

Lessons Learned: Application of Phytoremediation in Place of Conventional Pump and Treat at a Hydrocarbon-Impacted Site

San Joaquin Valley, CA
April 16, 2019

Overview

- Site Setting and Conceptual Model
- Phytoremediation Feasibility Considerations
- Phase 1 Phytoremediation Pilot Test
- Phase 1 Tree Health Issues and Lessons Learned
- Phase 2 Tree Planting - Applying Mitigation Measures
- Phase 2 Results
- Project Progression

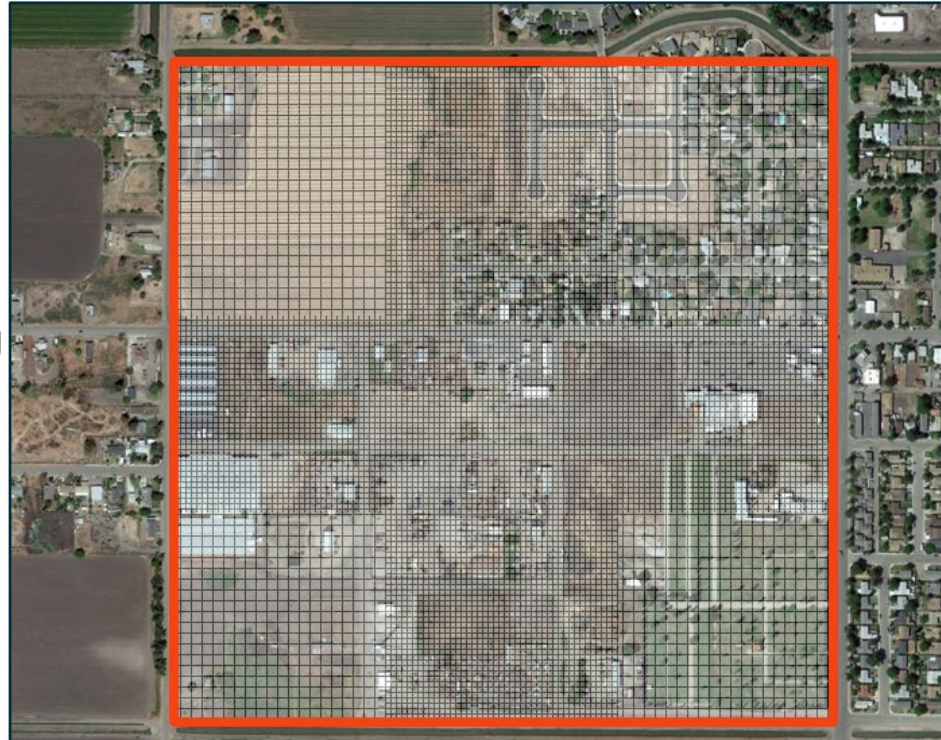


Pump and Treat Challenges



Phytoremediation Feasibility Considerations

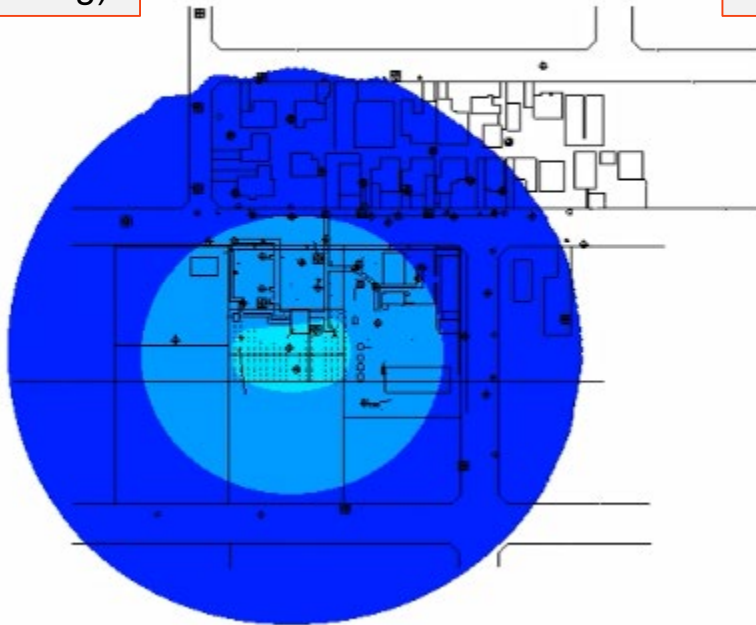
- **Preliminary Considerations**
 - Can a phyto approach provide similar hydraulic control to pump and treat system?
 - Groundwater model developed to predict hydraulic effects of planting of Poplar trees.
 - Using estimates of typical Poplar tree evapotranspiration rates, model indicated year-round hydraulic control is likely
 - As phytoremediation feasibility assessment progresses, model is continually updated to reflect actual trees planted and site conditions



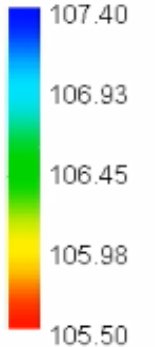
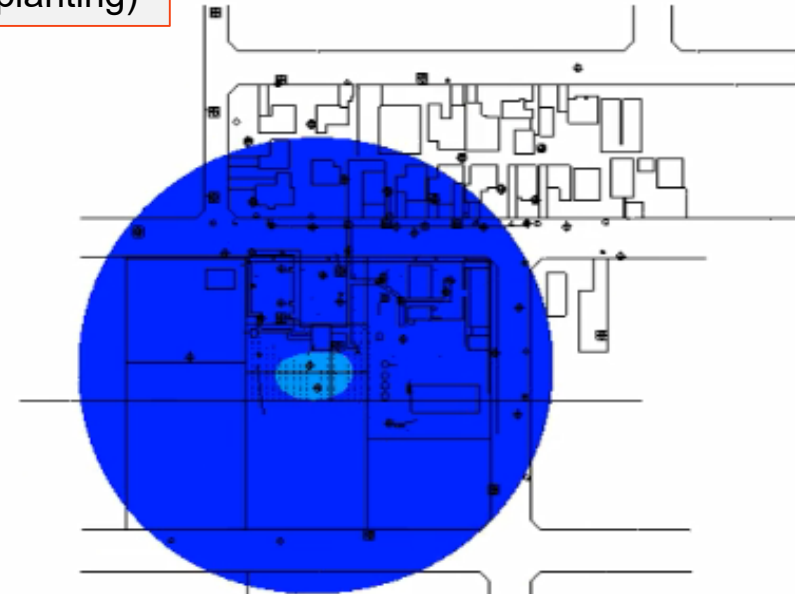
Model Output

Transient Simulation

Phase 1 poplar trees
(predicted drawdown –
6 months after planting)



Phase 1 poplar trees
(predicted drawdown –
12 months after planting)



Sustainability and Carbon Sequestration

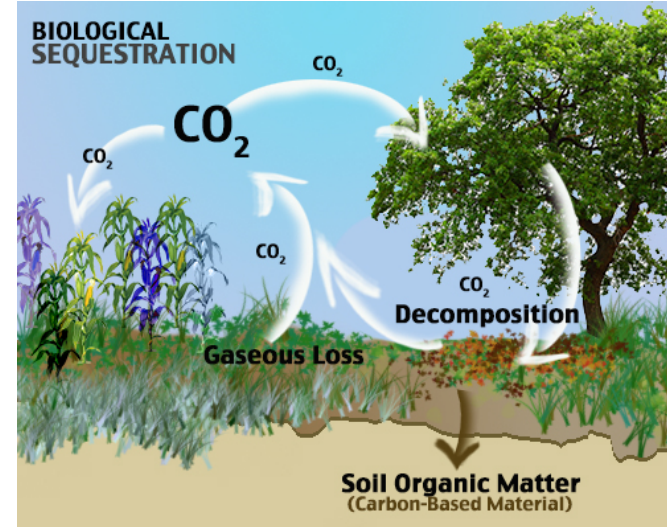
Sustainability Assessment Shows Reductions:

- Energy Consumption
- GHG Emissions (Nox, Sox, PM10)
- Field implementation risk factors
- Current P&T system produces 86 lbs of C emissions / 1 lb HC recovered

Carbon Sequestration

Estimated annual carbon sequestration due to planting of trees (lb CO₂/year):

- Phase 1 = 1,765 lbs
- Phase 1 + 2 = 3,460 lbs
- Phase 1+2+3 = 6,385 lbs



Source: <https://www.arb.ca.gov/cc/sequestration/seq.htm>

Habitat Enhancement



WILDLIFE
HABITAT COUNCIL



The poplar trees produce sap during the growing season which bees feed on.

The project has the potential to improve pollinator (bee) habitat and subsequently their populations which are currently in danger in the US and World wide.

A study of the bees is being worked into the project under the guidelines of the Wildlife Habitat Council and is anticipated to result in certification from the Council on enhancement of habitat in this area.



Phased Phyto Planting Plan

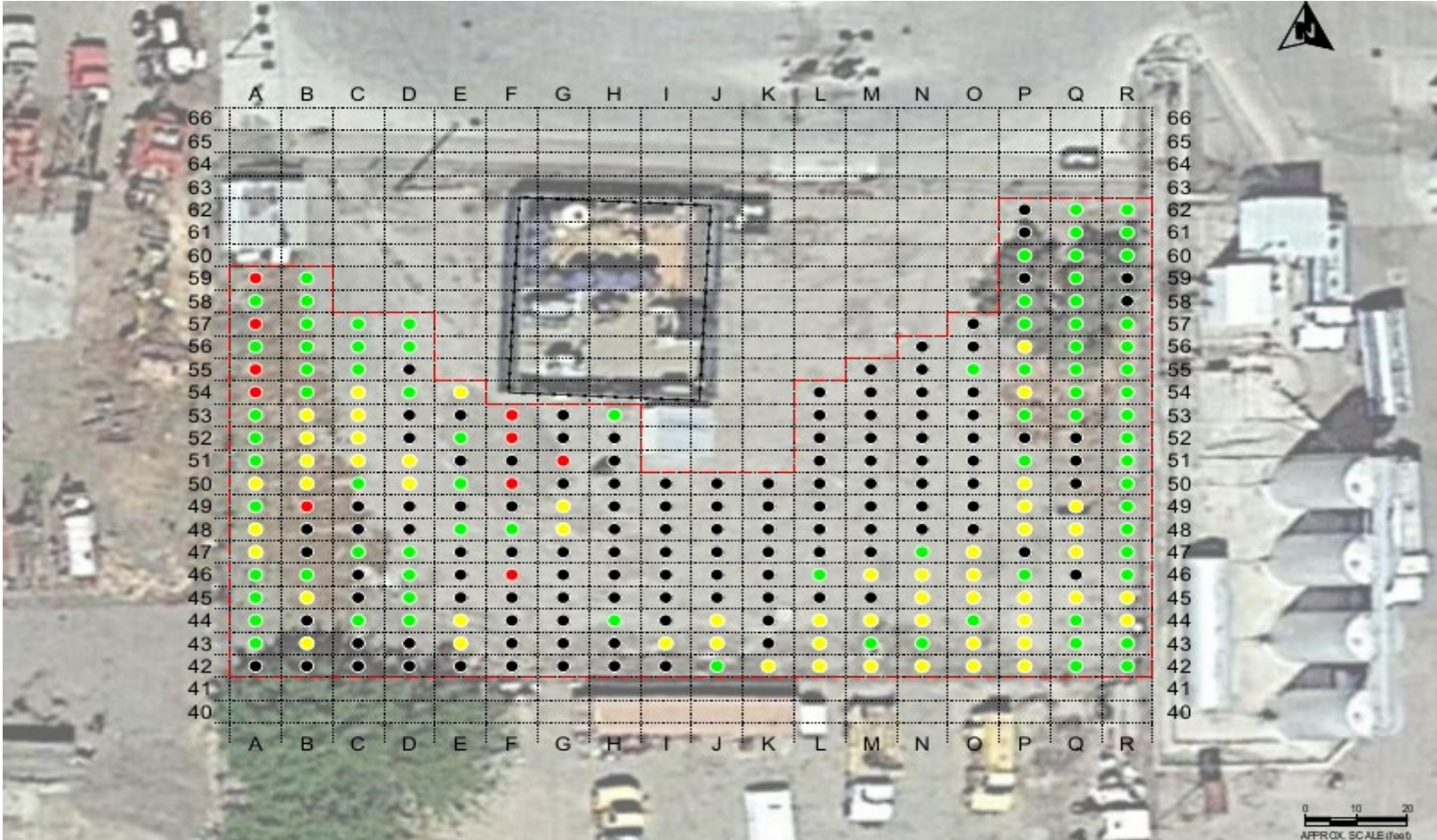


Tree Health Issues



Phase 1 trees experienced a combination of factors compromising tree health

Tree Health Status



Factors Affecting Tree Health

Primary

- Whip Exposure
- Planting Date
- Soil and Groundwater Chemistry

□ Secondary

- Hydrocarbon Concentration
- Climate, Bugs, and Bunnies

Secondary Tree Health Issues – Bugs and Bunnies



Tree Health Factors and Mitigation Measures

Contributing Factors	Mitigating Action
Whip Exposure	<ul style="list-style-type: none">• Plant whips with minimum 36 inches of exposure.• Use irrigation to supplement watering during first 1-2 years.• Use longer whips when possible.
Planting Date	<ul style="list-style-type: none">• Prepare early to ensure completion of the planting by mid-March.
Groundwater Chemistry	<ul style="list-style-type: none">• Use salt and boron tolerant hybrids.

Tree Health Factors and Mitigation Measures

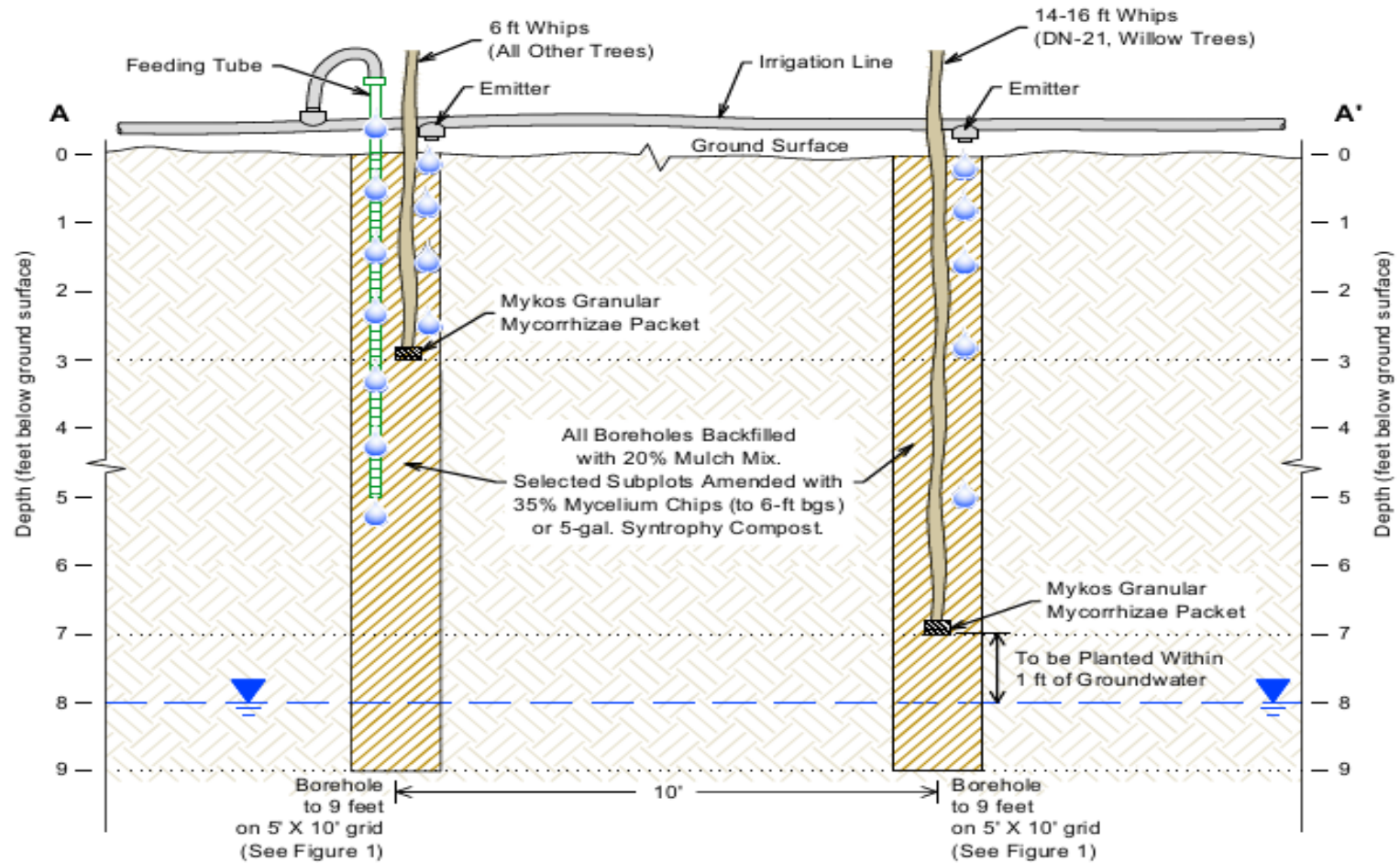
Contributing Factors	Mitigating Action
Hydrocarbon Concentration	<ul style="list-style-type: none">• Inoculate trees with endophytic bacteria which consume hydrocarbons within tree tissue to minimize toxic effects.
Climate, Bugs and Bunnies	<ul style="list-style-type: none">• Use supplemental irrigation in summer months during the first 1-2 years.• Use tree protectors to prevent rodents from eating bark.• Use pesticides as needed.
Soil and Groundwater Composition/Groundwater Level	<ul style="list-style-type: none">• Add organic mulch to backfill allowing whips time to establish roots and leaves prior to experiencing full impact of salt, boron, and hydrocarbon concentrations.

Phase 2 Pilot Study Plan

Multiple Tree Species



Phase 2: Planting Plan



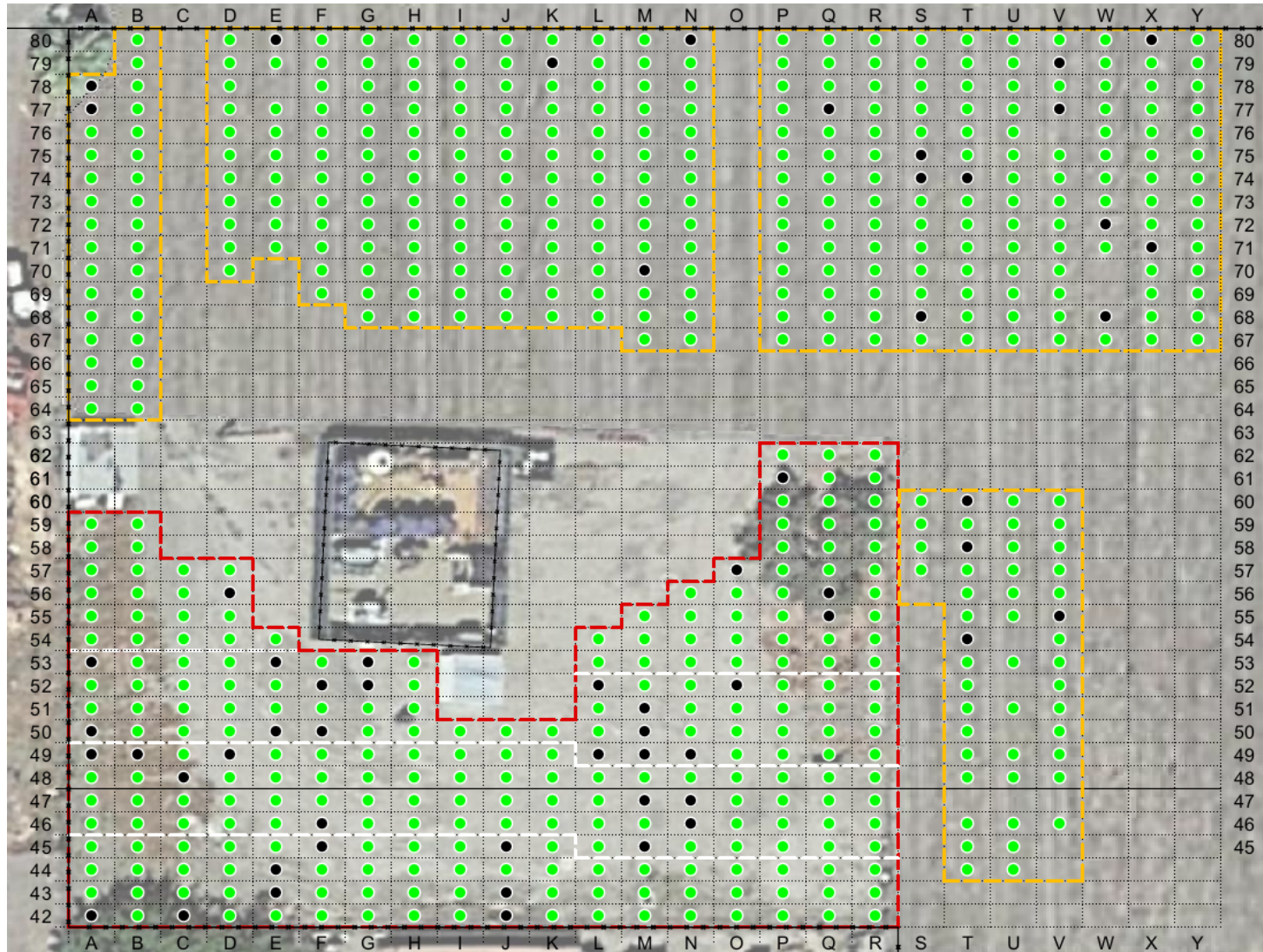
Phase 2: Implementation



Phase 2: Implementation



Tree Health Status



Tree Health Status

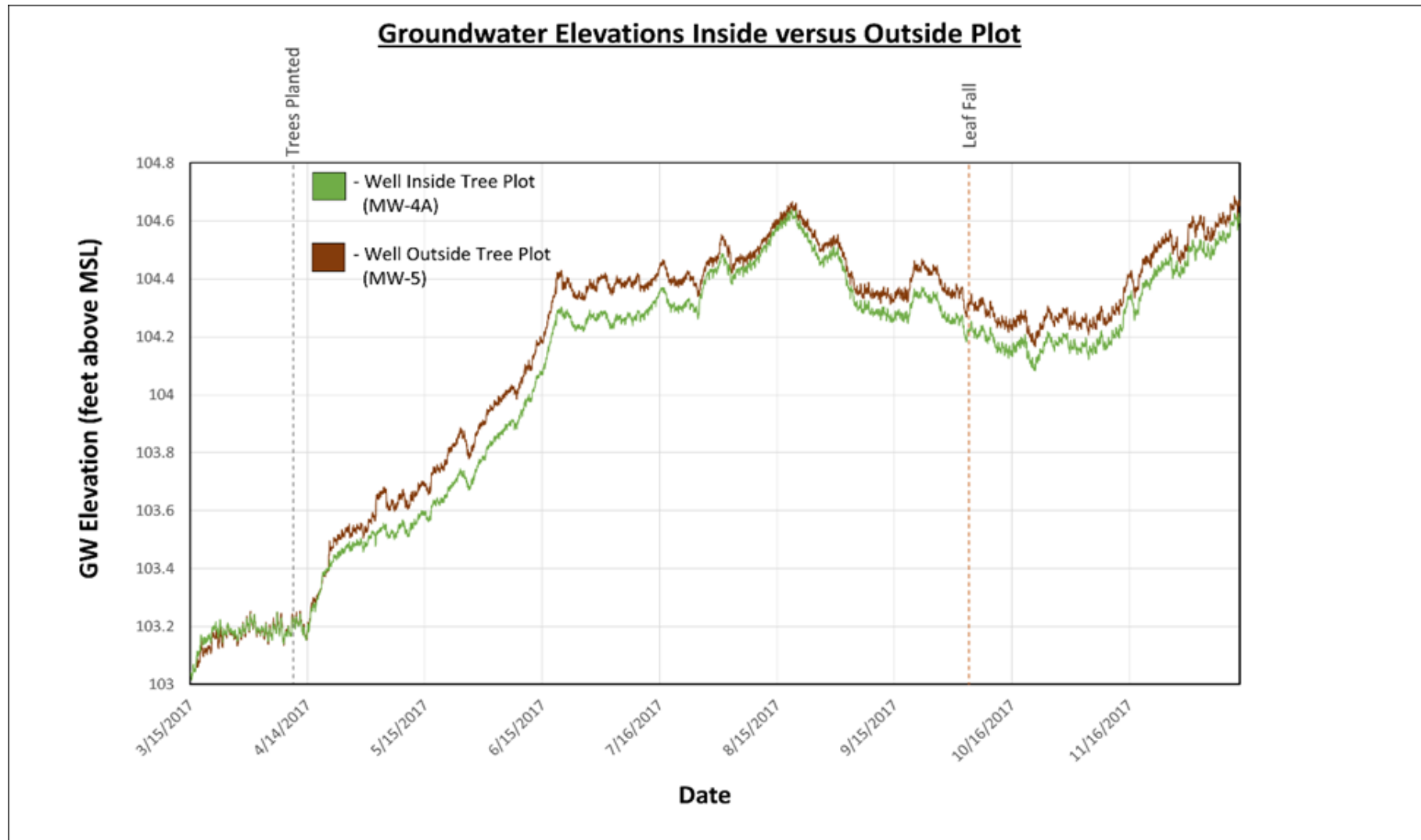


July 7, 2017



July 11, 2018

Transducer Data

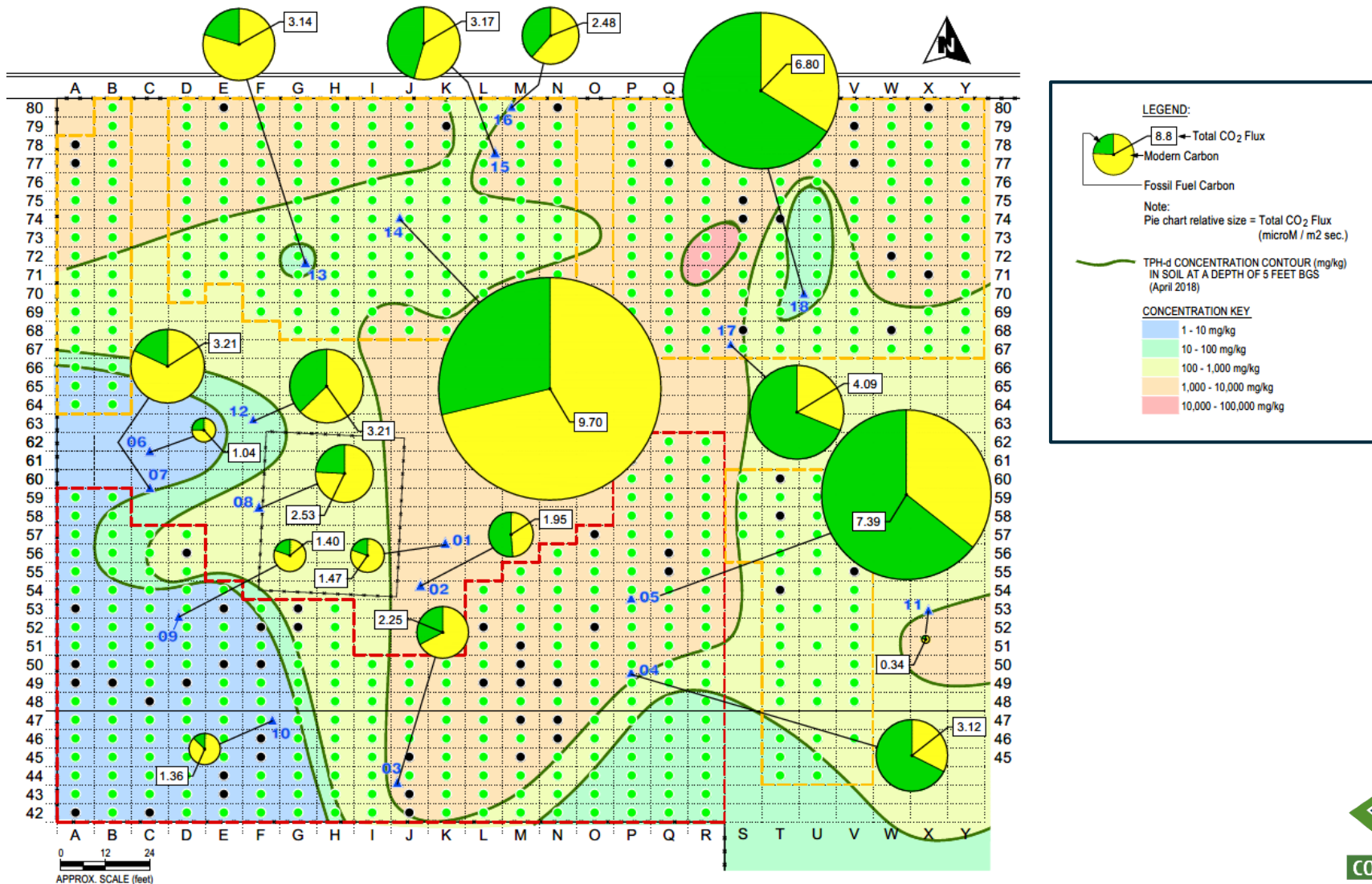


CO₂ Flux

□ CO₂ Flux Analysis

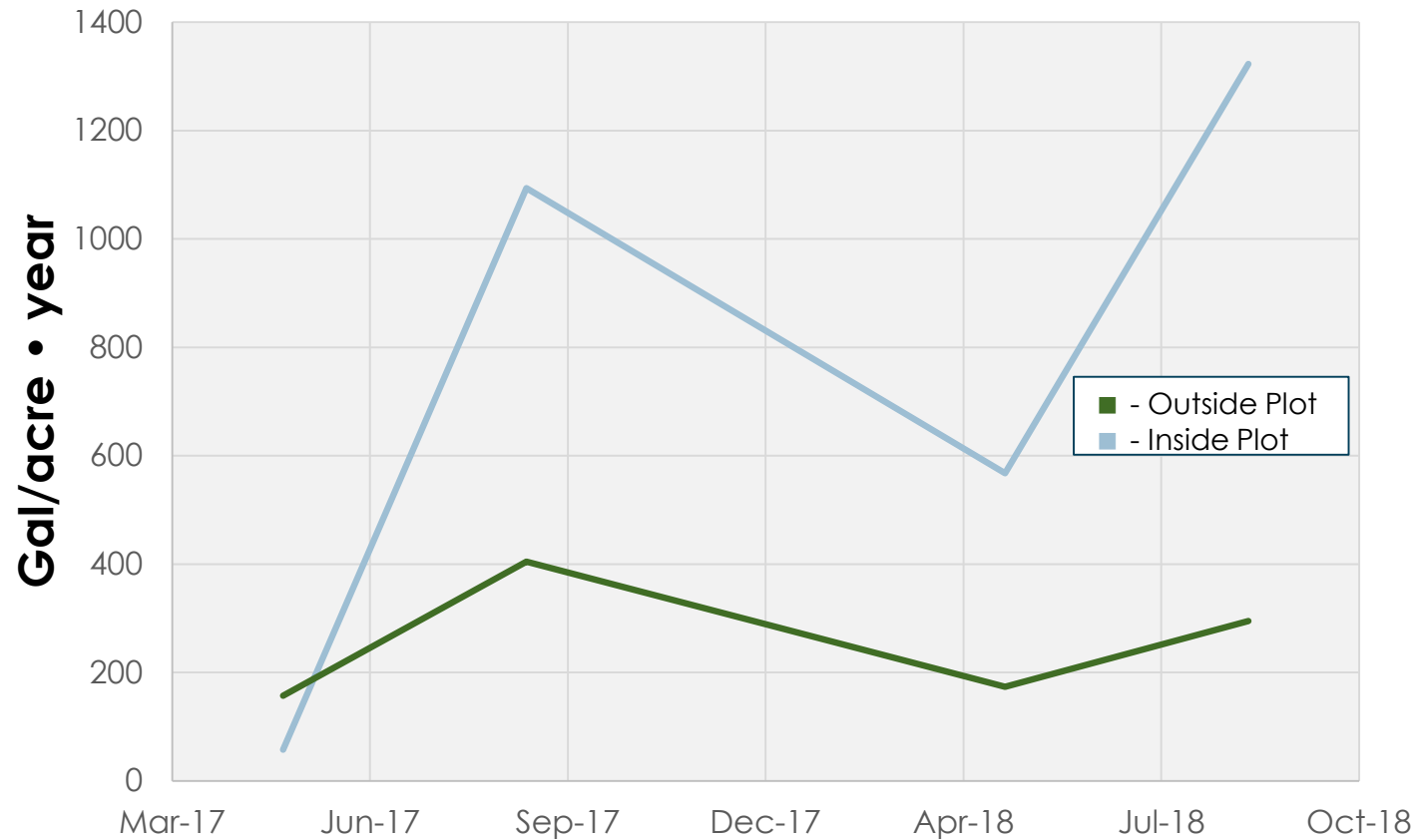
- CO₂ flux data provides information on subsurface biodegradation rates.
- Total of 18 tree plot and background locations.
- Four sampling events completed: May and September of 2017 and 2018.
- Data indicates greater overall CO₂ production in higher concentration area.
- Data indicates a greater portion of petroleum-derived CO₂ in higher soil concentration area.

CO₂ Flux Analysis – September 2018



Enhancement of NSZD Rates

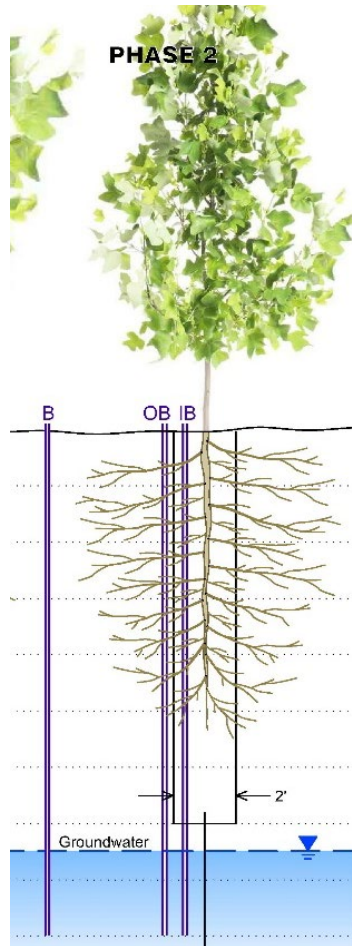
Average High Concentration Points



Enhancement of NSZD Rates

- Comparison of NSZD rates (gallons/acre-year) inside and outside the tree planted areas and within similar soil concentration zones, show elevated hydrocarbon biodegradation rates within the phytoremediation test area.
- The magnitude of the increase in the NSZD rate varies relative to the hydrocarbon concentration in the vadose zone soil.
- For high and medium concentration zones the increases are:
 - High (1,000 – 10,000 mg/kg diesel) range from 2.7 to 4.5
 - Medium (100 – 1,000 mg/kg diesel) range from 1.9 to 3.4
- The magnitude of the increase in the NSZD rate varies relative to the hydrocarbon concentration in the vadose zone soil.
- Biodegradation rates increase through the growing season as soil temperature rise and phytochemicals are excreted through the roots stimulating the microorganisms in the rhizosphere around the roots.

Evaluation of Vadose Zone Biodegradation

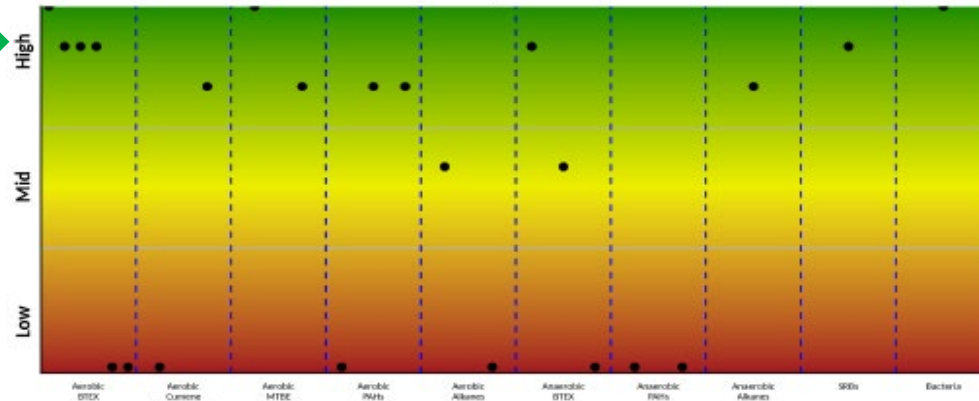


T-48 Willow

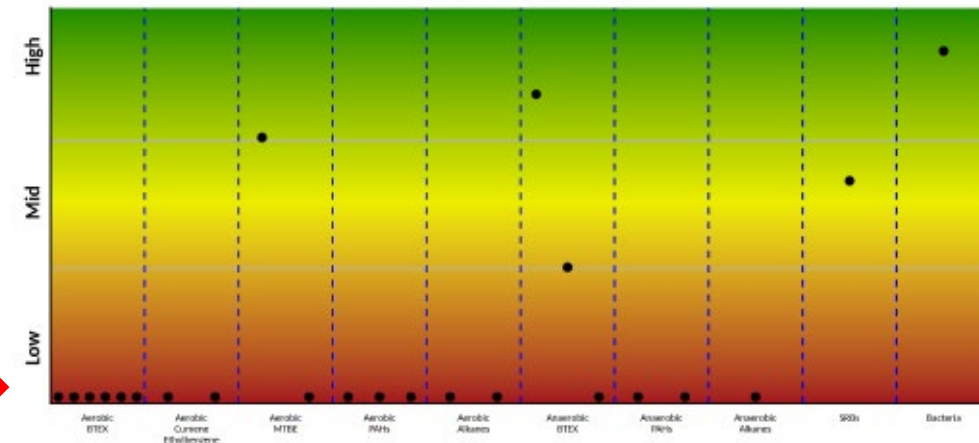


Higher hydrocarbon degrading microorganism concentrations associated with tree roots than in background

Tree Root Microbial Populations



Background Microbial Populations



Project Progression

- Successful implementation of tree health mitigation measures in Phase 2 allowed:
 - Confirmation of the trees ability to maintain hydraulic control
 - Full implementation of phytoremediation 1Q2019 (Phase 3)
 - Phase out of the SVE system 1Q2019
 - Phase out of the GWP&T system 1Q2020



Thank you for your time today!