Battelle
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Implementation of a Two-Year Phytoextraction Pilot Study at a Wood Treatment Chromated Copper Arsenate Site

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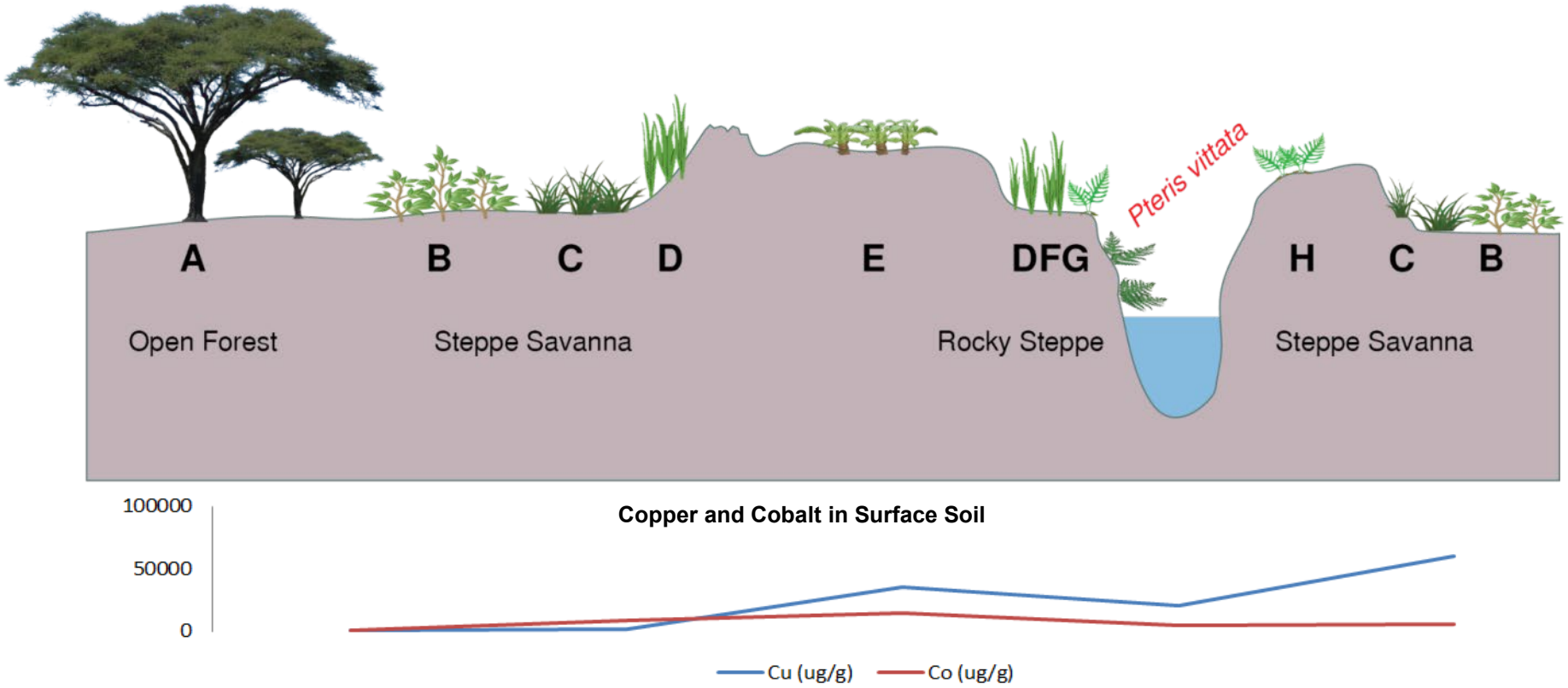
April 16, 2019

Geobotanical Precedence of *Pteris vittata*

Pteris vittata has often been observed on arsenical mine dumps (Wild, 1974).



Schematic transect across Etoile Mine, former Zaire, showing mineral floras and environment where *Pteris vittata* is found (Malaisse and Gregoire, 1978).

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Site Setting

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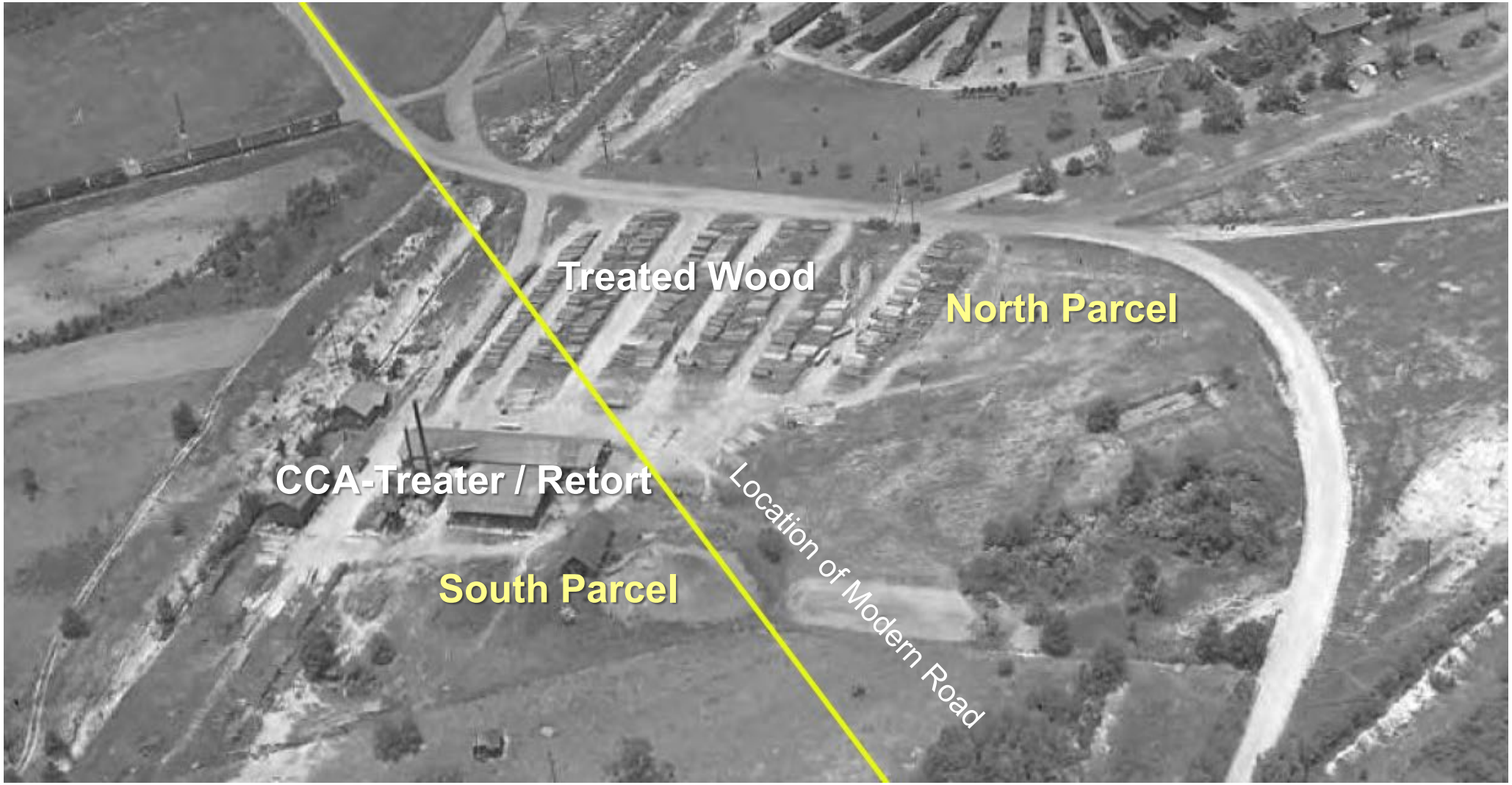
Chromated Copper Arsenate Wood Treatment



Aerial Photograph Circa 1949

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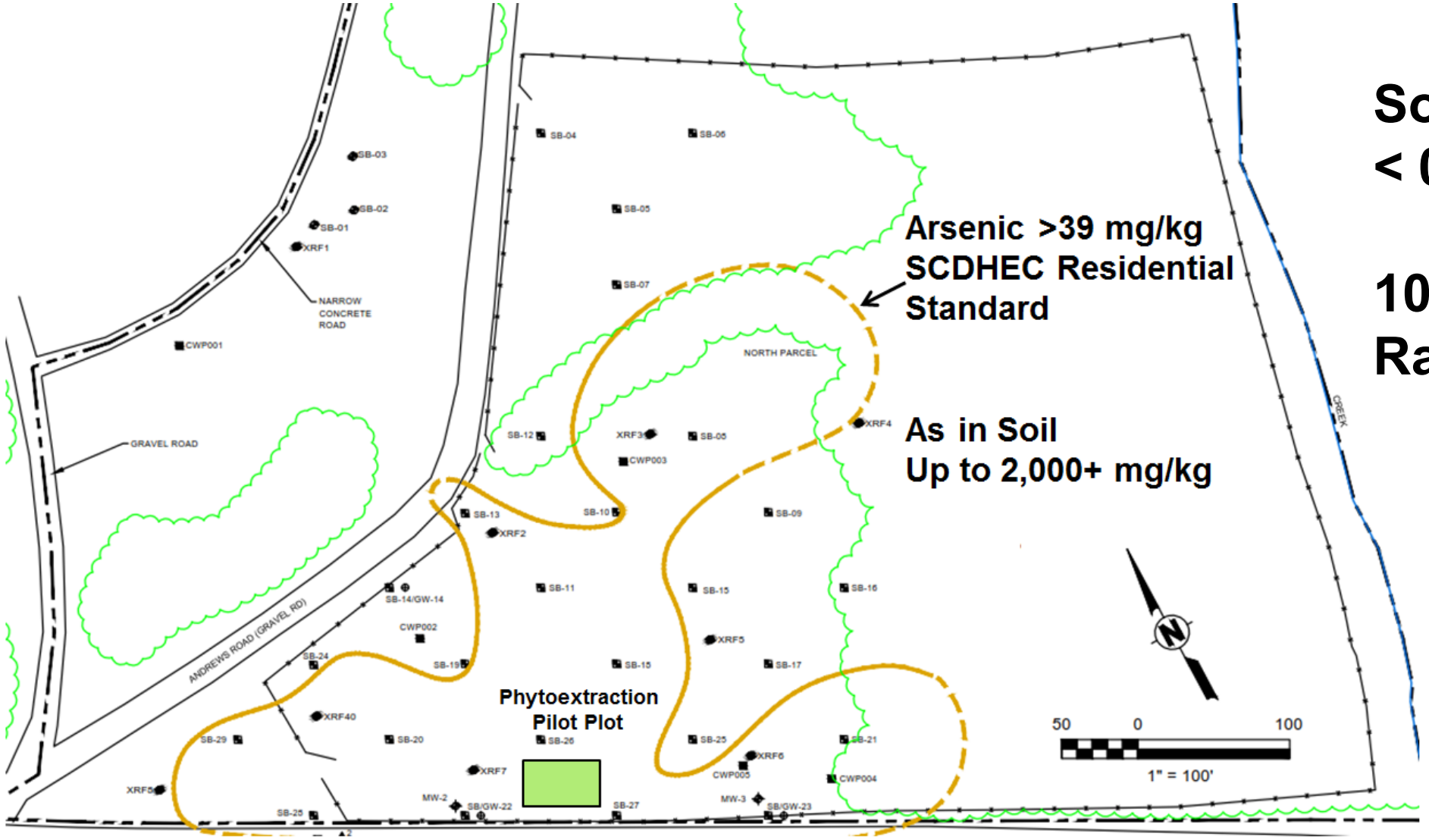
Arsenic Footprint – North Parcel



Soil Arsenic
< 0.5m

100-500 mg/kg
Range

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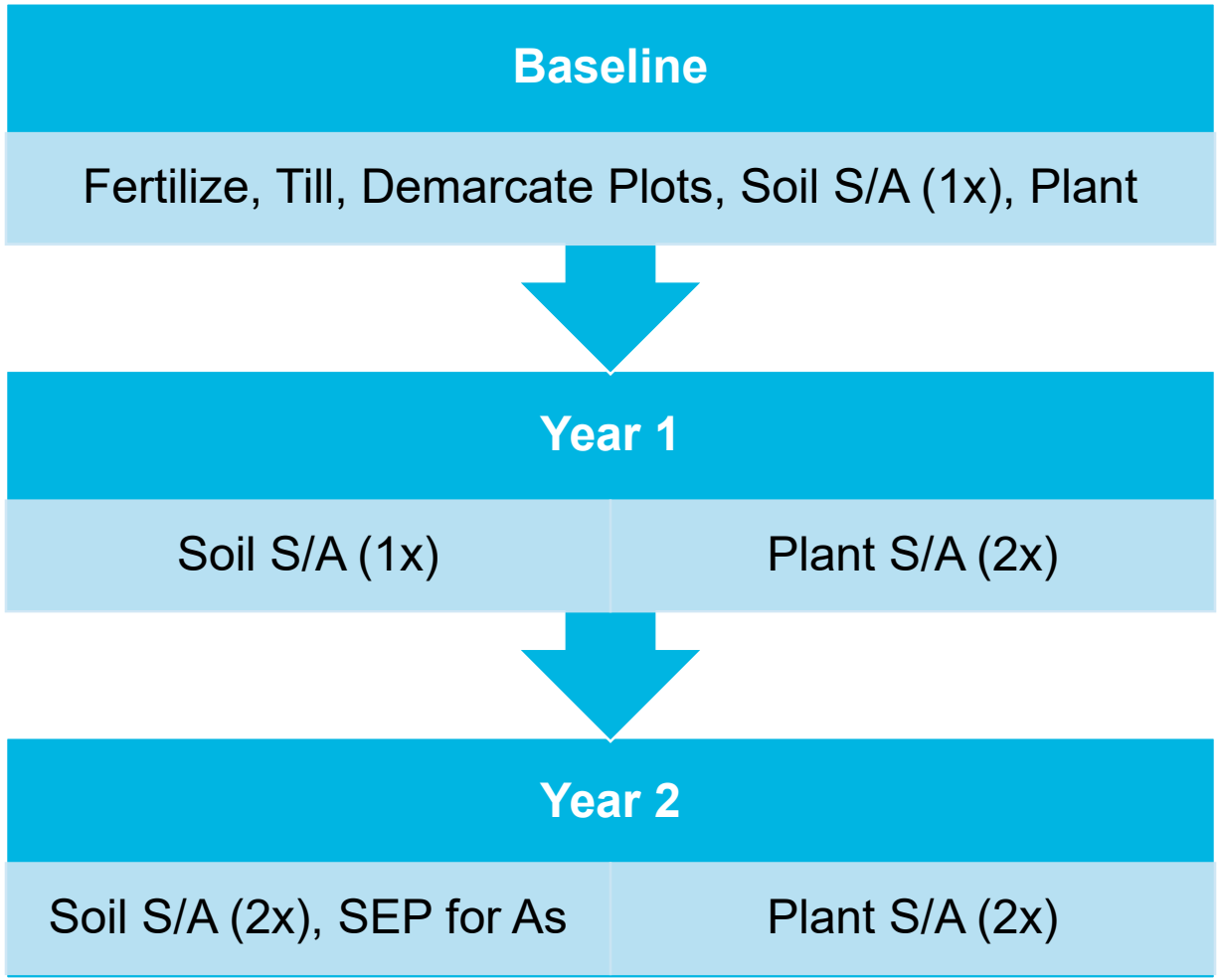
Pilot Design



Soil Analyses

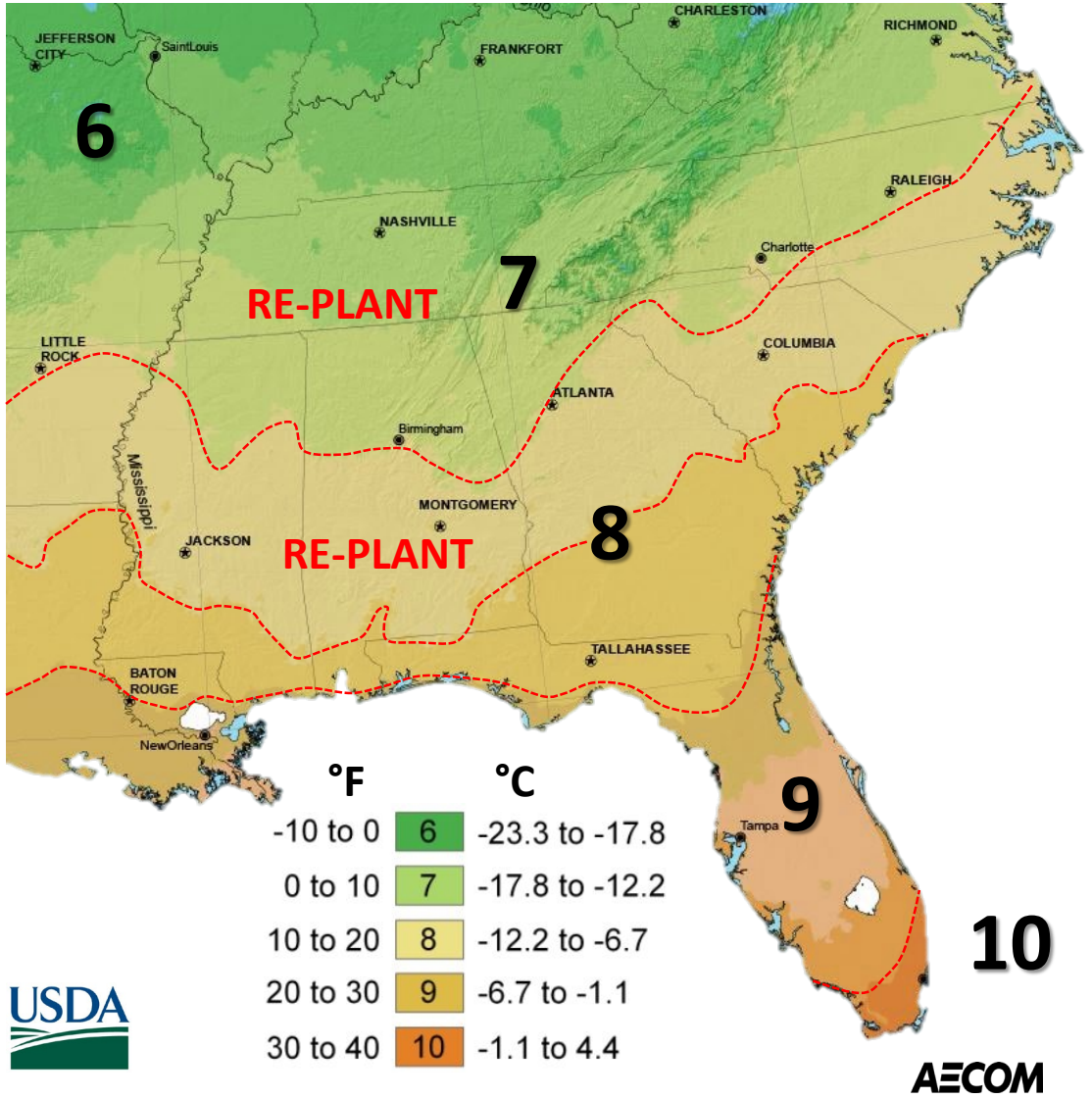
- pH, CEC, TOC, Mehlich 1, Twenty Metals (Method 3051), including As, Cu and Cr. UGA Extension.
- Sequential Extraction of As (Wenzel et al., 2001) and In Vitro Bio-Accessibility Assay (IVBA).

Plant Tissues

- Dry, Acid Digestion, ICP-MS. UGA.
- Mid-Season and Fall Harvest (Fronds and Stems)

Challenges with “Arsenic Ferns”

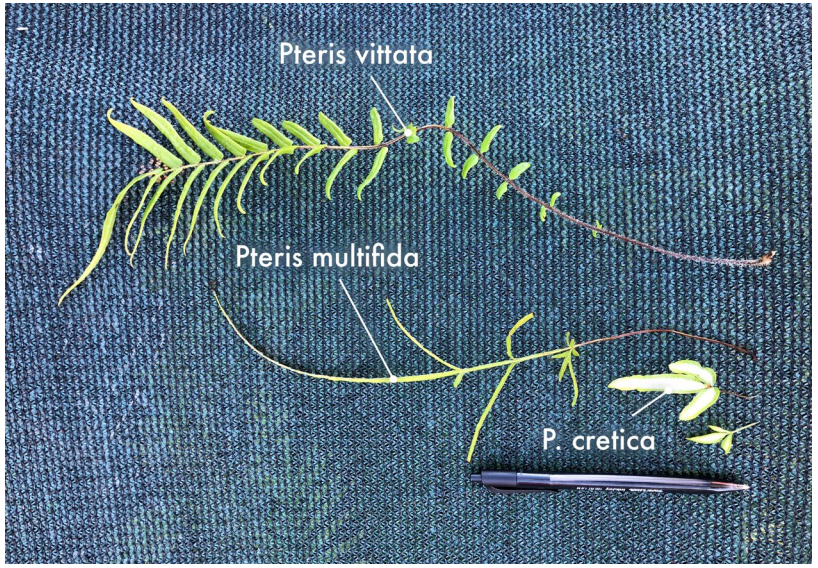
- Ferns of the Genus *Pteris* are tropical,
- Best to plant south of 30° N (Savannah, Georgia is good reference point),
- Assume re-planting in USDA Hardiness Zones 6, 7, and 8a and probably 8b,
- *Pteris vittata* has become established in S. Carolina, Georgia, Florida, Alabama, Louisiana, Texas, California, Puerto Rico and Hawaii.



Plant Selection

Selection Criteria

- Zone 8 Hardiness
- Documented Hyper-Accumulator
- Documented Accumulator
- Root Depth (0.5m)
- Sufficient Biomass
- Native Control Plot



Native Grass and Forb Mix

Species	Common Name	Percentage
Rudbeckia hirta	Blackeyed Susan	0.12
Helenium autumale	Common Sneezeweed	0.04
Echinacea purpurea	Purple Coneflower	0.15
Coreopsis lanceolata	Lanceleaf Coreopsis	0.20
Agrostis perrenans	Upland Bentgrass	0.11
Andropogon virginicus	Broomsedge	0.07
Panicum virgatum	Switchgrass	0.11
Andropogon gerardii	Big Bluestem	0.18
Helianthus maximiliani	Maximilian Sunflower	0.02

Plot showing *Equisetum hyemale* and *Pteris vittata* (Year 2 Growth).

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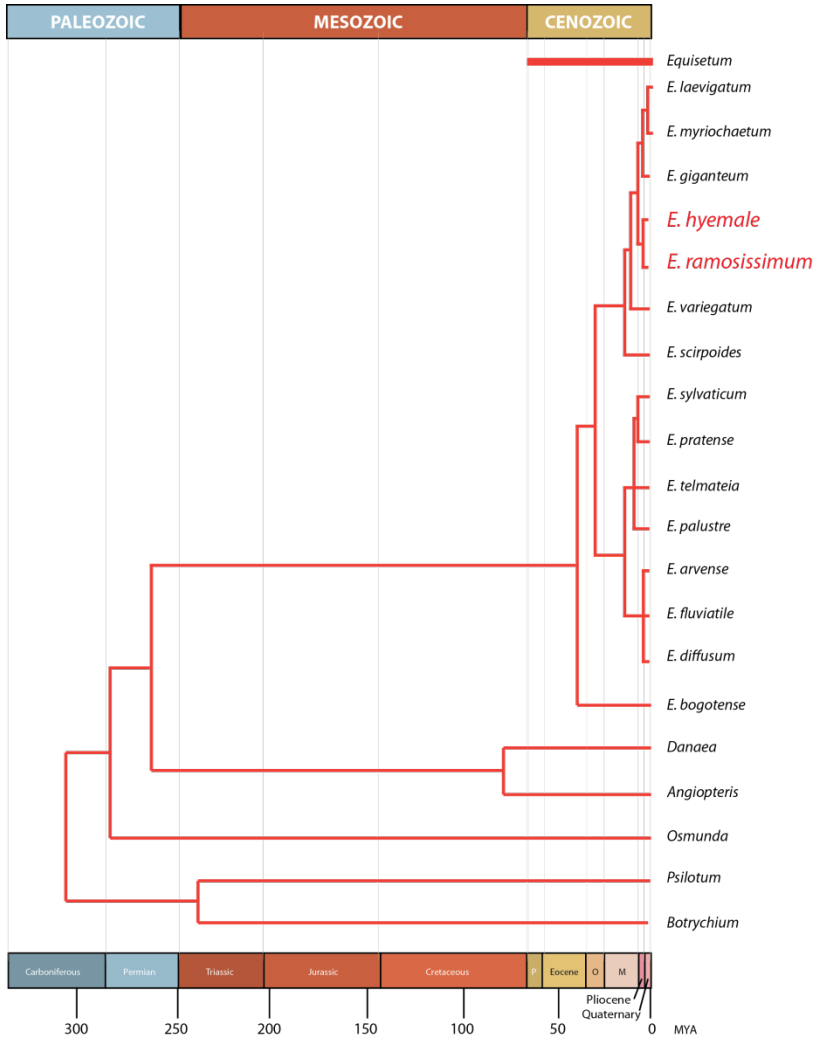
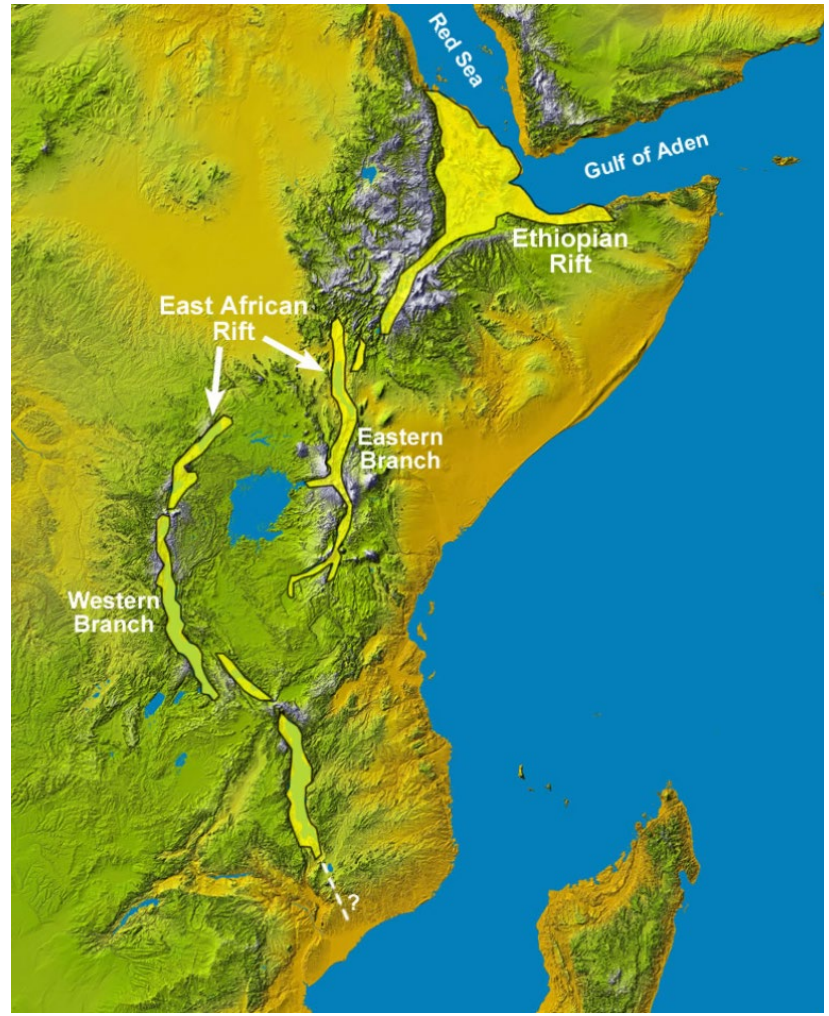
Evolutionary Basis for Arsenic Uptake in *E. hyemale*

E. hyemale

E. ramosissimum





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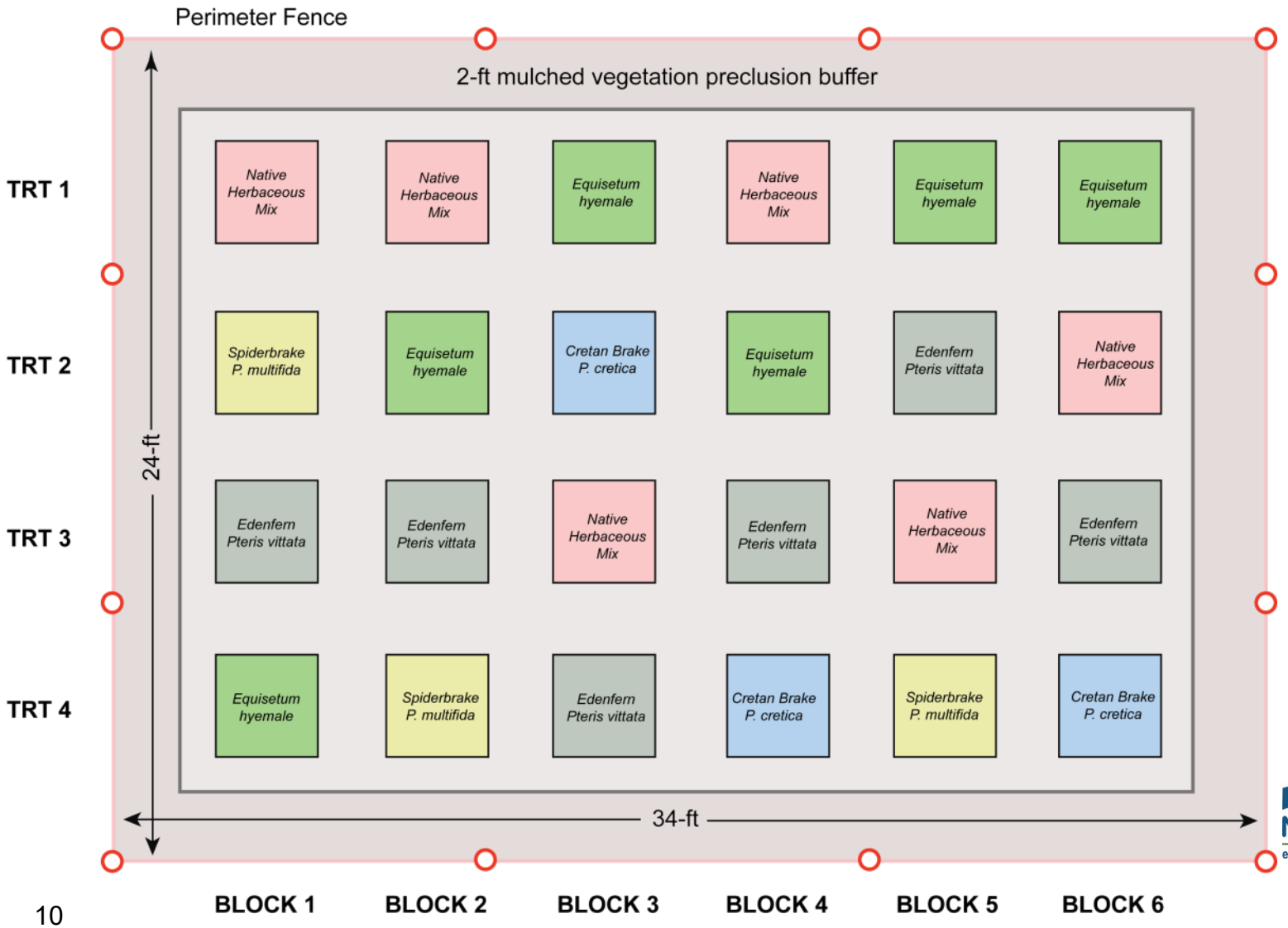
Phytoextraction Pilot Study Design – North Parcel



- Grasses and Asters
- *Equisetum hyemale*
- *Pteris vittata*
- *Pteris cretica*
- *Pteris multifida*

Nutter & Associates
environmental consultants

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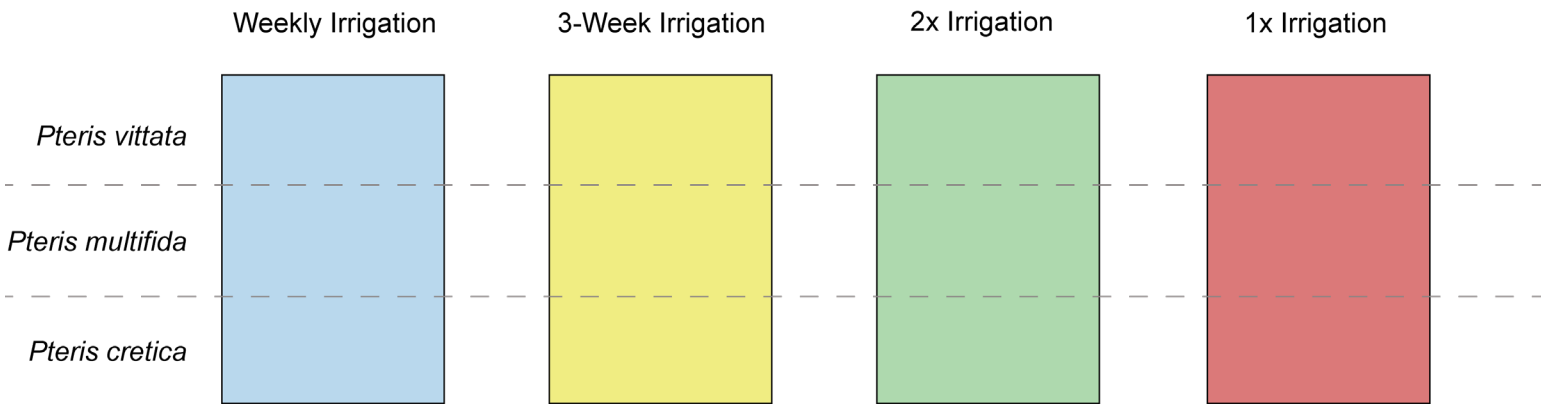
Irrigation Study Design – South Parcel



Blue – July 2018

Yellow – July 2018

Green – July 2018

Red – July 2018

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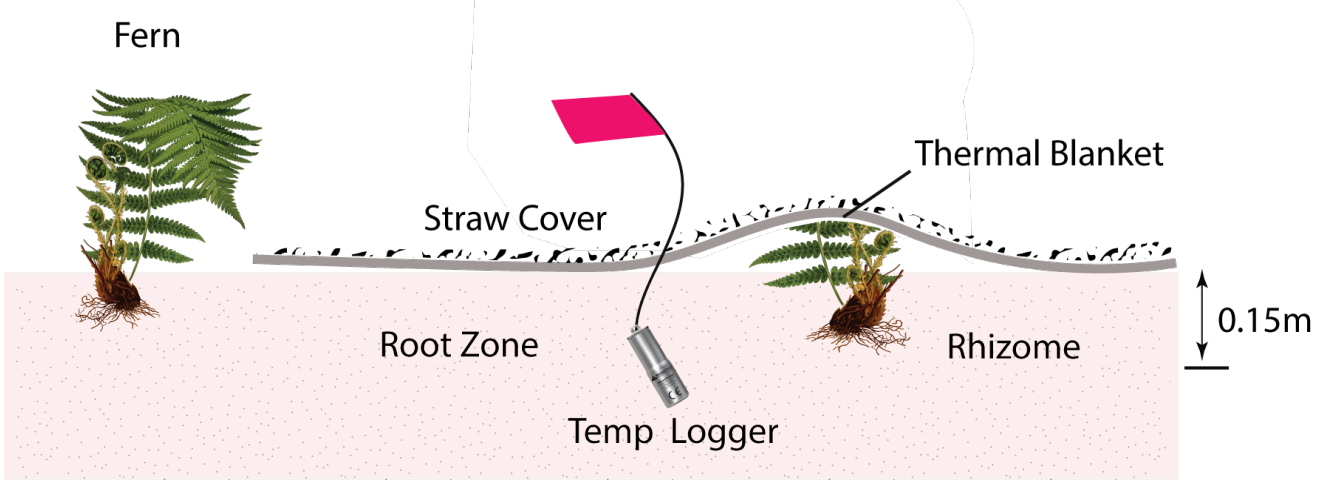
2018-2019 Winterization Study

- MicroTemp Logger
- -40 to +80 °C Range
- 0.1 °C Resolution
- ±0.5 °C Accuracy
- Log every hour during 16 week study



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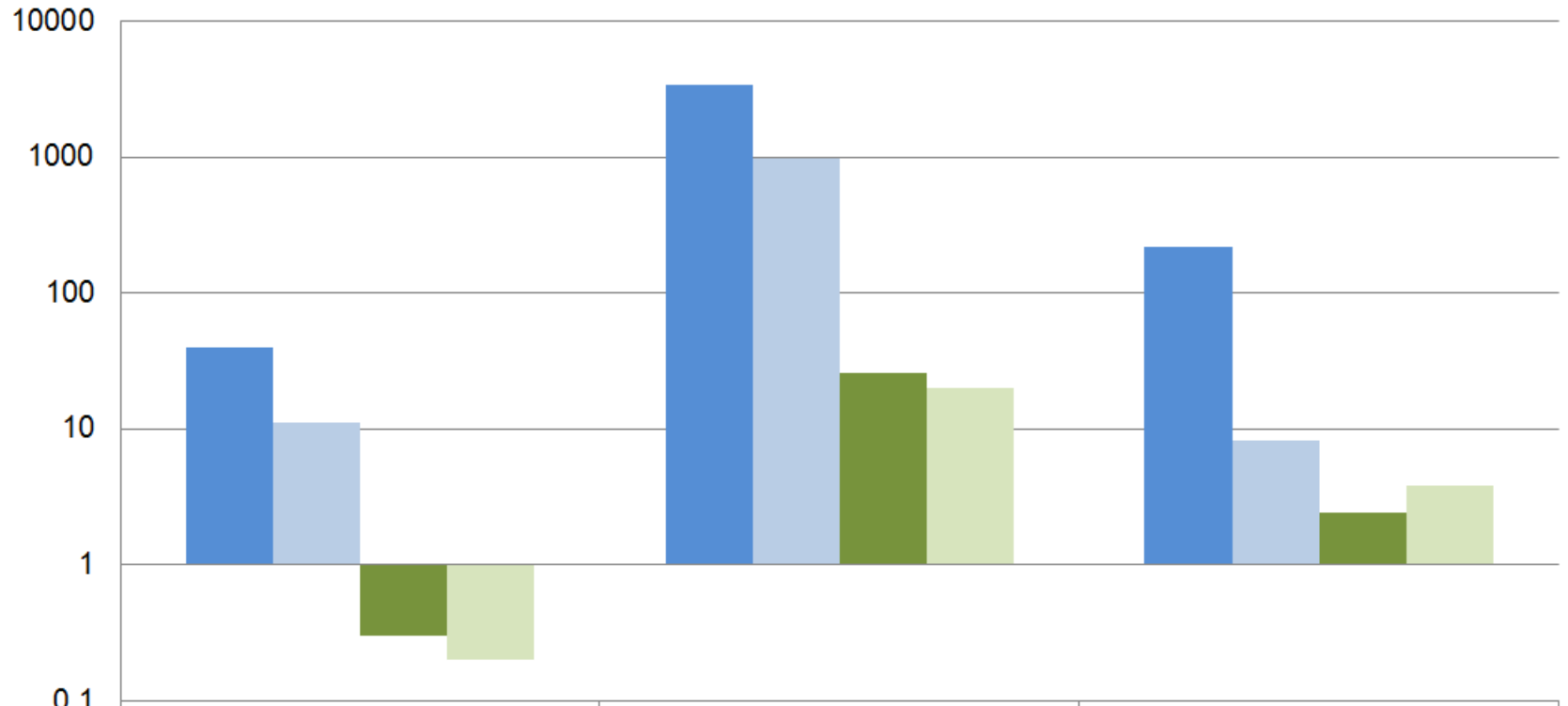
Results – Plant Uptake



	Final Calculated Bio-Concentration Factor (BCF)	Final Average Total Arsenic Uptake (mg/kg)	Final Calculated Average Total Arsenic Uptake (mg) Corrected for Biomass
Pteris vittata	40	3433	219
Pteris multifida	11	980	8.3
Equisetum hyemale	0.3	26	2.4
Grasses and Forbs	0.2	20	3.8

**Pteris cretica* not calculated due to insufficient biomass

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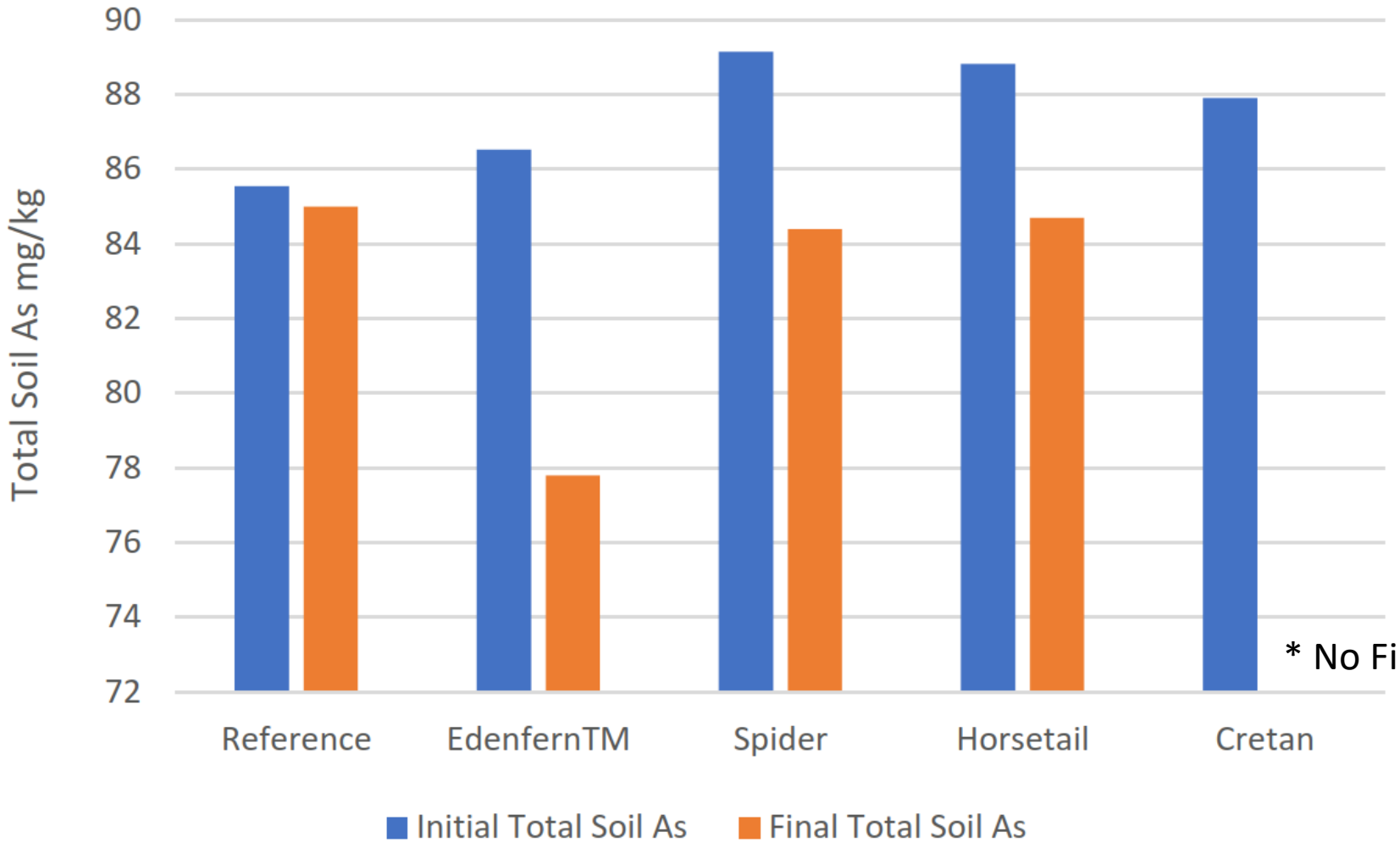
Results – Arsenic Soil Reduction (Year 2)



* No Final Soil Sample

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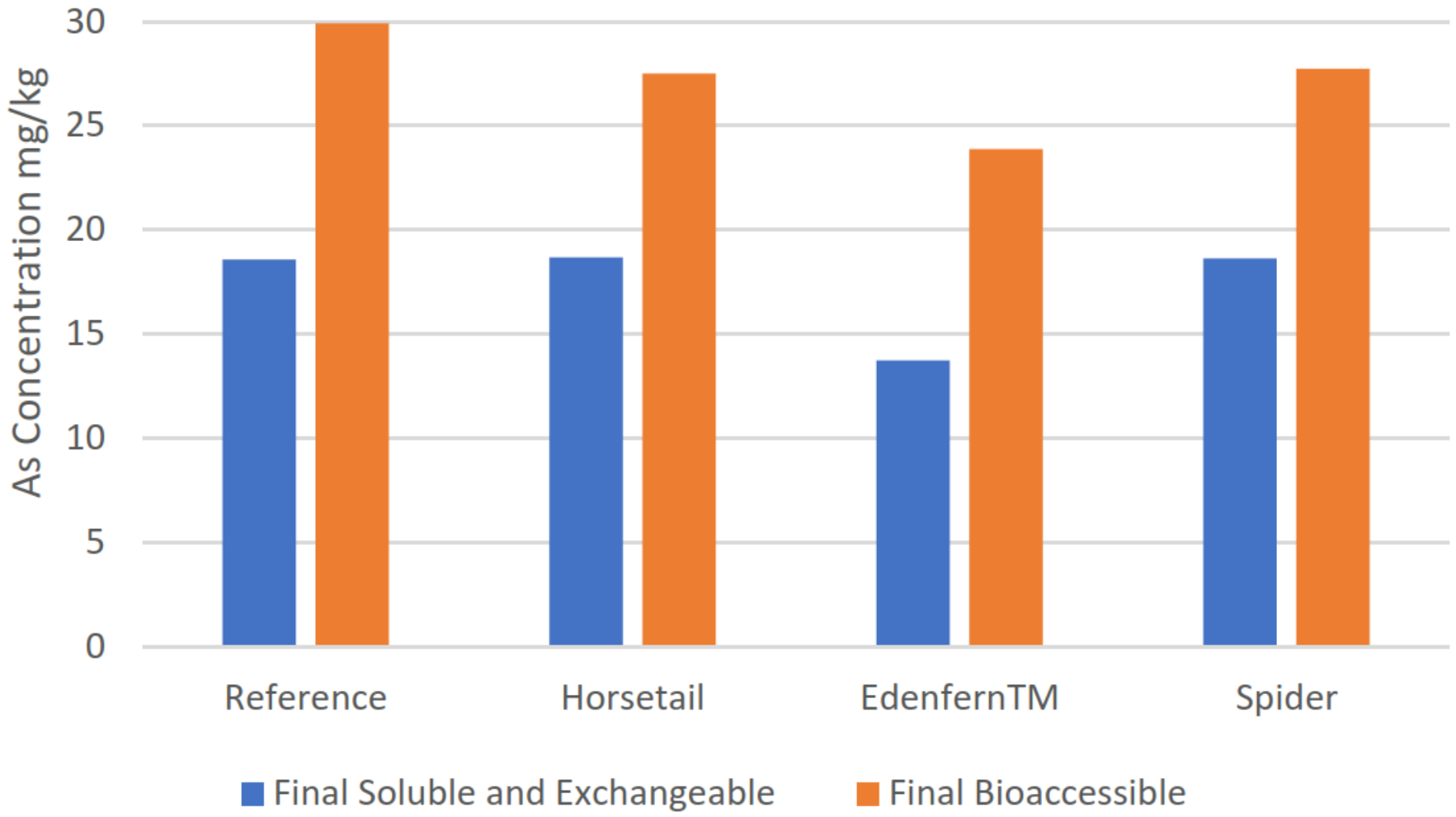
Results – Labile and Bio-Accessible Soil Arsenic (Year 2)



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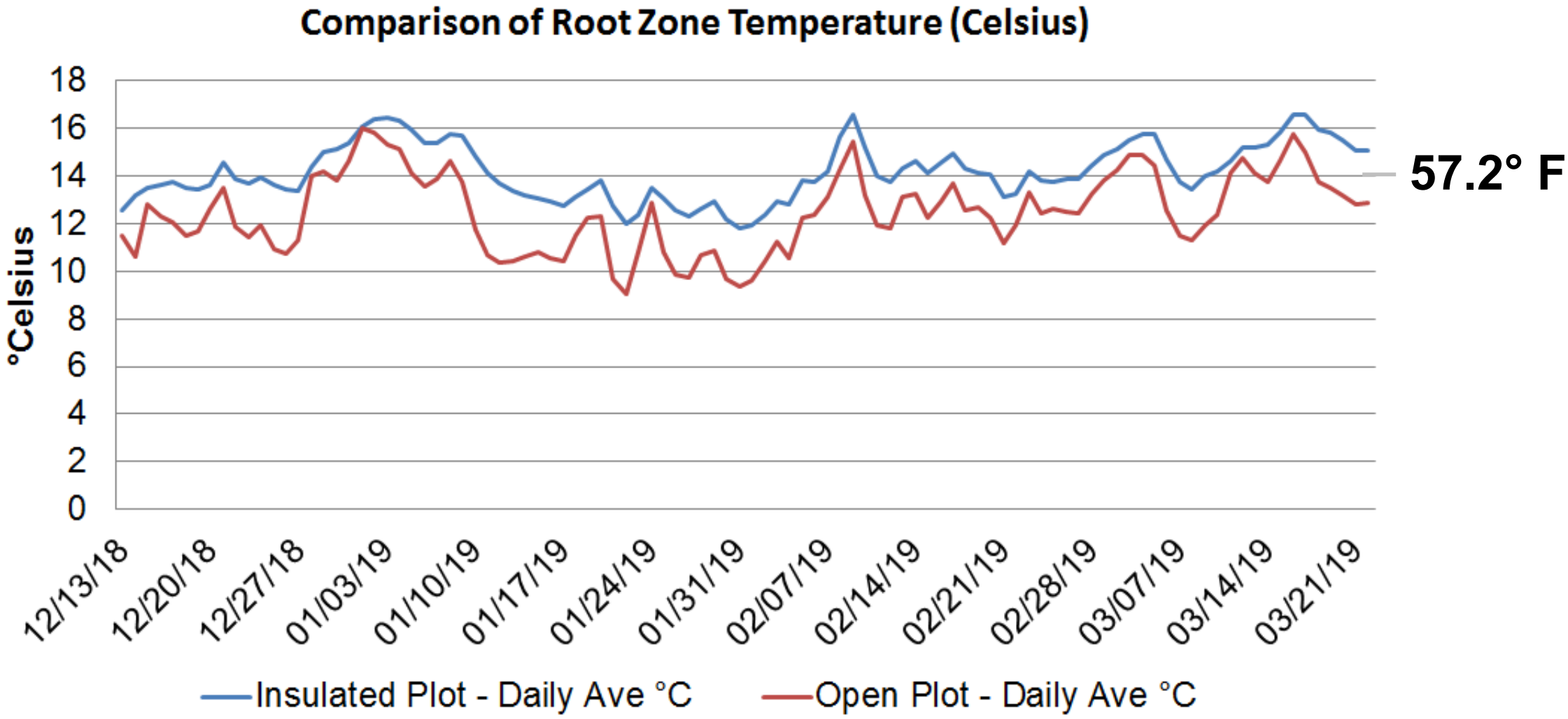
Average Soil Temperature Results



57.2° F

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Lessons Learned and Conclusions

- Weekly irrigation and shade cover recommended for appreciable growth and biomass,
- *P. vittata*, *P. multifida* and *P. cretica* are hyper-accumulators (>10 BCF),
- *P. cretica* too small to be significant for remediation,
- 10-year timeframe to reduce shallow Arsenic footprint at 100 mg/kg to 50% using *P. vittata*,
- Yearly re-planting recommended for Columbia, South Carolina, although winter soil temperature above freezing in 2018-2019,
- Ferns and Horsetails are self-propagating through spores and rhizomes,
- *Equisetum hyemale* is marginal arsenic accumulator, but test plot indicated 5% reduction in soil arsenic.

Test Plot	Apr-18	Oct-18	Difference Soil As Conc mg/kg	% Soil As Reduction
Forbs and Grasses Control	85.5	85	0.5	0.58%
Pteris vittata	86.5	77.8	8.7	10.06%
Pteris multifida	89	84.5	4.5	5.06%
Equisetum hyemale	88.9	84.6	4.3	4.84%

Fern gametophytes

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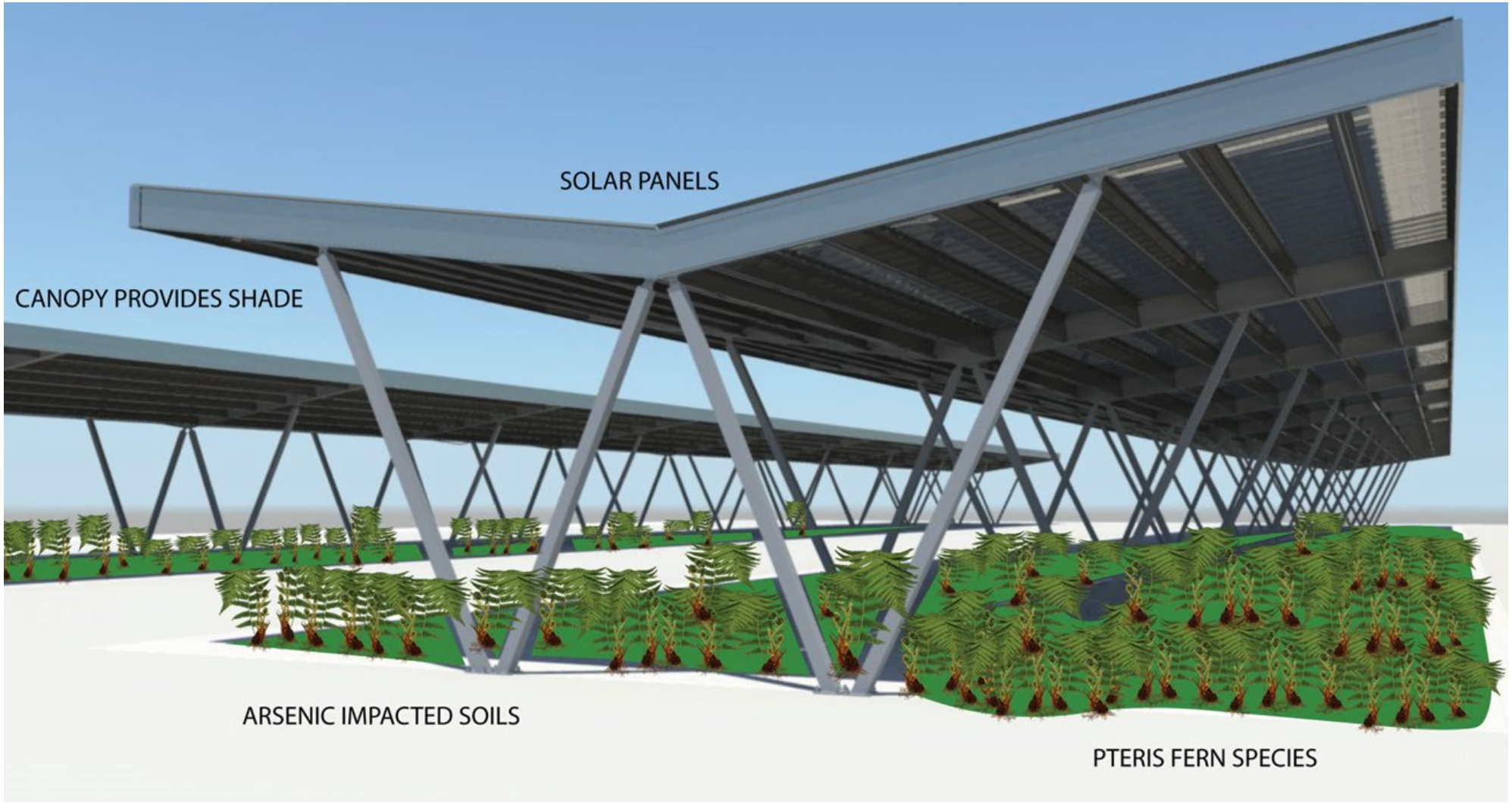
Conceptual Idea



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Thank You!

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