



RemTech
2019

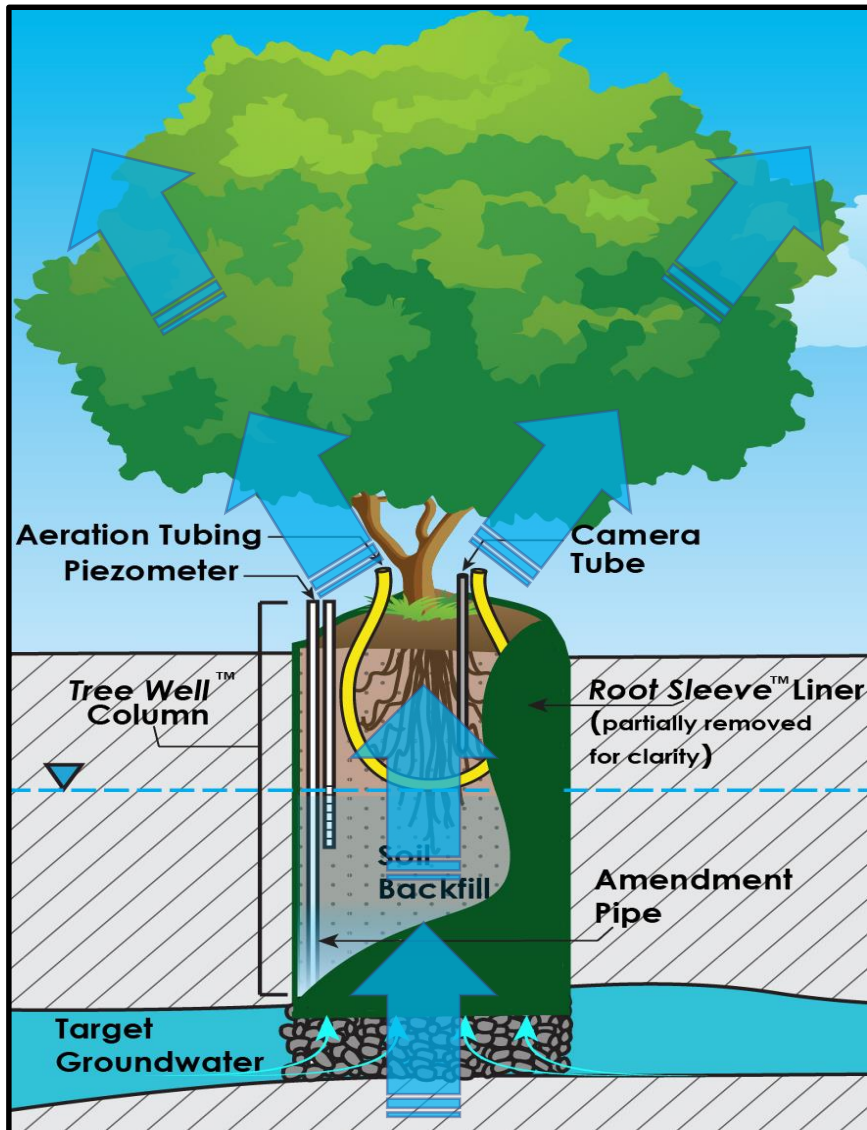
Geosyntec 
consultants

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Engineered Phytoremediation of Contaminated Aquifers – Adapting a Natural System to Meet Remedial Goals

Ron Gestler, James Linton, Karen Berry-Spark (*Geosyntec Consultants*)
Edward Gatliff, Paul Thomas, (*Applied Natural Sciences*)

The *TreeWell*® System: Key Benefits



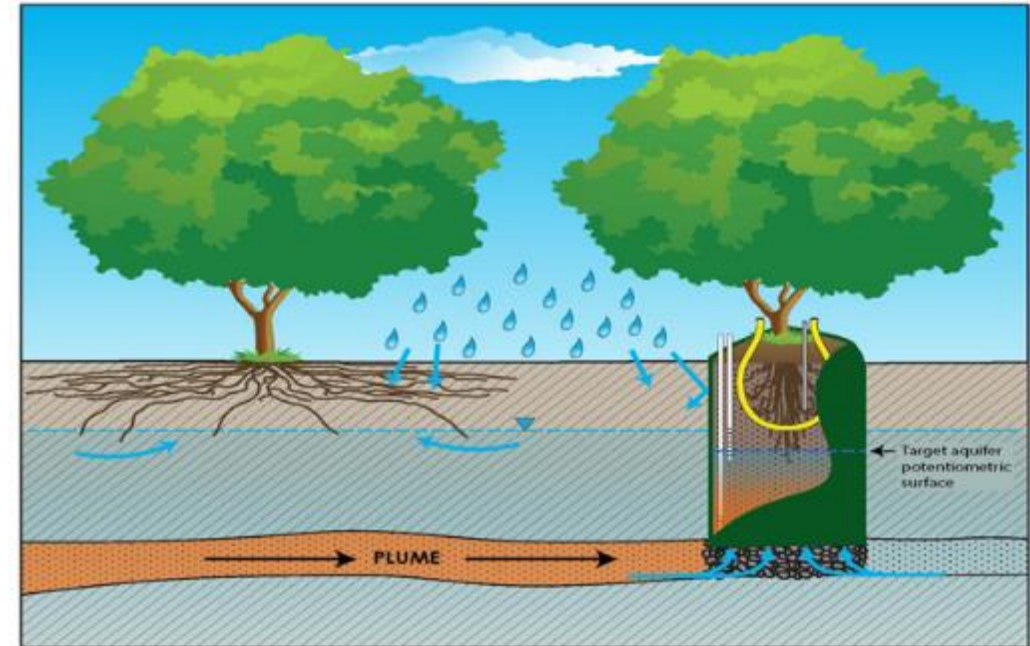
- Patented by Dr. Edd Gatliff of Applied Natural Sciences
- Targets specific groundwater by directing root growth downward
- Bioreactor effect in soil column of unit: reducing and oxidizing zones
- Effectively treats a wide range of contaminants
- Pre-treatment option (reactive treatment media – ZVI, etc.)
- Optimizes growing conditions
- Highly adaptable – can be tailored to specific site conditions
- Active treatment – in a passive manner

Why Use the *TreeWell* System?



Limitations of Conventional Phytoremediation

- Target groundwater too deep
- Site soils too poor, too compacted
- Contaminant concentrations too high
- Reliance on precipitation



Benefits of Engineered Phytoremediation using the *TreeWell* System

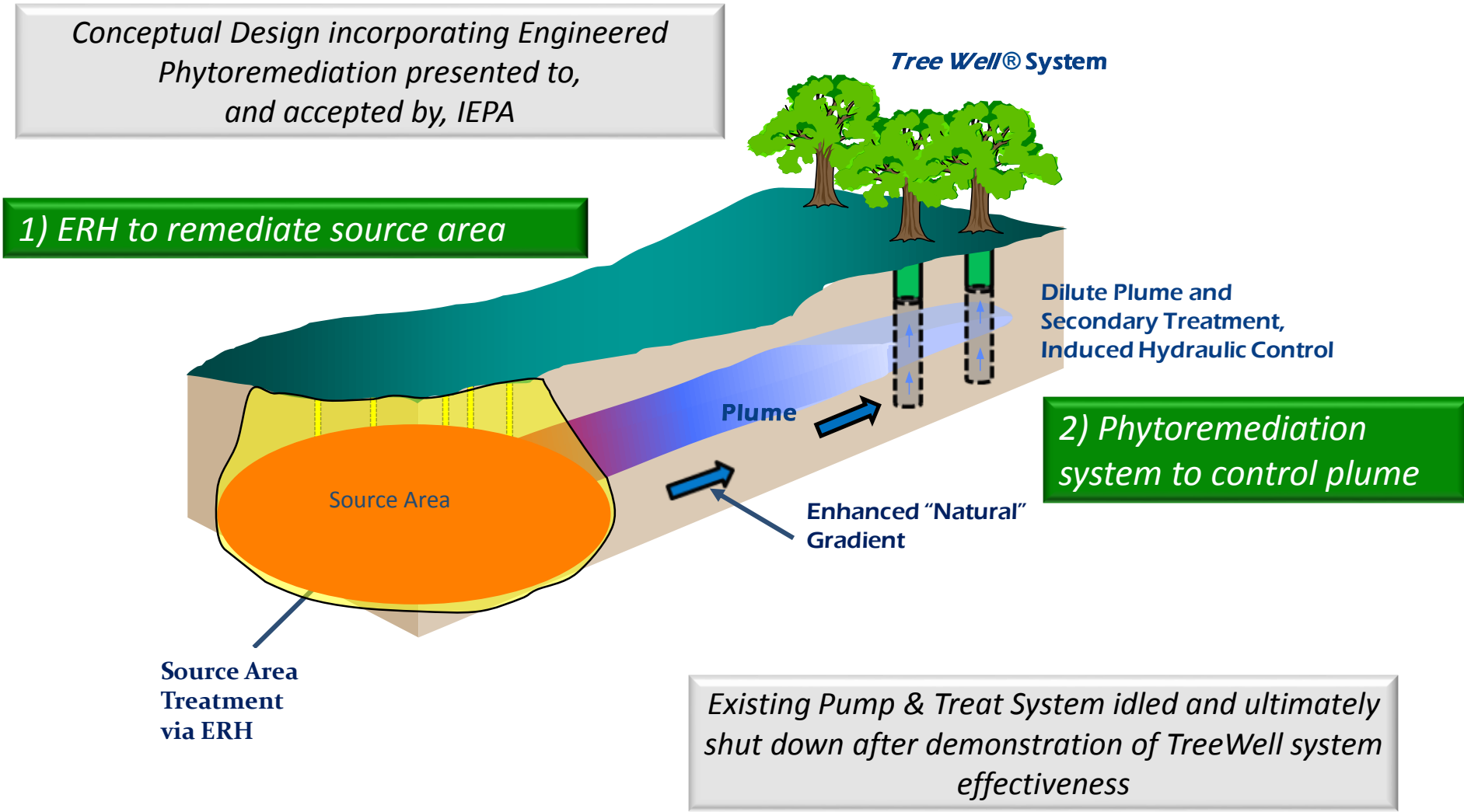
- Control plant growth, manage site conditions and target the zone of remedial effect
- For GW as deep as 15 meters bgs (or more)
- Treat high contaminant concentrations
- Can reduce the time to meet remedial goals
- Allows plants to ***THRIVE***

TreeWell Phytoremediation at Illinois Site



- Former refrigerant manufacturing facility
- Carbon Tetrachloride plume with DNAPL
- Primarily low K glacial till with sporadic sand zones
- Existing P&T system very inefficient, expensive (batch process)
- *TreeWell* phytoremediation system installed in 2015
- **IEPA approved disabling P&T system in 2016; now abandoned**

Conceptual Design for Integrated Remediation



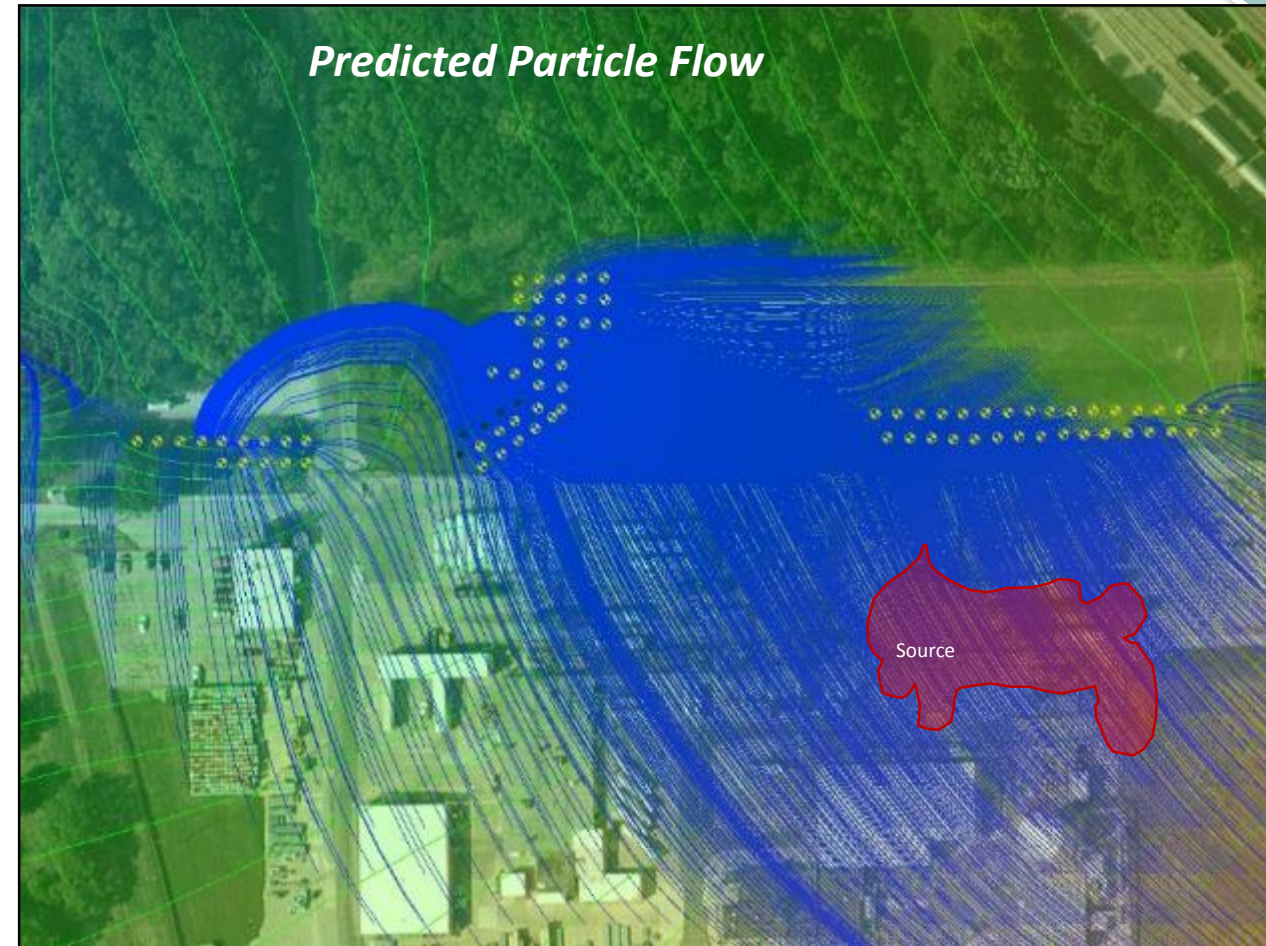
Modeled Groundwater Flow



Initial groundwater modeling performed prior to system installation

51 TreeWell units installed in 2015; additional 28 units in 2017

Excellent correlation of model predictions to observed hydraulic control

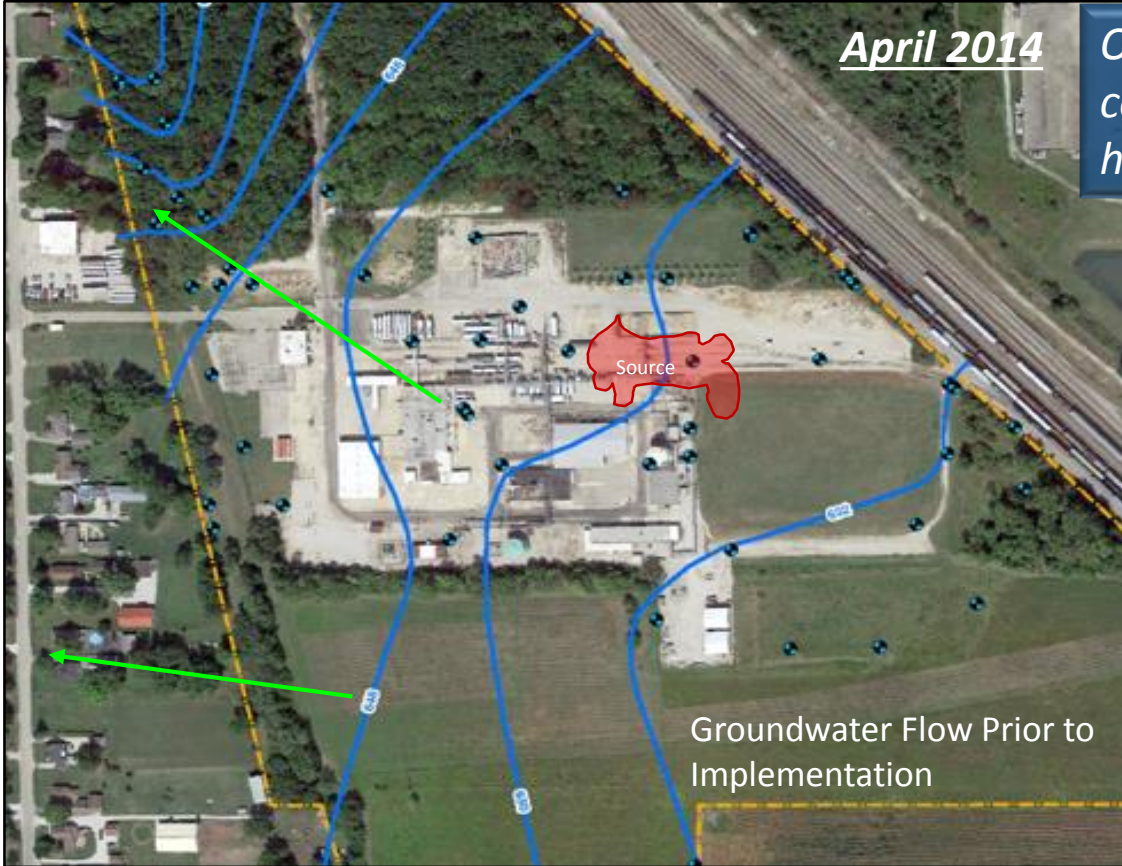


Hydraulic Control of CCL4 Plume



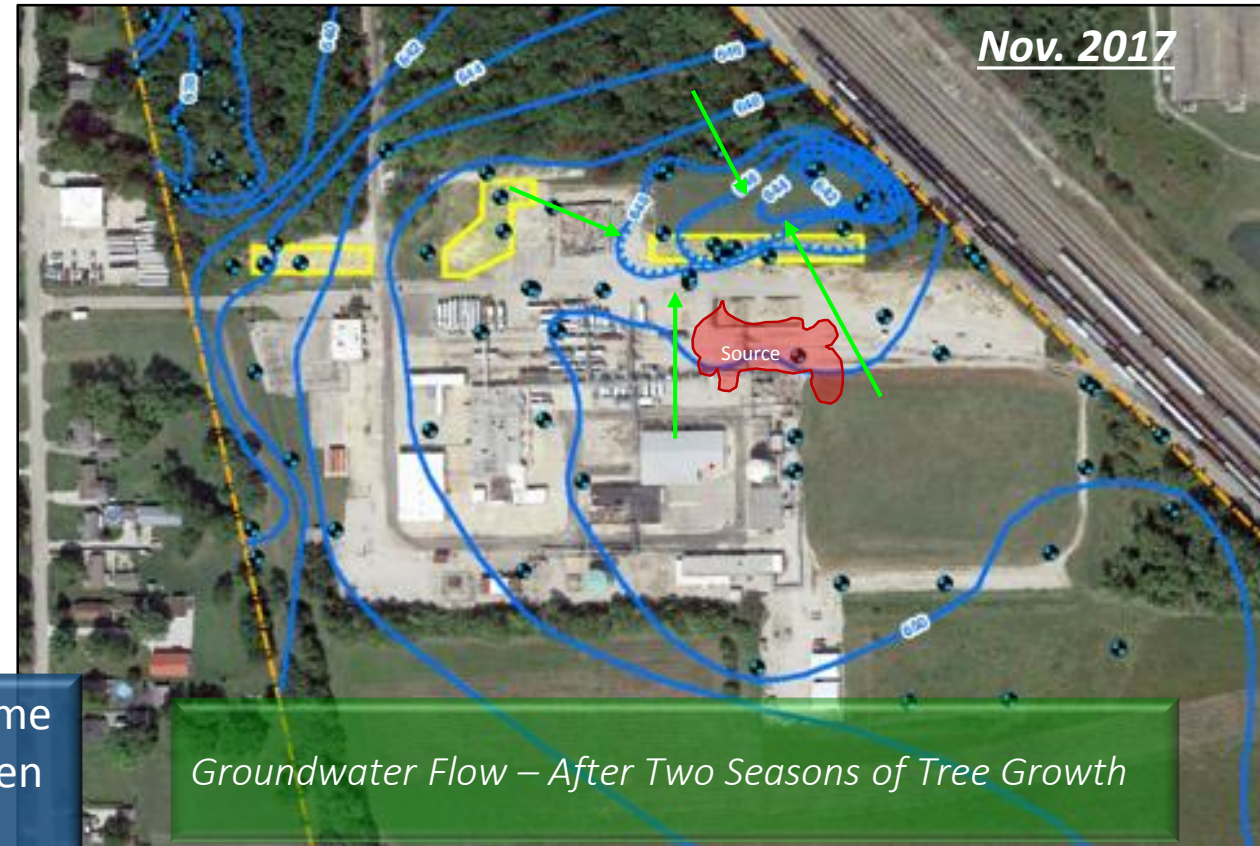
April 2014

Original P&T system – source control without plume hydraulic control



TreeWell units capturing plume and hydraulic control has been established

Nov. 2017



Hydraulic Control Maintained Through Mid-Winter (Feb 2018)



Hydraulic containment maintained despite winter dormancy of trees

Phytoremediation vs. P&T



Pump & Treat (Source Containment) System Operational Years (1980 – 2016)

100,000 Gallons per year – estimated maximum removal rate of groundwater or average of < 275 gallons per day (GPD) (<0.2 gpm)

Five pumping wells in operation - no significant/observable groundwater hydraulic influence (2013-2016 period)

\$75K - Average Annual Cost (approx). of O&M 2013 - 2016 (excluding treatment and groundwater monitoring)

P&T System was ineffective

System idled in 2016 during proof of concept/pilot of Engineered Phytoremediation System

Engineered Phytoremediation

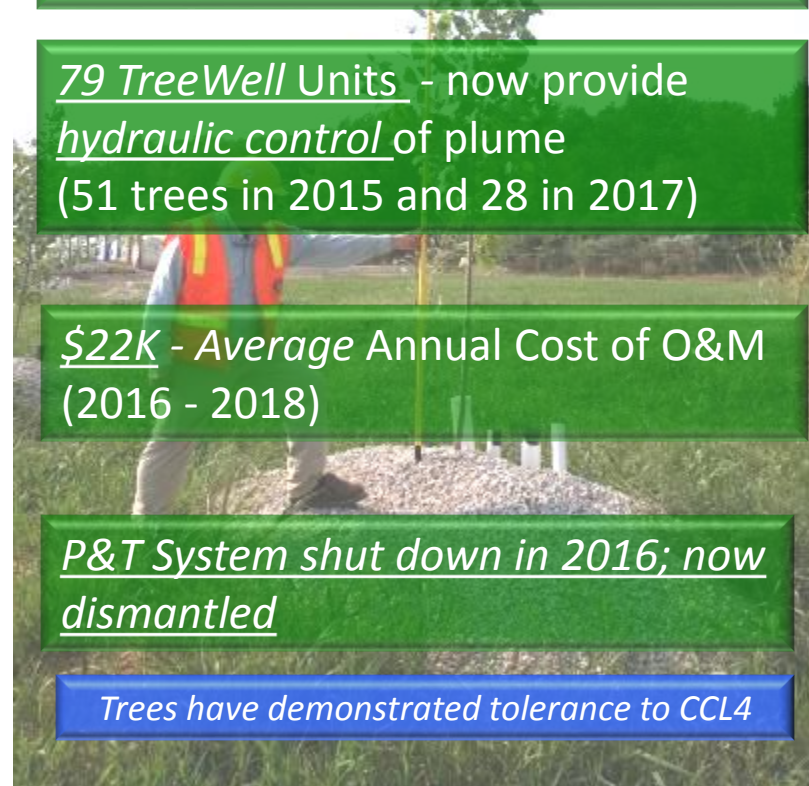
>1,00,000 gallons per year is estimated current extraction rate via engineered phytoremediation (3 gpm +/-)

79 TreeWell Units - now provide hydraulic control of plume (51 trees in 2015 and 28 in 2017)

\$22K - Average Annual Cost of O&M (2016 - 2018)

P&T System shut down in 2016; now dismantled

Trees have demonstrated tolerance to CCL4



Results To-Date Summary



The *TreeWell* phytoremediation system has:

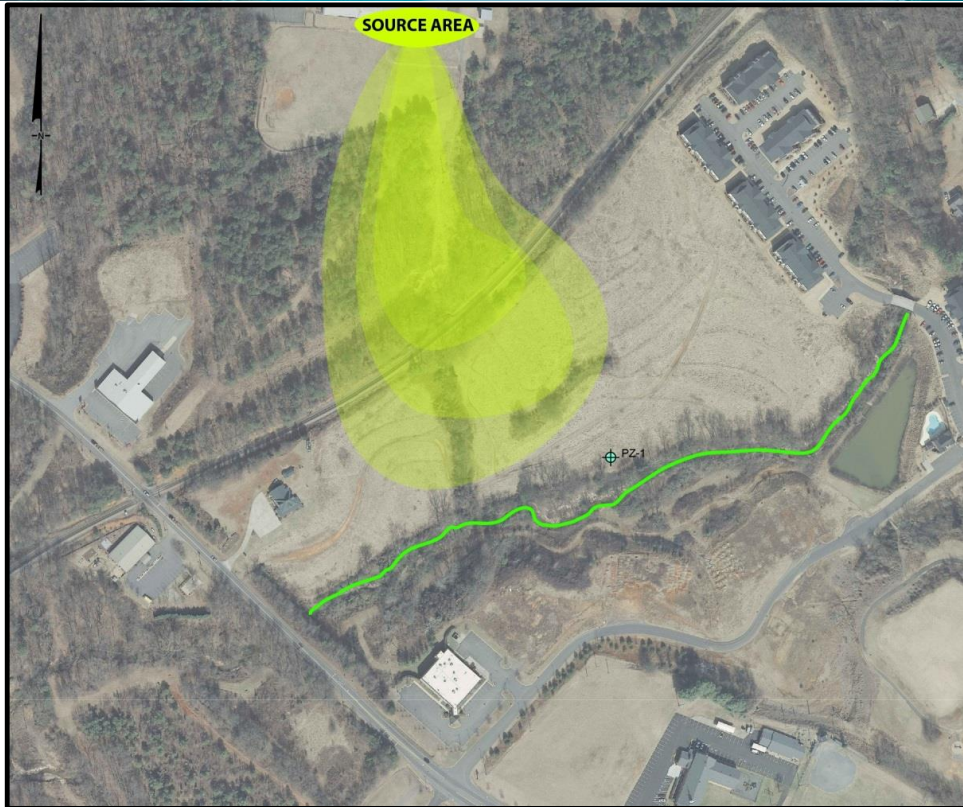
- 1) Obtained hydraulic control of the plume in just two growing seasons;
- 2) Enabled abandonment of the P&T system; and
- 3) Supported excellent tree health



Next Steps...

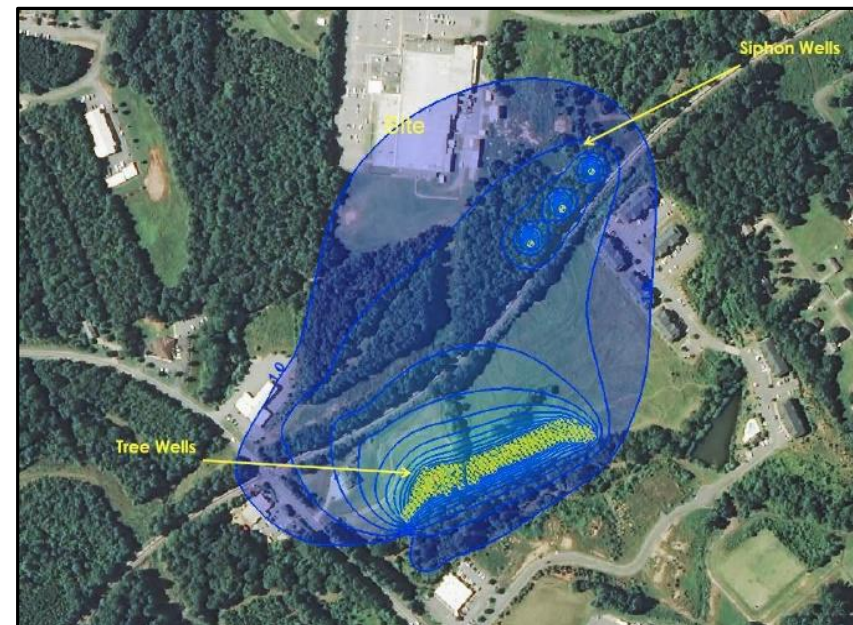
- Complete the ERH remediation at source area
- We will have then met IEPA goals
- Apply for conditional closure (anticipated in 2020)

TreeWell Phytoremediation at North Carolina Site



- Former auto part manufacturing facility in North Carolina
- CVOC and 1,4-dioxane plume
- Saprolite over fractured bedrock
- Existing system consisted of a series of ART® wells with ozone injection – excessive O&M costs due to well fouling
- System not effective in low permeability saprolite

- Modeling conducted to determine number and placement of *TreeWell* units to prevent discharge to adjacent stream

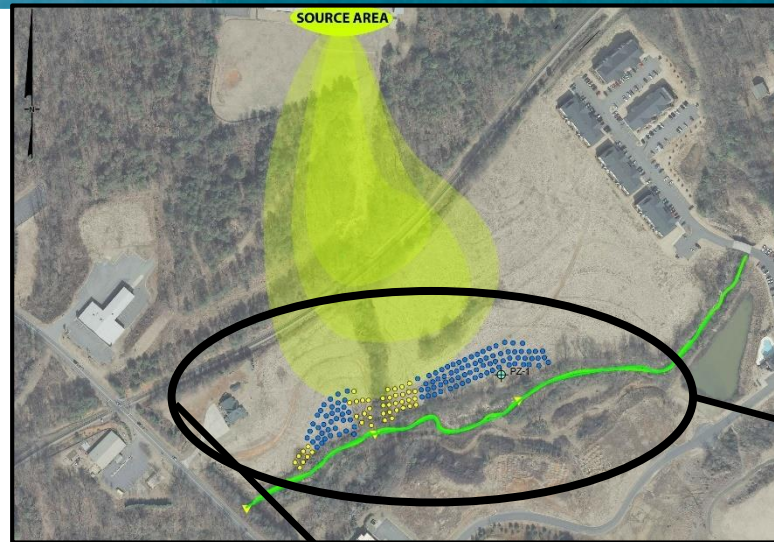


Concept Development of Phyto-Barrier



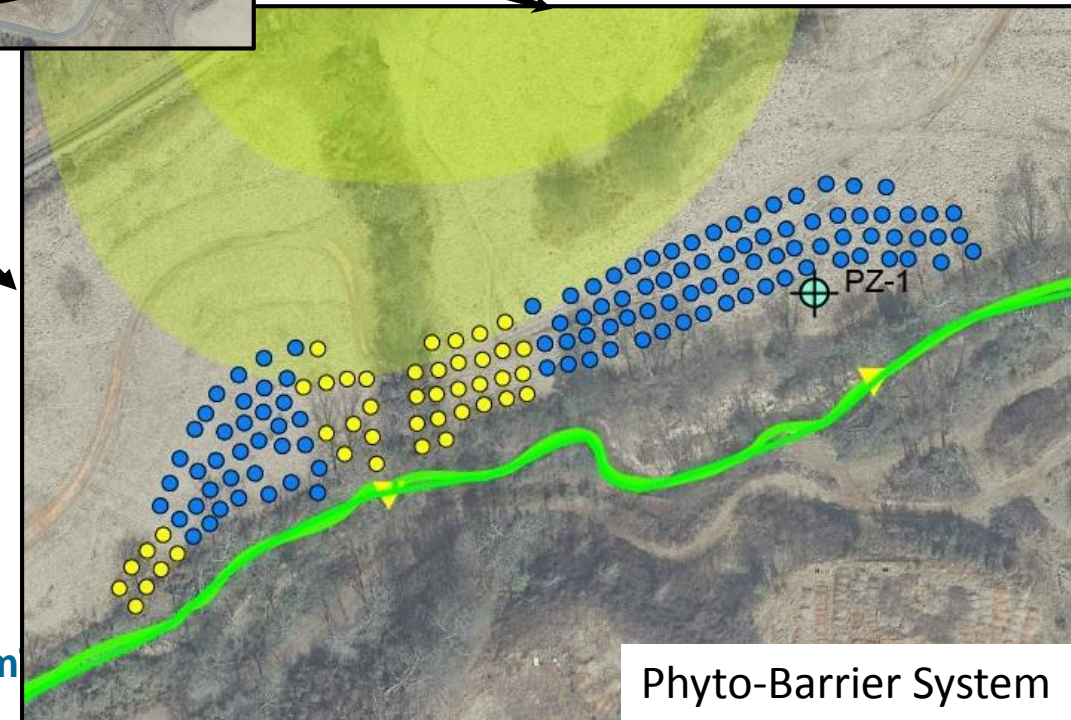
FOCUSED FEASIBILITY STUDY

- Rebound study
- Aquifer performance testing
- Vertical Profile Sampling
- Groundwater modeling to determine capture requirements
- Results indicated phytoremediation would be effective



CONCEPTUAL DESIGN

- A phyto-barrier to reduce overall flow to creek
- Install planting units along creek boundary - adequate to meet RGs
- Groundwater modeling revisited



Phytoremediation System Installation – Spring 2015



Tree Planting



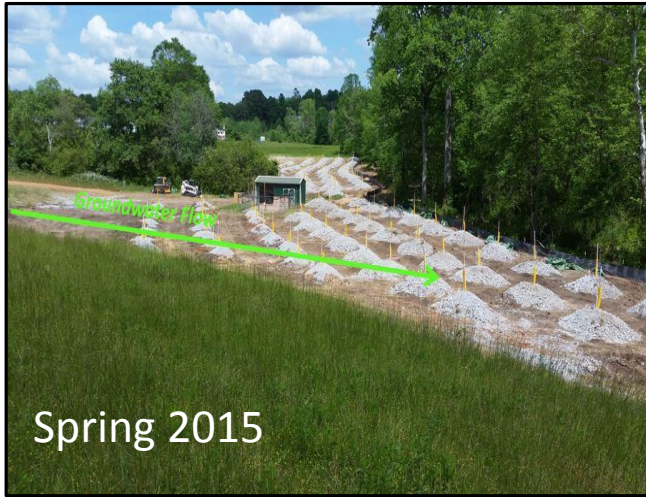
Spring 2015 Installation of 150 units adjacent to creek

- 1.1-meter units drilled to 5- to 7-meter depth
- Three native species:
 - Golden Willow (*Salix alba*)
 - Tulip Poplar (*Liriodendron tulipifera*)
 - London Plane (*Platanus acerifolia*)



Completed System

Outcome



- By end of second growing season inward gradient to the units
- Trees are now well-established, surface water concentrations have not exceeded NC surface water criteria
- 2016 – Regulatory approval of Risk-Based Closure with phyto system as engineering control
- **ART® System has been dismantled**
- **Currently negotiating conditional NFA with NC**



Canadian *TreeWell* Phytoremediation Projects



- Multiple sites in Ontario and Alberta
- Pilot study to evaluate technology for PCB-impacted groundwater



Central Florida 1,4-Dioxane Site



Site Background

- Manufacturing facility in Central Florida
- CVOC, 1,4-dioxane and arsenic groundwater plume in fractured bedrock
- Initial remedy: Long-term pump & treat system with UV/Peroxide
 - >\$300K/Year O&M costs
 - >20 Years to meet Remedial Goals



TreeWell System Installation & Outcome

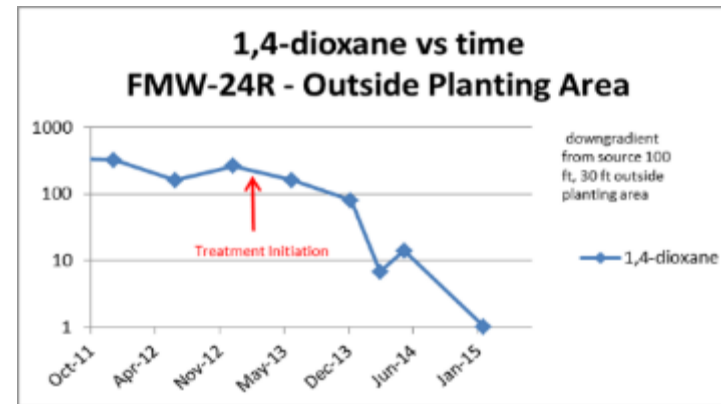
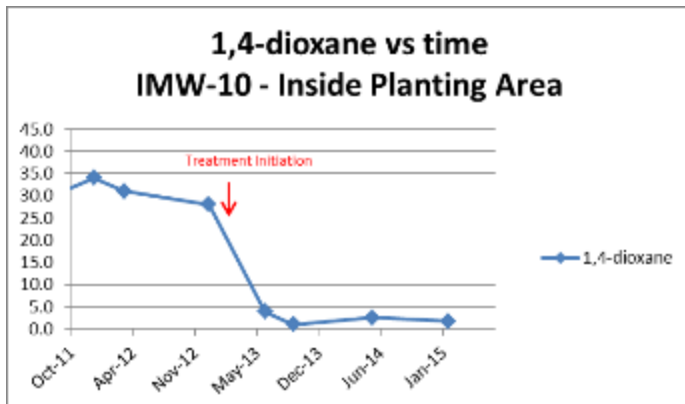
- 154 *TreeWell* units planted in 2013
- Cost to implement: about the same as one year O&M for the P&T system
- Hydraulic capture demonstrated by 2014 – P&T system idled and dismantled
- Groundwater concentrations significantly reduced



Central Florida 1,4-Dioxane Site



- Comparison of GW flow at time of *TreeWell* system installation (Yellow) vs. 18 months post-installation (Blue)
- Gradient reversal in only two growing seasons
- Experience at Sarasota with predicted groundwater response versus actual has been applied to modeling of other sites with similar success



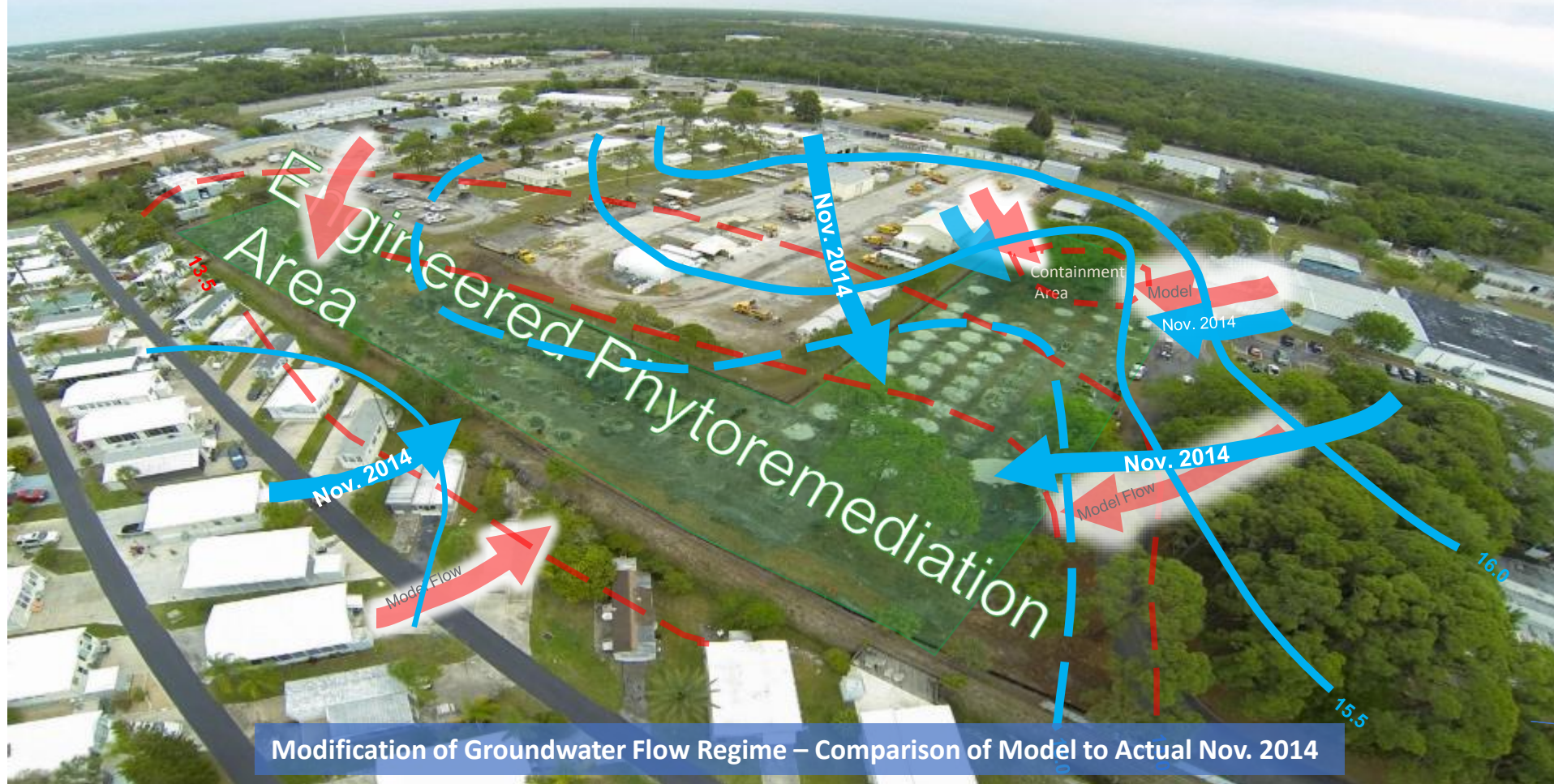
- Dissolved-phase concentrations have decreased significantly and rapidly since implementation

All indicated concentrations in µg/L

Central Florida Modeled vs Actual Groundwater Flow



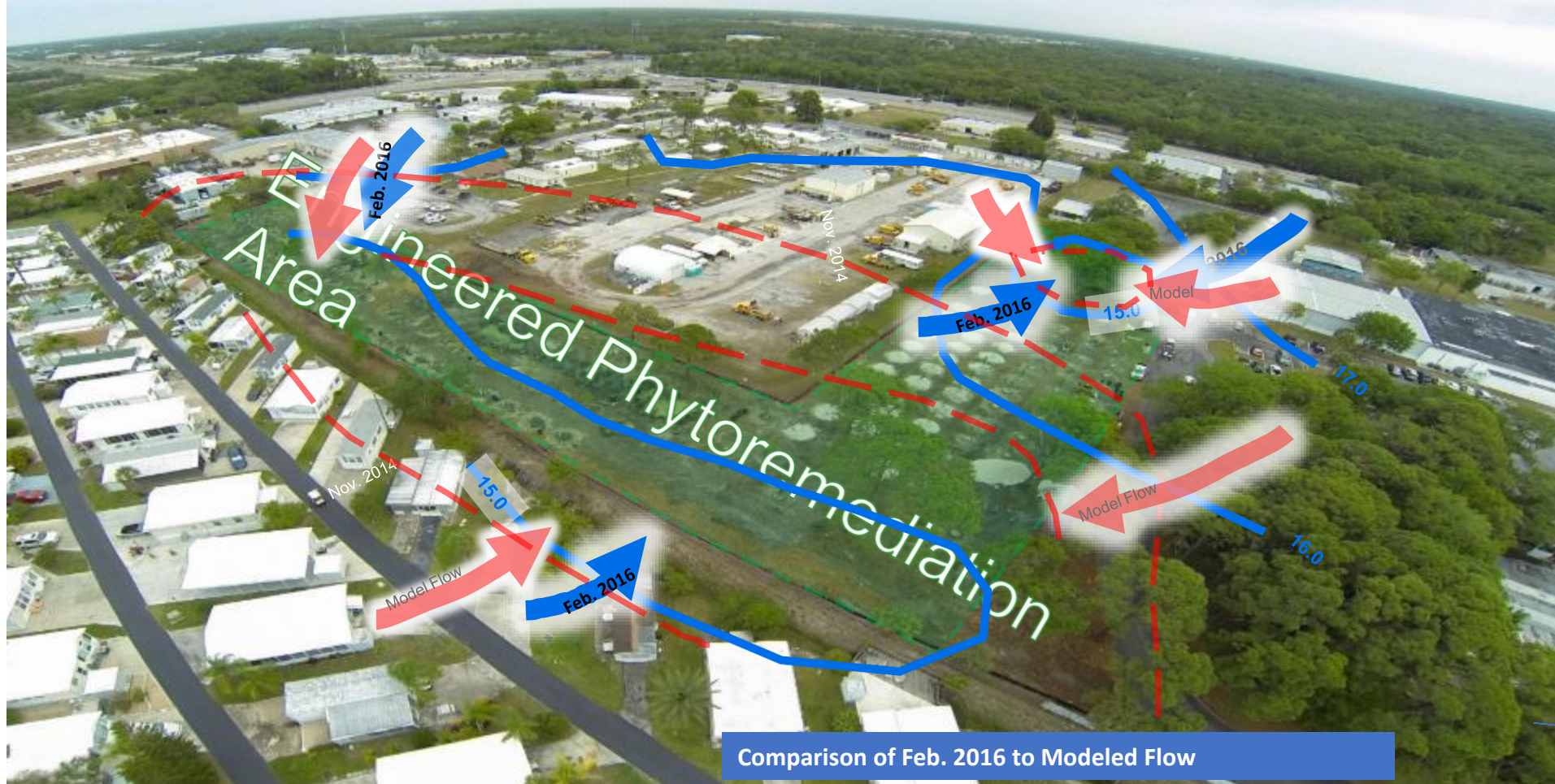
Sarasota - Performance of Phytoremediation System
Actual versus Groundwater Model Prediction (cont'd)



Central Florida Modeled vs Actual Groundwater Flow



Sarasota - Performance of Phytoremediation System
Actual versus Groundwater Model Prediction (cont'd)



Project Summary



In other words, an ineffective and costly P&T system was replaced with effective, low-cost phytotechnology...



Resulting in:

- *Significant savings to the client*
- *A happy client and regulator*

No Further Action granted in 2016

Site Rehabilitation Completion Order officially closed the site in 2018

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SW Louisiana DNAPL Site



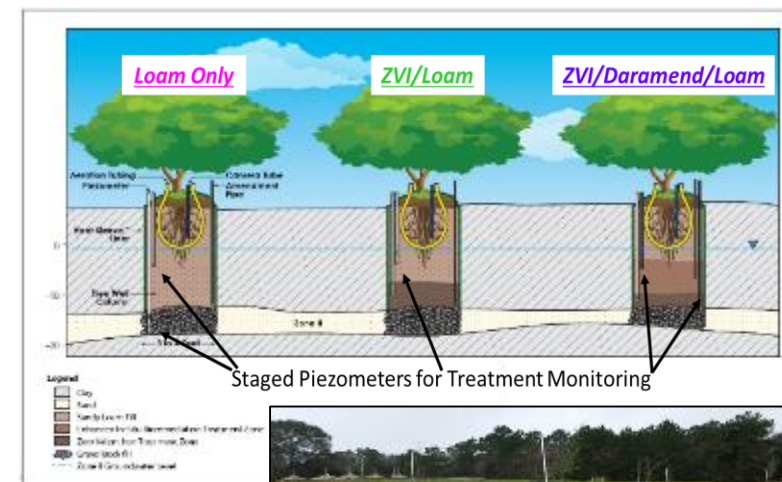
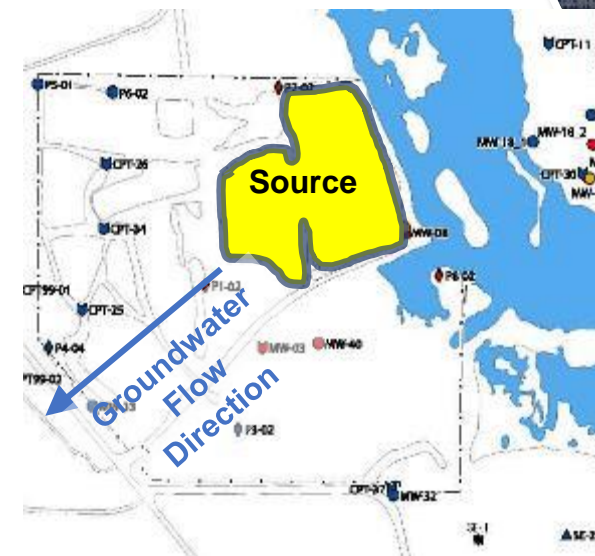
TreeWell Technology Effective at Source Areas

Site Background

- Former waste disposal facility
- Interbedded clay and sand
- Total VOCs at source in 1000s mg/L
- Chlorinated ethenes, ethanes, and methanes
- Initial remedy: Bioremediation, but ineffective at source areas

TreeWell Pilot Test

- Pilot Test initiated in 2015 to evaluate effectiveness of *TreeWell* technology, pre-treatment options and phytotoxicity
- Identify best tree species for full-scale system



SW Louisiana DNAPL Site



Promising Results:

- Greater than 10X decrease in CVOC concentrations in all 3 treatment configurations for both High & Low Plots
- As much as 5 orders of magnitude decrease in CVOCs in some units
- ZVI appears adequate to reduce CVOCs to below phytotoxic levels
- Overall plant growth and health good



Initial Planting



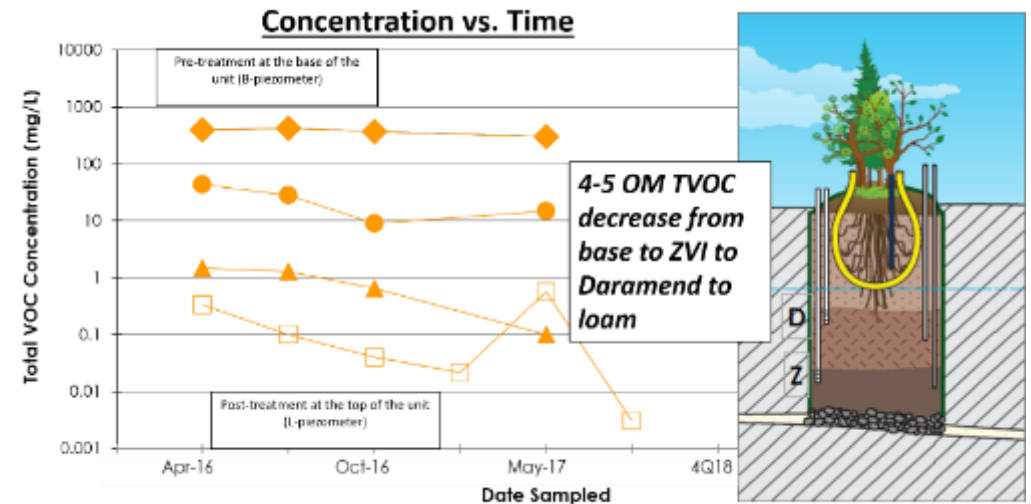
November 2016



August 2018

Based on Results To-Date:

- Additional units have been installed to target deeper GW units
- Similar system was installed at nearby sister site



Summary of Phytoremediation Technology: Key Benefits



- Plant-based remediation technology can be very effective
 - Particularly targeted system such as *TreeWell* tech
- Highly **adaptable** to specific site conditions and contaminants
- Applicable to emerging contaminants
- Applicable to many sites: cold climates, dry climates, deep and/or confined aquifers, sites with covers/caps, etc.
- Potential of **significant cost-savings** over conventional treatment options:
Typical TW Unit cost = \$2,000 to \$5,000
- Great **alternative to P&T** systems
- Green & Sustainable technology
- Well-accepted by regulatory community
- Numerous secondary benefits



Thank You



Questions?

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