CONTAINMENT OF A 1,4-DIOXANE PLUME USING *TREEWELL®* PHYTOREMEDIATION TECHNOLOGIES

Christopher Gale (ans.cgale@treewell.com) (Applied Natural Sciences, Encinitas, CA, USA), Frank Volkering (TAUW bv, Deventer, The Netherlands)

BACKGROUND/OBJECTIVES

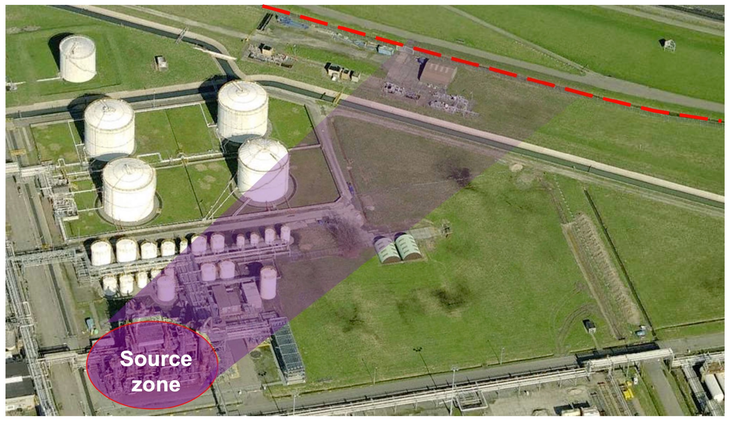
Site History

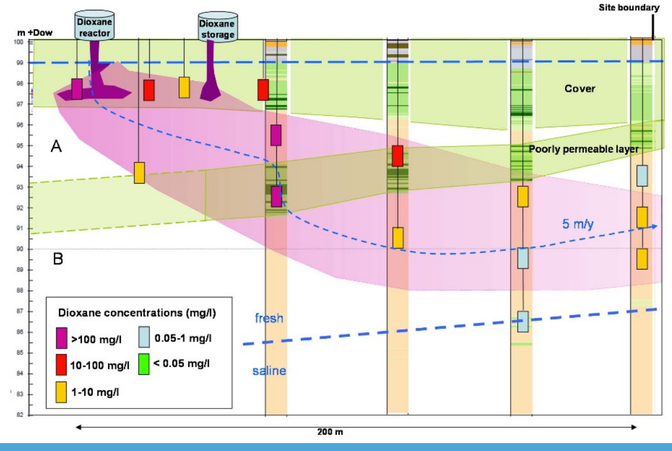
- Site is a large chemical production plant – formerly produced 1,4-dioxane
- 1,4-Dioxane concentrations as high as 1,500 mg/L in downgradient plume
- Impacted groundwater migrating towards nearby surface water body
- Groundwater impacts in 2 separate water bearing units separated by a low permeability layer:
  - Layer A – 4-6 m bgs
  - Layer B – 7-10 m bgs
- Typical containment alternatives labor and energy intensive and unattractive when considering economic and sustainability considerations
- More economic and sustainable nature based remedial alternative was desired

Objectives

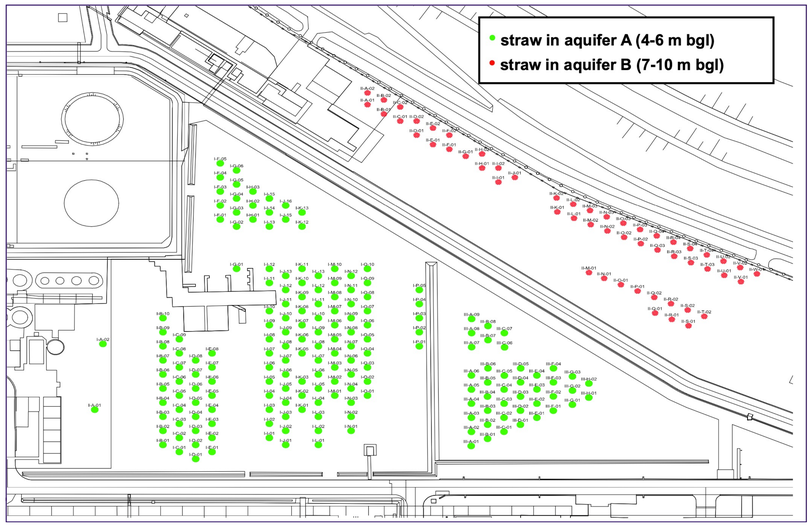
- Phytoremediation selected as a sustainable nature-based alternative for containing the groundwater plume and preventing migration to the nearby surface water body
- Trees to provide provide hydraulic containment and mass removal through transpiration of 1,4-dioxane into the atmosphere where it will be photodegraded

SITE CONDITIONS: GROUNDWATER IMPACTS IN SHALLOW AQUIFERS FROM 4-10 M BGS



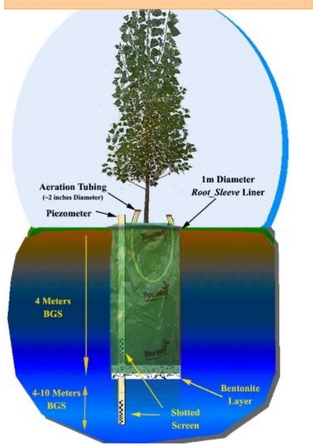


IMPLEMENTATION/DESIGN

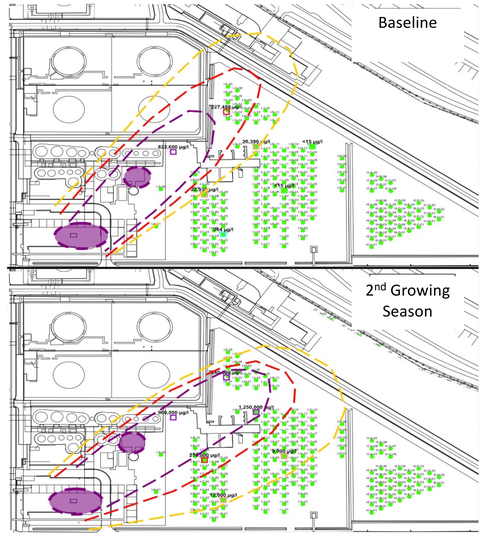


- 250 Straw *TreeWell* Units installed downgradient of the source area
  - 185 Units In Aquifer A
  - 54 Units in Aquifer B
- System designed to account for groundwater flow rates across planting area to provide a sufficient number of trees to capture the needed volume of groundwater
- Straw *TreeWell* units allow for access to deeper water
  - Closed bottom *TreeWell* units constructed with a dual screened well installed through the bottom of the liner
  - One well screen placed at the target groundwater interval
  - Second well screen placed above the bentonite seal at the bottom of the closed bottom *TreeWell* unit and below static groundwater level

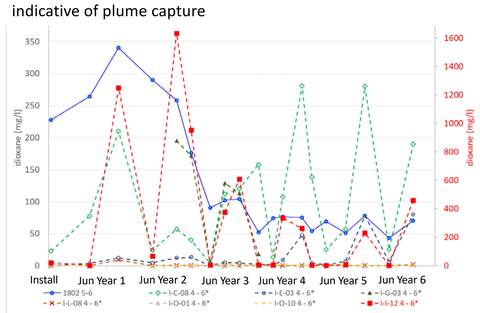
Schematic of Straw *TreeWell* Unit



RESULTS



Groundwater monitoring results demonstrate shallow plume is drawn into phytoremediation area during active growing season, indicative of plume capture



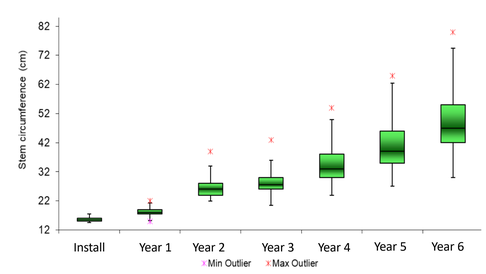
Groundwater monitoring results indicate steady decrease in 1,4-dioxance concentrations since planting (solid line) Seasonal variability in *TreeWell* unit straws (dashed lines) is reflective of active pumping by trees actively drawing water in

Tree	Dioxane evaporation$ (µg/h/tree)				% evaporation of expected uptake*			
	2016	2017	2018	2019	2016	2017	2018	2019
I-A-02	40	307	70.1	66	0.00%	0.22%	0.05%	0.04%
I-C-09	8	6.7	3.8	18.4	0.00%	0.00%	0.00%	0.05%
I-D-08	2,320	48.5	-		0.47%	0.02%	-	
I-H-03	24	0.7	21.5	37.9	0.00%	0.00%	0,04%	0.03%
II-C-02	1.2	4.0	1.2	< dl	0.00%	0.04%	0.01%	nd
I-I-12	-	733	-		-	0.25%	-	
I-F-02	-	63.4	-		-	0.09%	-	
average	**478**	**166**	**24.1**		**< 0.10%**	**0.09%**	**0.03%**	**0.03%**

$: Assuming a face leaf area of 0.7 m^2 for the branches with a total face leaf area of 16-26 m^2 for the trees depending on stem diameter

* Based on groundwater concentration estimated from results of nearby monitoring

Measurements of 1,4-dioxane evapotranspiration rates indicate less than approximately 0.10% of the mass entering the phytoremediation system is being transpired to the atmosphere. The observed difference in measured vs expected transpiration rates were explained by evidence of biodegradation in the root zone (work done by others).



Overall tree health has been satisfactory since initial planting, with steady overall growth, indicative of increased water consumption

Tree growth and health assessments are a key component of a *TreeWell* based phytoremediation program to monitor for potential stressors that could affect tree health and therefore system efficacy

CONCLUSIONS

TreeWell unit-based system has demonstrated ability to provide full "overall" hydraulic containment after the first growing season.

Overall tree health has been satisfactory since initial planting.

High estimated mass uptake (50-100 kg/y)

Evapotranspiration accounts for less than 0.10% of the 1,4-dioxane mass taken up by the trees.

Evidence of 1,4-dioxane biodegradation in the root zone.

No evidence of phytotoxic effects due to high 1,4-dioxane concentrations.

Engineered phytoremediation system has proven to be a cost effective, sustainable, nature based remedial alternative for providing hydraulic containment even at an active chemical production plant.