EFFECTIVE MANAGEMENT of a RECALCITRANT PETROLEUM HYDROCARBON IMPACTED SITE by PHYTOREMEDIATION

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Sustainable In-Situ Remediation Co-operative Alliance

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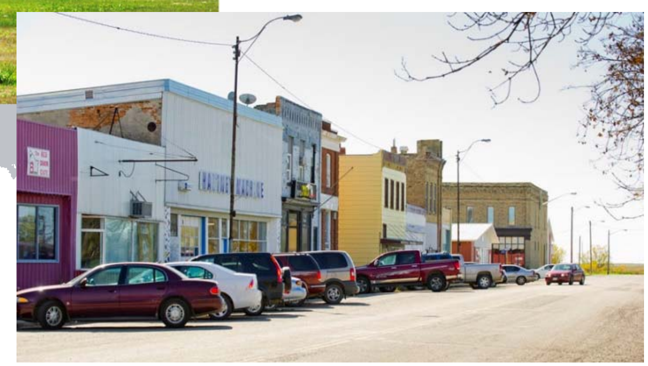
SIRCA

- Sustainable In-Situ Remediation Co-operative Alliance
  - Dedicated to advancing research activities, remediation technologies and risk assessment on contaminated sites.
  - Est. 2014 by Federated Co-operatives Limited and other Co-operative research partners
  - Industrial Research Chair at University of Saskatchewan
  - www.sirca.coop

Site facts



Hartney, Manitoba

Pop.: 400
Est: 1882
SW Manitoba, Canada

Problem

- Petroleum Hydrocarbon Impacted Site
  - Vacant
  - Small rural property
  - Low value
  - No intended future use
- Low level impacts
  - Low risk
  - Limited soil disposal options

Problem

- Typical site condition
- As a Co-op, our client has a strong commitment to the community and managing these legacy sites

Research Initiatives

Objective: Establish phytoremediation as a sustainable option to remediate former recalcitrant petroleum hydrocarbon impacted bulk plant sites.

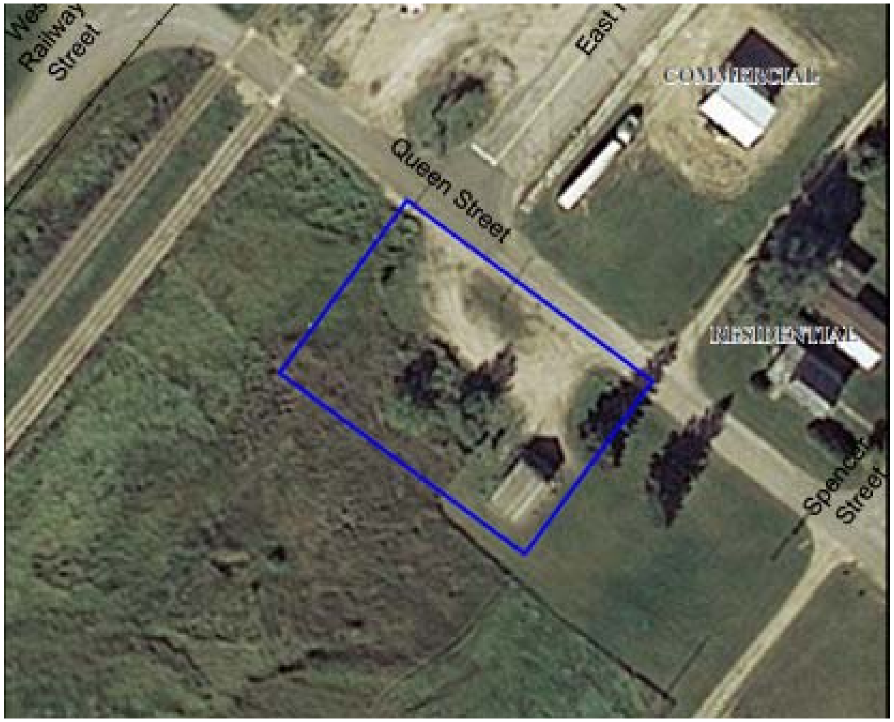
- Soil mixing
  - Improve subsurface bioremediation conditions
    - Addition and distribution of nutrients
    - Improve uniformity of O_2 and native microbial populations
    - Reduce soil compaction typical of traffic and use patterns
- Application of a microbial root growth supplement
  - Typical in landscaping industry to enhance survival and establishment of trees and shrubs

Research Initiatives

- Evaluate the use of lower growing tree species
  - Typical popular and willow species associated to phytoremediation pose a potential growth height issue to overhead utilities
- Evaluate the effects on groundwater conditions
  - Hydraulic control and limiting the off-site migration of impacts
- 10 year study time frame

Initial site conditions

- Typical bulk plant site
  - Oil shed
  - 5-12,500 L fuel ASTs
  - Truck and rail loading
  - Low overhead utilities
- Decommissioned 1992
- Assessed 1996
- No further action until remedial activities in 2012



1996 assessment results

- Glaciolacusterine sediments, glacial clay till and shale
- Shallow subsurface conditions
  – 0-0.5m clay and granular fill
  – 0.5-3.0m sand
  – 3.0-4.8m silty clay
  – >4.8m high plastic clay
- Impact zone 0-3.1 m bgl
- GW depth 1.3-1.5 m bgl
- Regional potable conditions however limited to no use in area

PHC concentrations (range in ppm)

	Soil	GW
Benzene	2.8-5.7	0.26
Toluene	0.24-45	0.66
Ethylbenzene	2.4-13	0.13
Xylenes	1.5-74	0.43
Total volatile*	380	64
Total semi-volatile**	41-1400	0.06

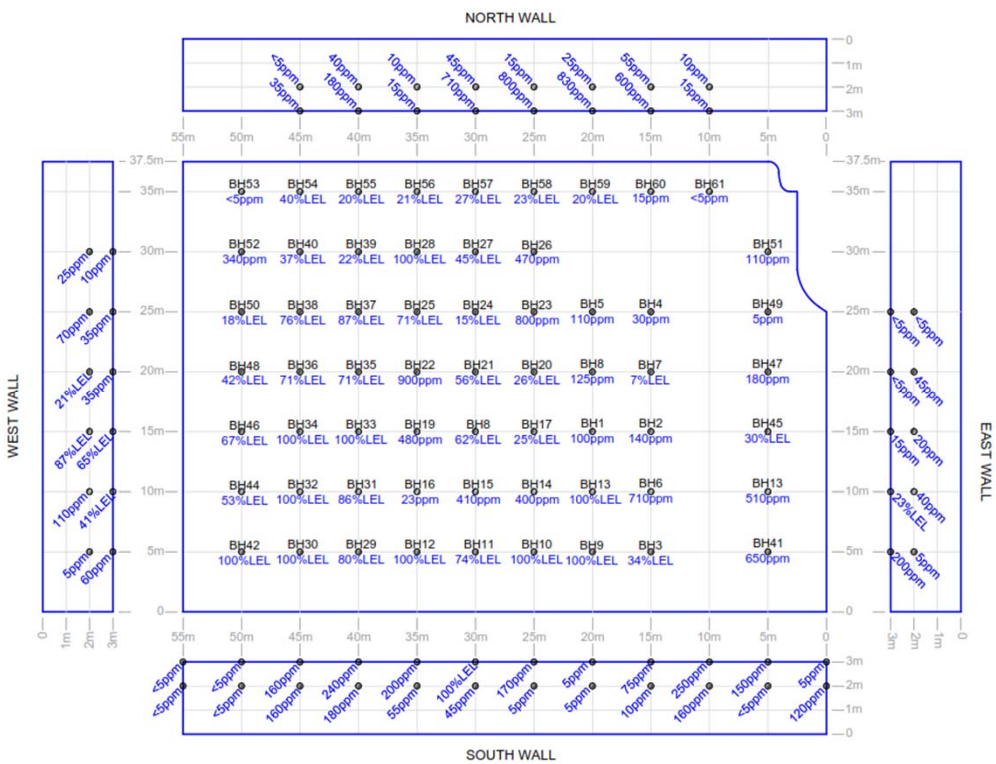
* ≈PHC F1/F2 range plus BTEX
** ≈PHC F2-F4 range

Soil mixing - 2012

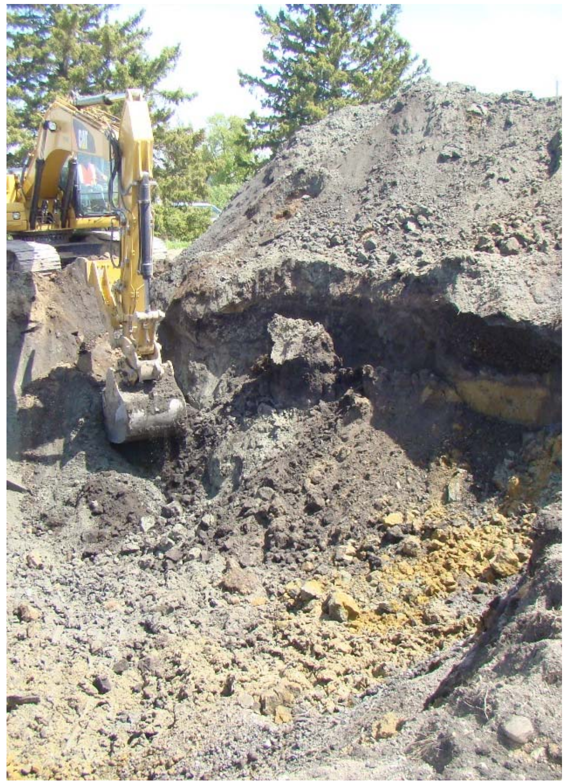
- Excavation 55m x 38m x 3m deep
- Homogenized soils
- Soil blended with 1300kg agricultural fertilizer
  - 420kg 46-0-0 urea
  - 409kg 0-0-6 potash
  - 472kg 11-52-0 urea phosphorous blend
  - application rate 0.2 kg/m^3 soil

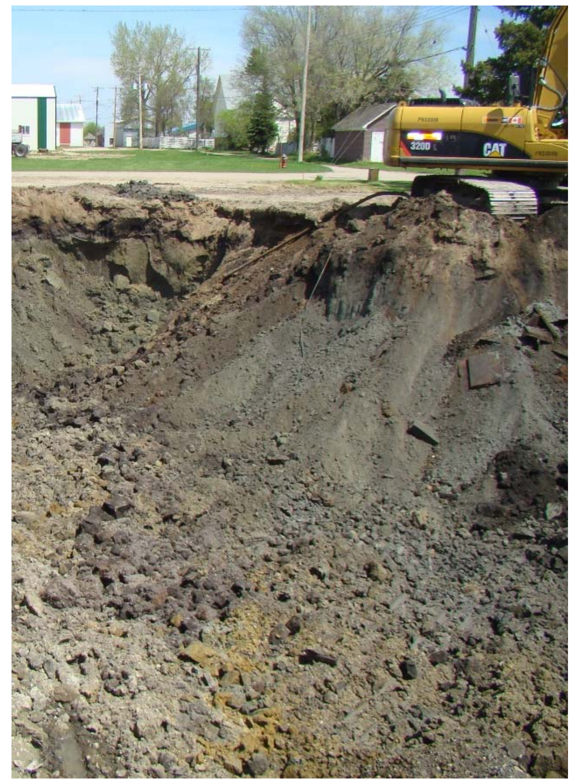
Soil mixing – sampling

- Soils were sampled during excavation and blending
  - Sampling assisted in achieving relative homogeneity
- Excavation extents sampled
  - Soil vapours 30->100% LEL
- Select samples submitted for BTEX and PHC F1-F4 fraction analysis and nutrients
- Backfilled in 1 m thick lifts



Soil mixing – excavation





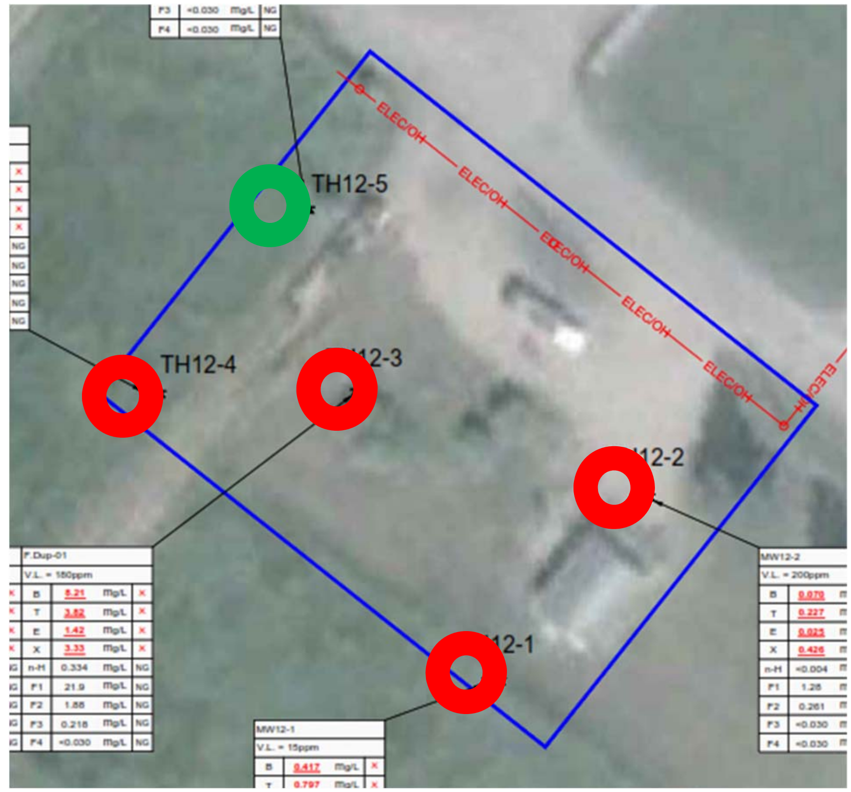
Soil mixing – backfilling

Monitor well – install

- On completion of backfilling, five monitor wells installed May 2012
- 50 mm diameter
- 4.6-6.1 m depth
- Wells located within impacted zone and along perimeter

Monitor well – sampling results

- Initial GW sampling June 2012
- Depth to water 1.6 to 2.2 m bgl
- Sheen detected in 3 of 5 wells
- Standard field testing
- PHC samples determined:
  - 0.4-7.3 mg/L benzene
  - 0.2-3.8 mg/L toluene
  - 0.2-1.4 mg/L ethyl-benzene
  - 0.6-3.3 mg/L xylenes
- Nutrients
  - No detectable NO_3
  - 1.3-5.9 mg/L NH_3



Tree planting

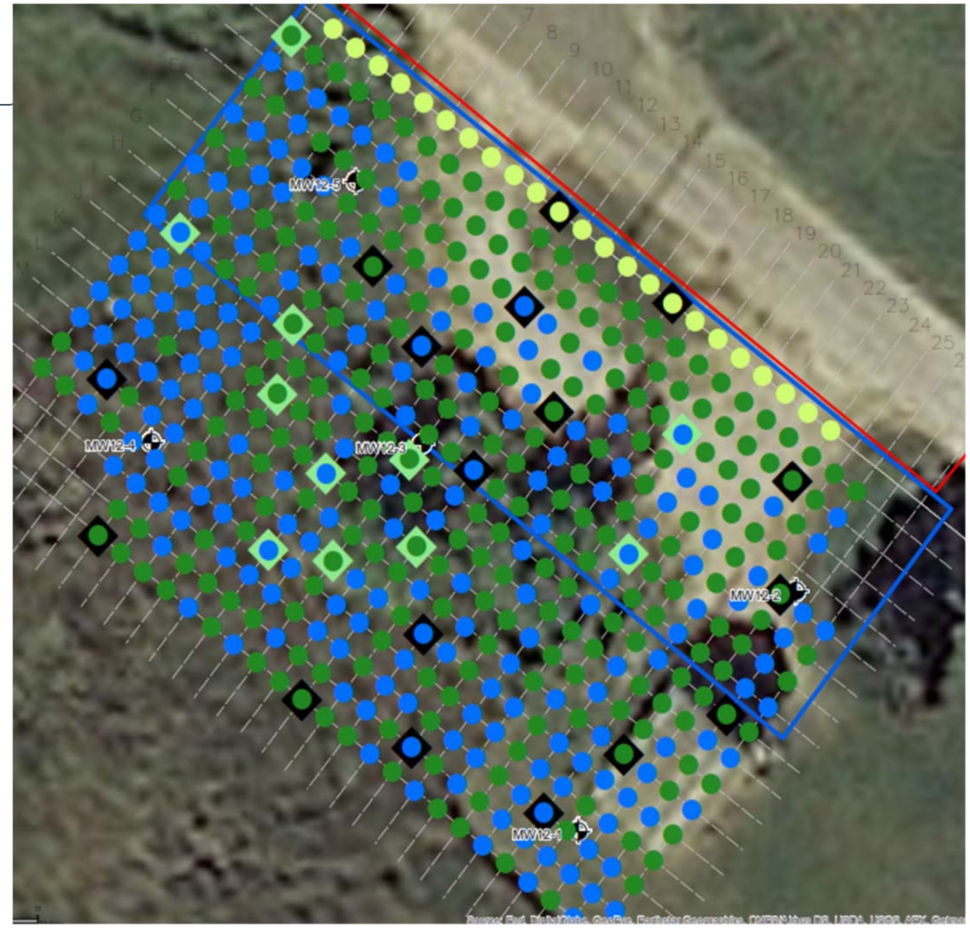
- 476 trees planted
  - 2.2 m average spacing
- Two groups established
  - Control
  - Soils amended with Myke® tree and shrub mycorrhizae
- Mix of poplars and willows
  - Deep rooting
  - Maturity height of 15-30m poplars and 4.5-9m willows
- 1 row of cottoneasters planted under power lines
  - 4m height at maturity

Tree planting

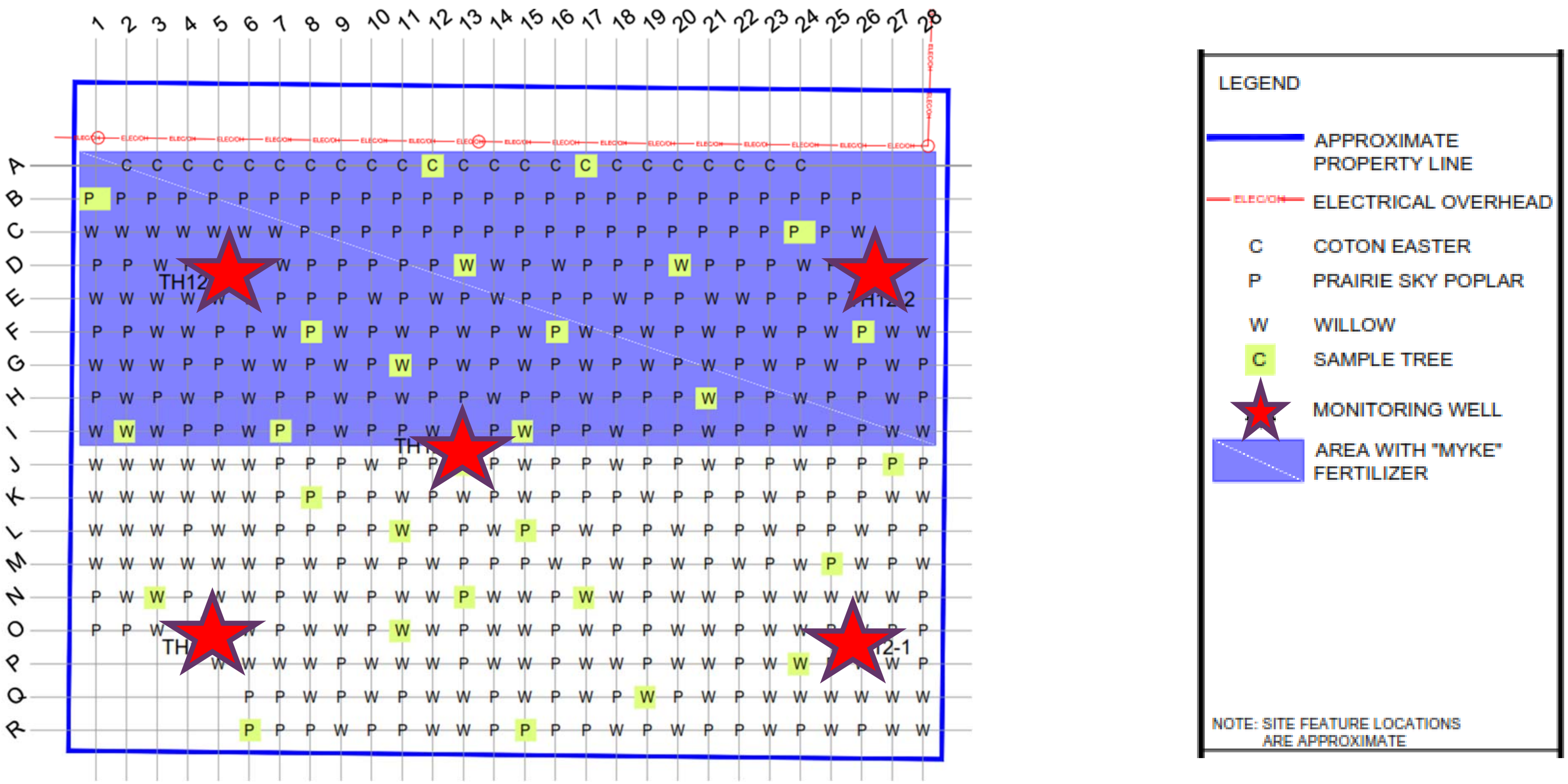
Tree planting

Tree planting - layout

- Due to tree availability, two types of poplar and three types of willow used
  - Primarily prairie sky poplar and golden willow
- 17 trees selected to monitor health and growth
- On four occasions in 1st year:
  - Trees were watered and weeds controlled



Tree planting - layout



Results – fall 2014 monitoring

- Groundwater drawdown in the order of 1.5m in the centre of the planted area.
  - Inferred hydraulic control occurring
  - Further study required
- Hydrocarbons
  - Sheen detected
  - BTEX reduction 10 to 70%
  - PHC F1 and F2 fractions – limited reduction
- Nutrient concentrations
  - Slight phosphorus increase
  - Slight reduction in ammonia and TOC
  - Low concentrations of NO_3

Tree evaluation – fall 2014

Tree Species	Control			Myke®		
	Condition	Height (m)	Dia. (mm)	Condition	Height (m)	Dia. (mm)
Contoneaster	n/a	n/a	n/a	Good	Min	n/a
Tower Popular	Excellent	1.0-1.7	13-23	Good	n/a	n/a
P. Sky Poplar	Good	2.3-2.5	23-52	Good	2.3-3.2	28-37
Golden Willow	Good	0.3-0.5	20-21	Excellent	1.3-2.2	17-30
Hybrid Willow	Excellent	3.1	30	Good	n/a	n/a
Laurel Leaf	n/a	n/a	n/a	Good	0.3	9

Note – Growth relative to initial measurements

Results – summer 2016 monitoring

- Groundwater drawdown in the order of 0.7m northern portion of planted area.
  - Overall 1m lower apparent GW table
  - Possible hydraulic effect
  - Hydraulic conductivity 10^{-4} to 10^{-5} cm/s
- Hydrocarbons
  - No sheen
  - BTEX reduction 30 to >95%
  - PHC F1/F2 fractions – 80-90% reduction
- Nutrient concentrations
  - Slight phosphorus increase
  - Slight reduction in ammonia and TOC
  - No measurable NO_3
  - Increase in dissolved iron in impact area
  - Decrease in sulphate

Tree evaluation – summer 2016

Tree Species	Control			Myke®		
	Condition	Height (m)	Dia. (mm)	Condition	Height (m)	Dia. (mm)
Contoneaster	n/a	n/a	n/a	Good	Min	shrubby
Tower Popular	Fair-Good	>2-2.1	13-23 25-31	Good	n/a	n/a
P. Sky Poplar	Good**	>3.1	78	Good	>3.3-4.3	58-61
Golden Willow	Good**	1.3	25-31	Excellent	>3.7-3.17	26-32
Hybrid Willow	Good	3.2	49	Good	n/a	n/a
Laurel Leaf	n/a	n/a	n/a	**		

Note

- *Growth relative to initial measurements*
- ** - One tree died*
- *> Height exceeded*

Lessons learned to date

- Soil mixing:
  - Volatilized impacts and reduced ‘hot spots’
  - Soil compaction reduced and amendment reasonably blended
  - Excavation and blending with a typical excavator (no blending tooling) was effective and locally available
- The Myke® treated trees:
  - Improved overall health, decreased mortality.
  - Increased height and breast diameter

Lessons learned to date

- Use of cotoneasters as a low growing tree species
  - Tree health is good
  - Trees planted near mature height
  - Suitable in locations with mature height limitations
  - Shrubby dense growth with flowering shoots
- Trees increased water demand appears to be providing a positive hydraulic effect at the site
- PHC concentrations in groundwater have decreased 30->95% based on the overall approach

Go forward plan - 2018

- Continued monitoring
- Reduce seasonality and monitor same month of year
- Additional off-site assessment wells required to evaluate zone of effect as trees mature
- Potentially complete a water demand assessment
- Photo catalogue of study trees
- Further subsurface assessment

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