alt 1907 ft

Results

Tree Growth



Compost and Trench Treatments

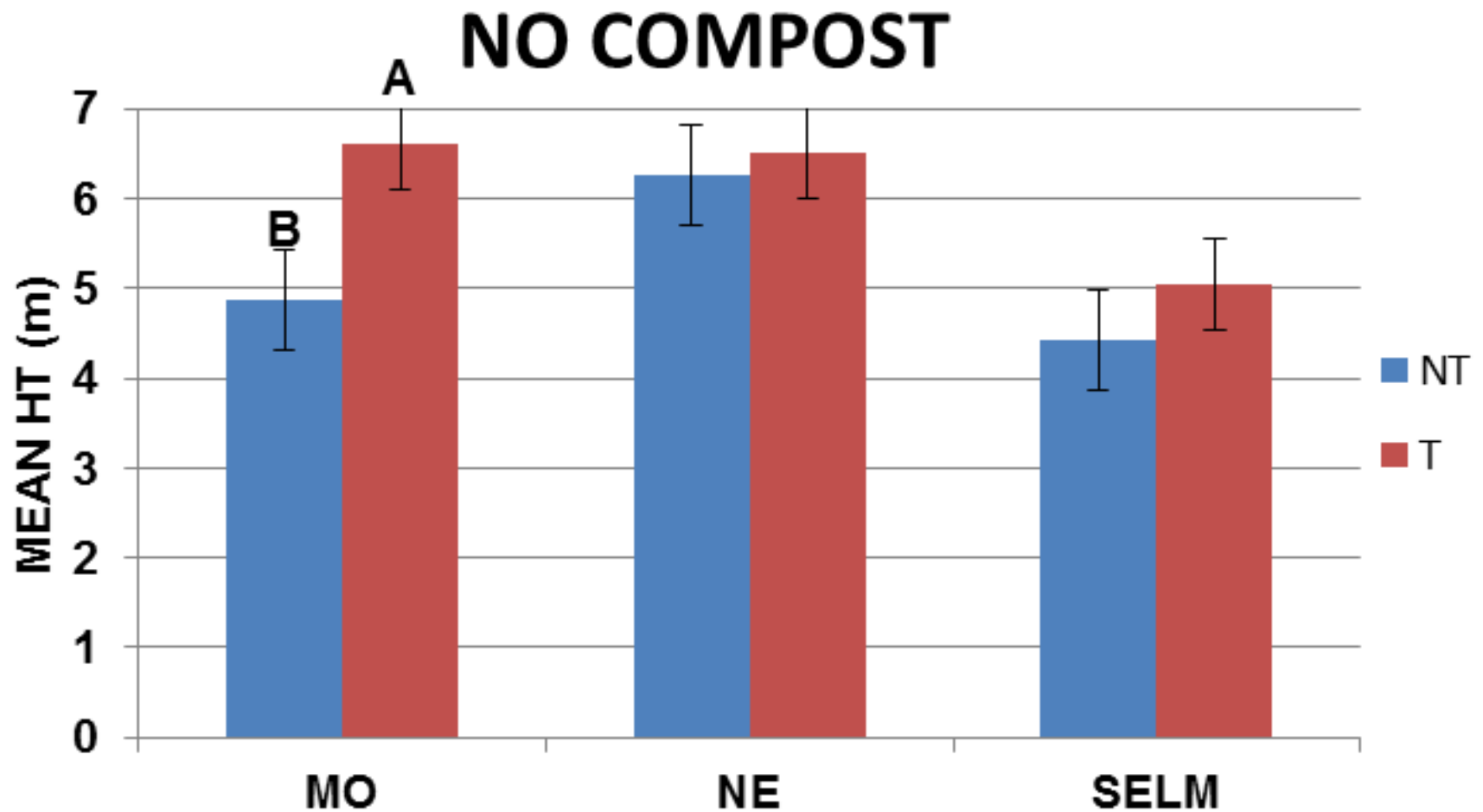
NO COMPOST

-MO, significant effect with trenching

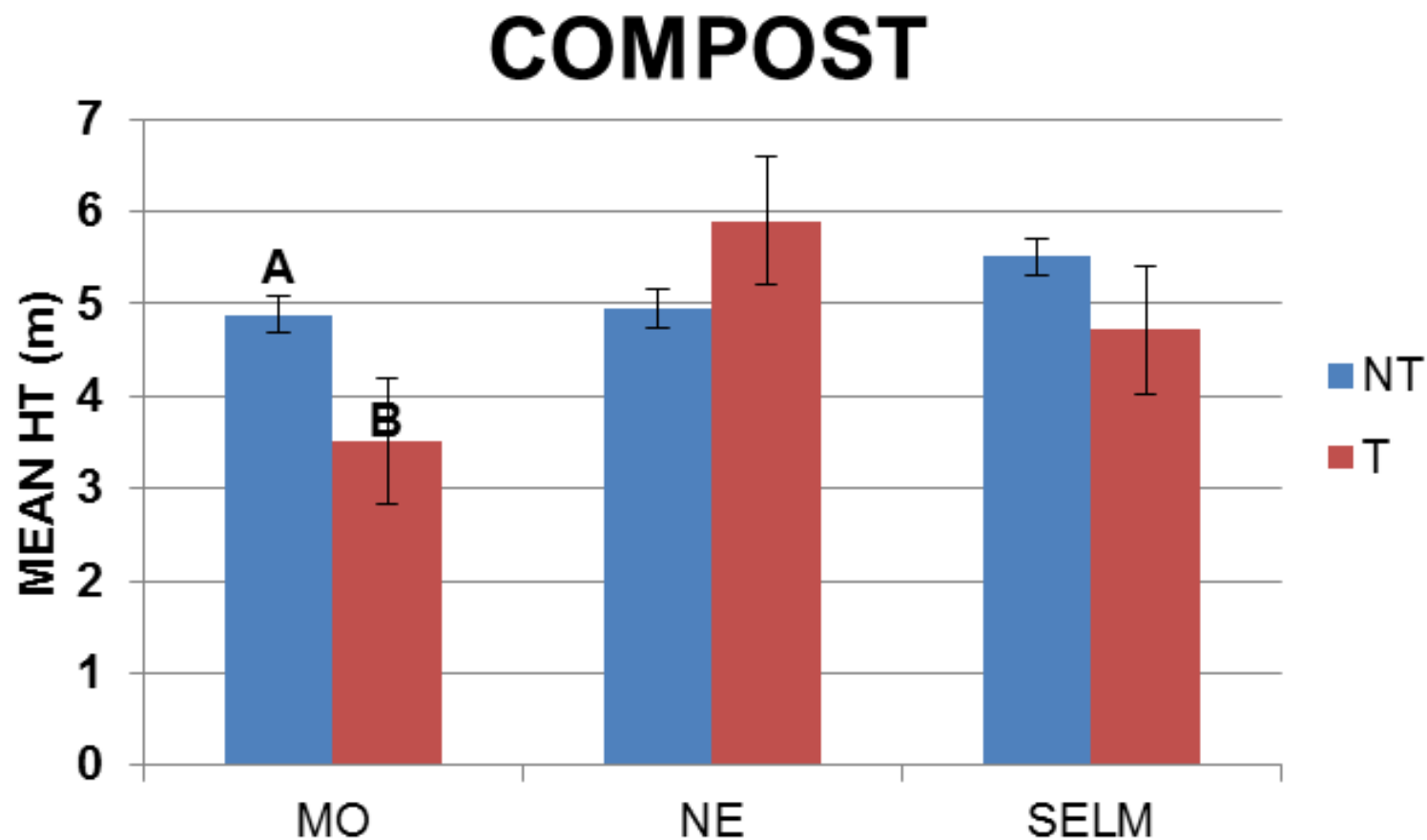
COMPOST

- Addition of compost only showed significant effect MO tree source and no significant effect with NB, SELM.

Height at 8 Years



Height at 8 Years



2006

Before and After



2014



Tree Establishment Bottom line

- ◉ Just needed to add irrigation for first 2 years, to get trees established.
- ◉ Compost, trenching, tree shelters had inconsistent effects.
- ◉ Establishing trees provided stabilization of the soil, improved microclimate, and ecological succession (nature) did the rest!

2014 EXCAVATION of 11 year old cottonwood

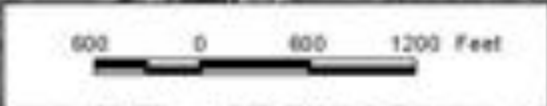
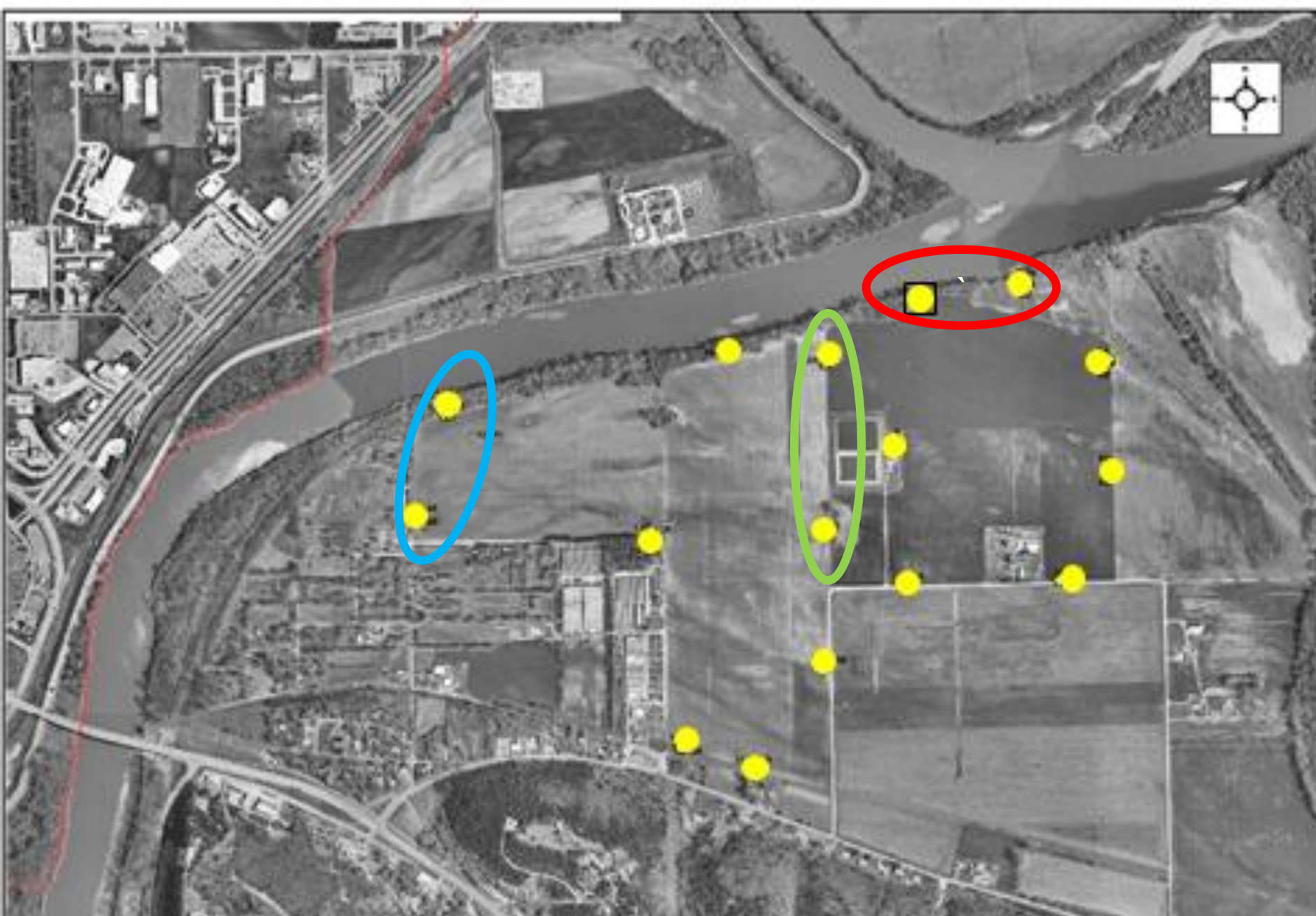
- Did the trees reach groundwater?





Root depth estimated to water table at 18'

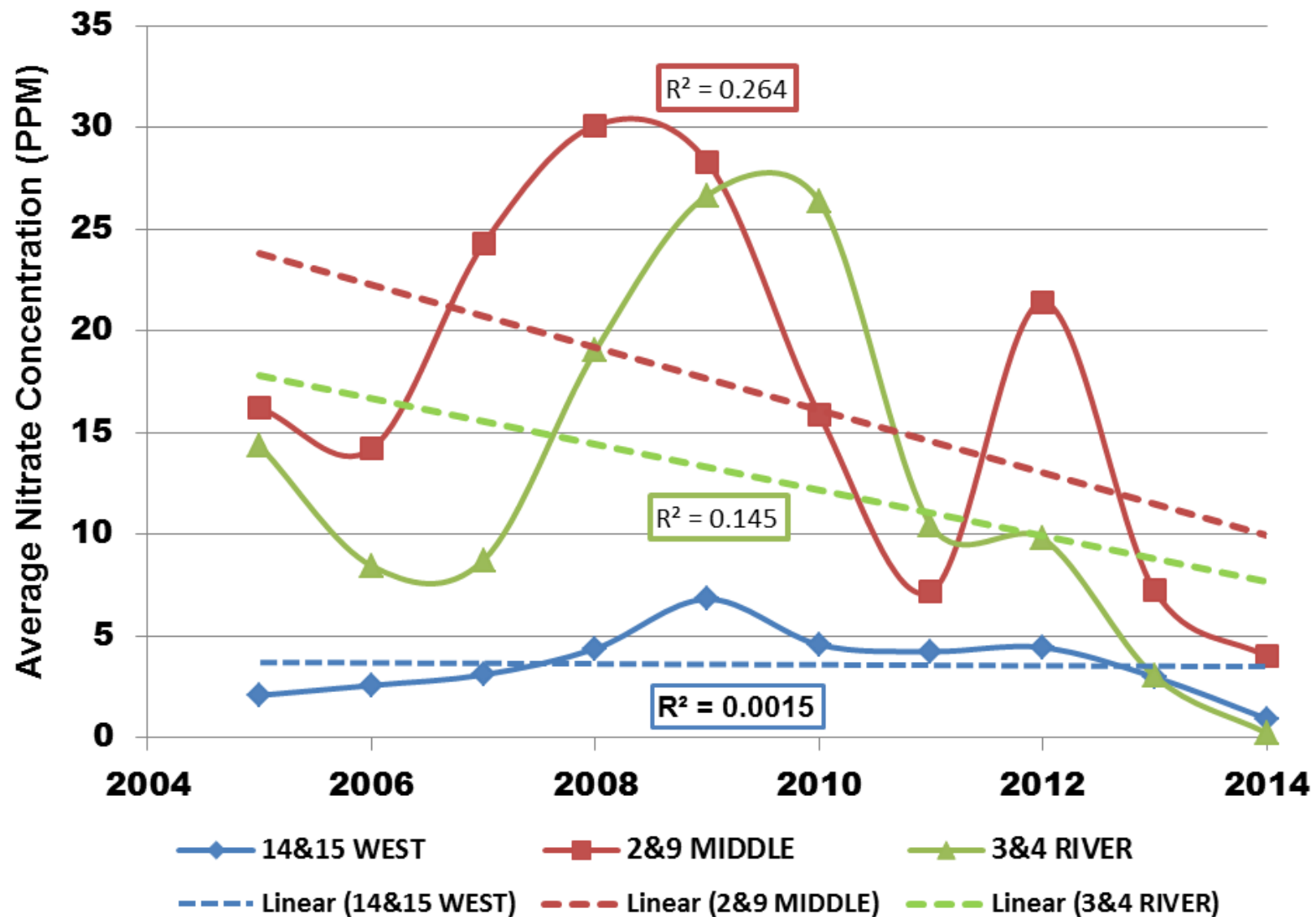




City of Manhattan Bioscience Farm Management Areas
Groundwater Test Wells



Wells



Conclusion

- Addition of **irrigation**, aided in success of tree establishment.
- Shelter additions to trees aided in success of **survival** of all trees.
- Trenching and Compost effects were inconsistent.
- Some evidence for poplar planting aiding the remediation.

Case Study #2: KSU Old Chemical Waste Landfill

- On-campus landfill for hazardous and low level radioactive waste disposal site from 1960 to 1988.
- 1987 contaminants detected in groundwater.
- Site officially closed 1989.
- **Potential Thursday field trip visit.**



Kimball Ave

408

Photo taken 2012,
after excavation
of landfill

Objectives

- Document performance of various cottonwood sources.

Remediation objective

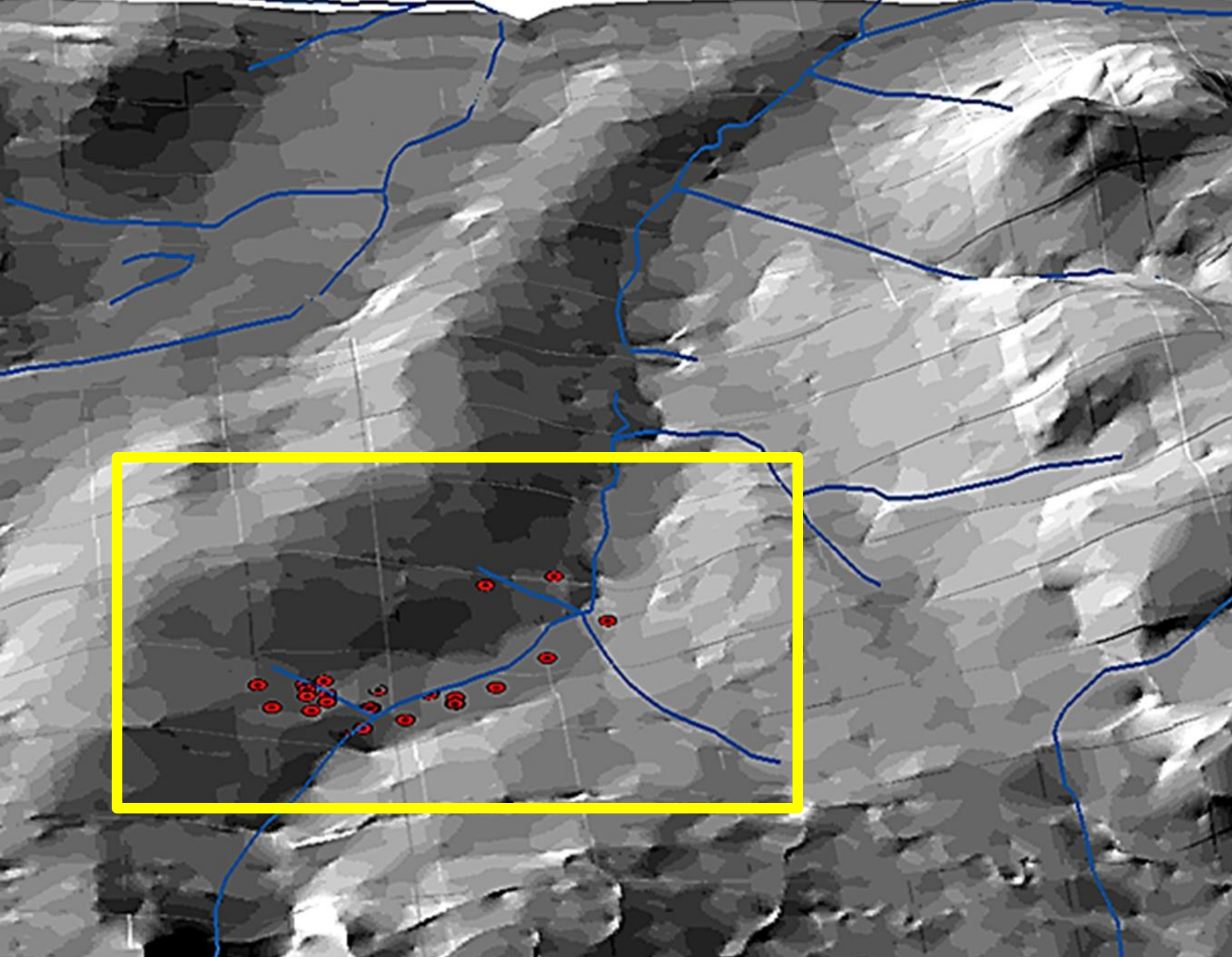
- Planting Cottonwood trees with the goal to get hydraulic control, and transpire 1,4 Dioxane from groundwater.*

Volatilization of Dioxane

- Dioxane has the ability to move freely through plants by transpiration, is easily photodegraded in the atmosphere.
- Has the similar volatilization of water.
- The level of dioxane observed in the leaves is about half of that observed in root water because vapor pressure deficit from leaf to air is twice that of water, thus dioxane evaporates twice as fast as water at ambient 50% relative humidity.

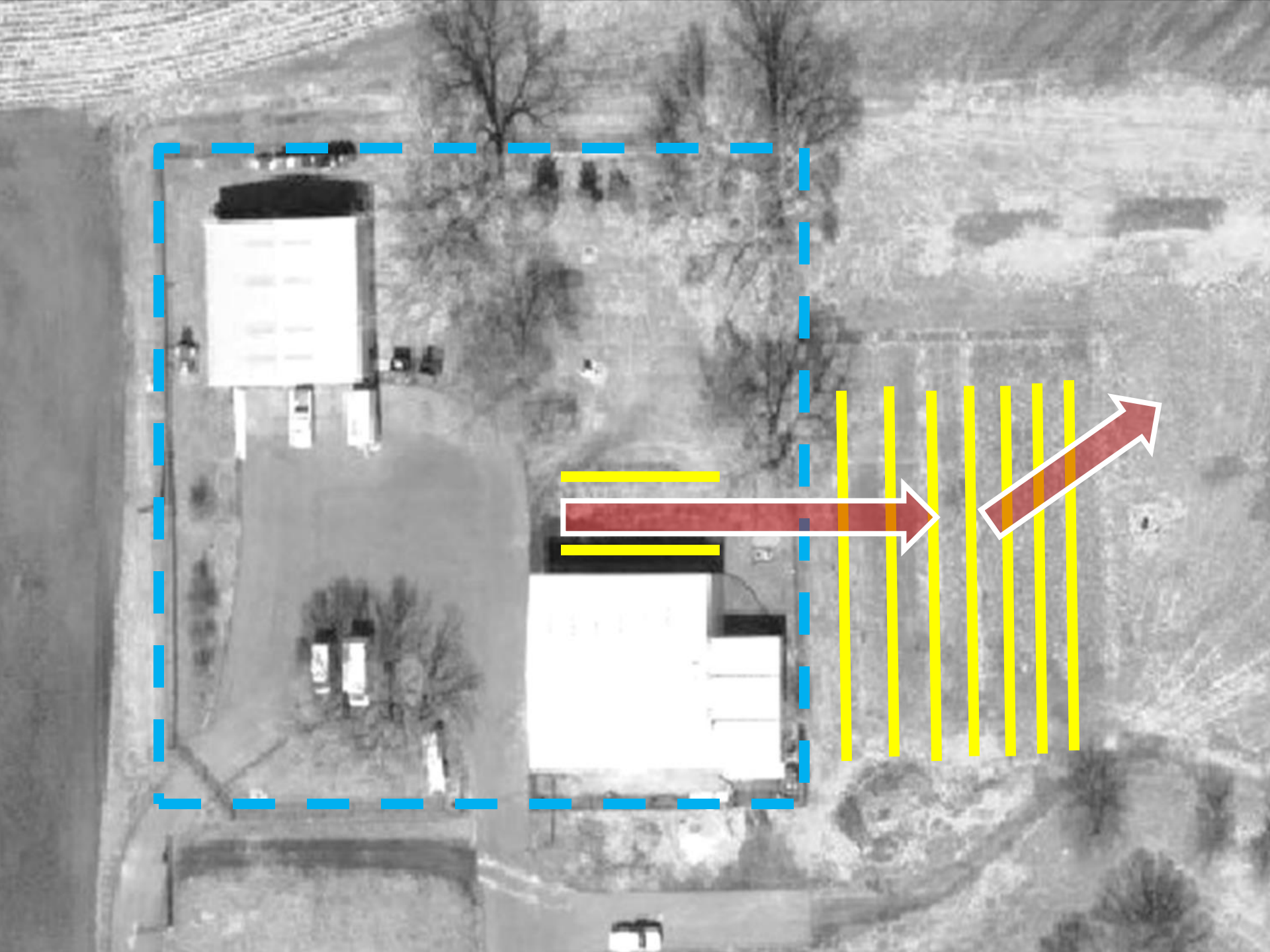
Remediation Efforts

- Monitoring data collection began in 1990's, and the site was “capped” with paved parking and a building.
- Tree plantation installed 2005, and 2007.
 - Three trenched rows of poplars over the area of highest contamination
 - 15 rows down gradient from the hot spot to impede plume migration and enhance the uptake of contaminant.
- In 2010, a trench was dug to feed ground water to a treatment shed that uses UV light and hydrogen peroxide.
- In 2012, major excavation of site, due to further plume migration.









Poplar varieties:

- **Nor'easter (*Populus deltoides* x *canadensis*)** : hybrid poplar clone
- **Souixland (*Populus deltoides* subsp *monilifera*)** : cottonwood clone, selected in North Dakota
- **McHenry (*Populus deltoides* subsp *monilifera*)**: Plains cottonwood selection from Wichita
- **MeadWestvaco (*Populus deltoides*)**: Eastern cottonwood variety



Trench planting inside the fence





2nd year growth
MeadWestvaco



2005



2013

Tree Growth

2005

2009

2009

2013

Westvaco
McHenry

Mean Diameter

7.2 inches

7.1 inches

Mean Height

46ft

43ft

Results

- **MeadWestvaco** have grown the tallest, with a narrower crown,
- **McHenry** have also grown well, with a wider crown
- **Souixland** doing fair, moderate mortality
- **Nor'Easter** poorly formed, suffers dieback and mortality



2012
EXCAVATION



W4

W10

W16

W15

W8

W14

W9

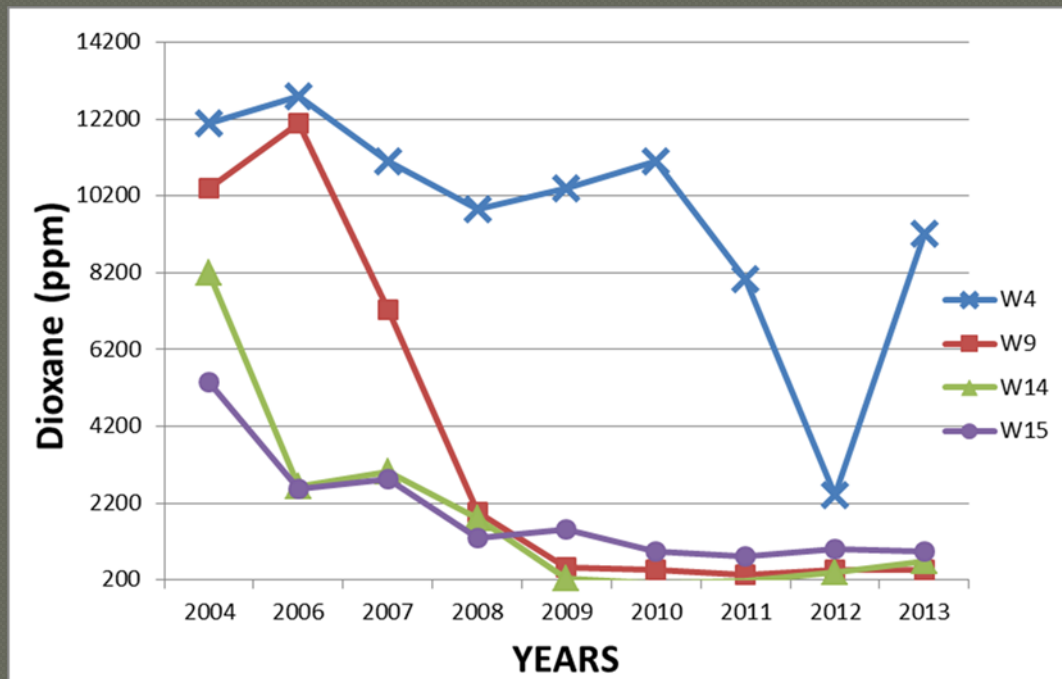
W7

W13

W17

W1

Dioxane Levels Over time





W4

W10

W16

W15

W8

W14

W9

W7

W13

W17

W1

Results

- Dioxane levels have declined over time in the majority of the wells, although high levels are still being detected.
- Hydraulic control of the plume has not been achieved yet, neither with trees nor the pump and treat interception.
- Dioxane continues to be detected at high levels, even after old landfill material was excavated in 2012 and shipped out.

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