Phytoremediation as an On-Site Ex Situ Remediation Option

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Background

- In situ techniques often have limited application or long timelines in fine-grained soils.
- For rapid remediation at fine-grained sites, excavation is still a common technique.
- However, excavation does not necessarily require landfill disposal of impacted soils.
- Onsite treatment of hydrocarbon-impacted soils is often a feasible approach.

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Definitions

- Ex situ – soils removed from their native location, may still be on the site
- Phytoremediation - attenuation of impacts (in this case hydrocarbon impacts) via the cultivation of suitable plants

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Theory of Phytoremediation at Hydrocarbon-Impacted Sites

- Bring sub-surface soils up to the root-zone depth
- Amend sub-soils for optimal plant growth
- Seed with PGPR-treated seeds that promote microbial activity in the root zone (rhizosphere)
- Irrigate and mow as required
- Monitor progress of soil remediation

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Case Study

- Former Shell-owned facility in southern Manitoba
- Hydrocarbon contamination down to 5.5 m depth
- Fine-grained soil, excavation was selected as appropriate remediation technique
- Identified vapour inhalation pathway as governing criteria

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Case Study

- Historical soil sampling identified soil impacts:
  - benzene concentrations up to 25 mg/kg
  - F1 concentrations up to 2500 mg/kg
  - F2 concentrations up to 810 mg/kg
- Groundwater impacts occasionally exceeded inhalation criteria (intermittent impacts in the heart of the plume, no exceedances downgradient)

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Subject Site – before excavation

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Feasibility Assessment

- Laboratory test completed to assess feasibility of phytoremediation
- Results indicated phytoremediation an appropriate option in conjunction with fertilizer and other amendments.

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Greenhouse tests for soil amendment and PGPR effects

Soil Amendment

- Peatmoss - PGPR

+ Peatmoss - PGPR

Fall Rye Oats Tall Fescue Barley Ryegrass

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PGPR

+ PGPR
+ Peatmoss

- PGPR
+ Peatmoss

Oats

+ PGPR
+ Peatmoss

- PGPR
+ Peatmoss

Ryegrass/Tall fescue

Excavation Activities

- Excavated a treatment pad over entire site (2550 m^2) & stockpiled 2800 m^3 clean soil on-site
- Excavated impacts to as deep as 5.5 m, backfilled with clean stockpile to 1.5 m below grade
- Spread impacted soil on the pad (1.5 m depth)
- Amended soil with peat, fertilizer and topped with 10 cm of topsoil

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Removal of topsoil & clean soil

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Excavation of impacted soil

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Backfilling bottom with clean soil

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Placing impacted soil on top

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Planting & Maintenance

- Planted a treated seed mixture (PGPR-amended seeds) of rye grass and fescue
- Little or no maintenance was required - irrigated & mowed over the 2007 season

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Seeding – June 21, 2007

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Plant growth – July 27, 2007

Plant Growth Survey

Plant Growth Parameters	
Ground Coverage	100%
Plant Height (unmowed)	38 cm
Density	1350 plants/m^2
Biomass	190 g dry wt/m^2

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Success of Plant Growth

- Plant growth was excellent. Seeds germinated quickly and grew throughout the site.
- Plant growth did not appear inhibited by contaminants – growth was typical of good topsoil.
- Site was mowed 4 times in 2007.

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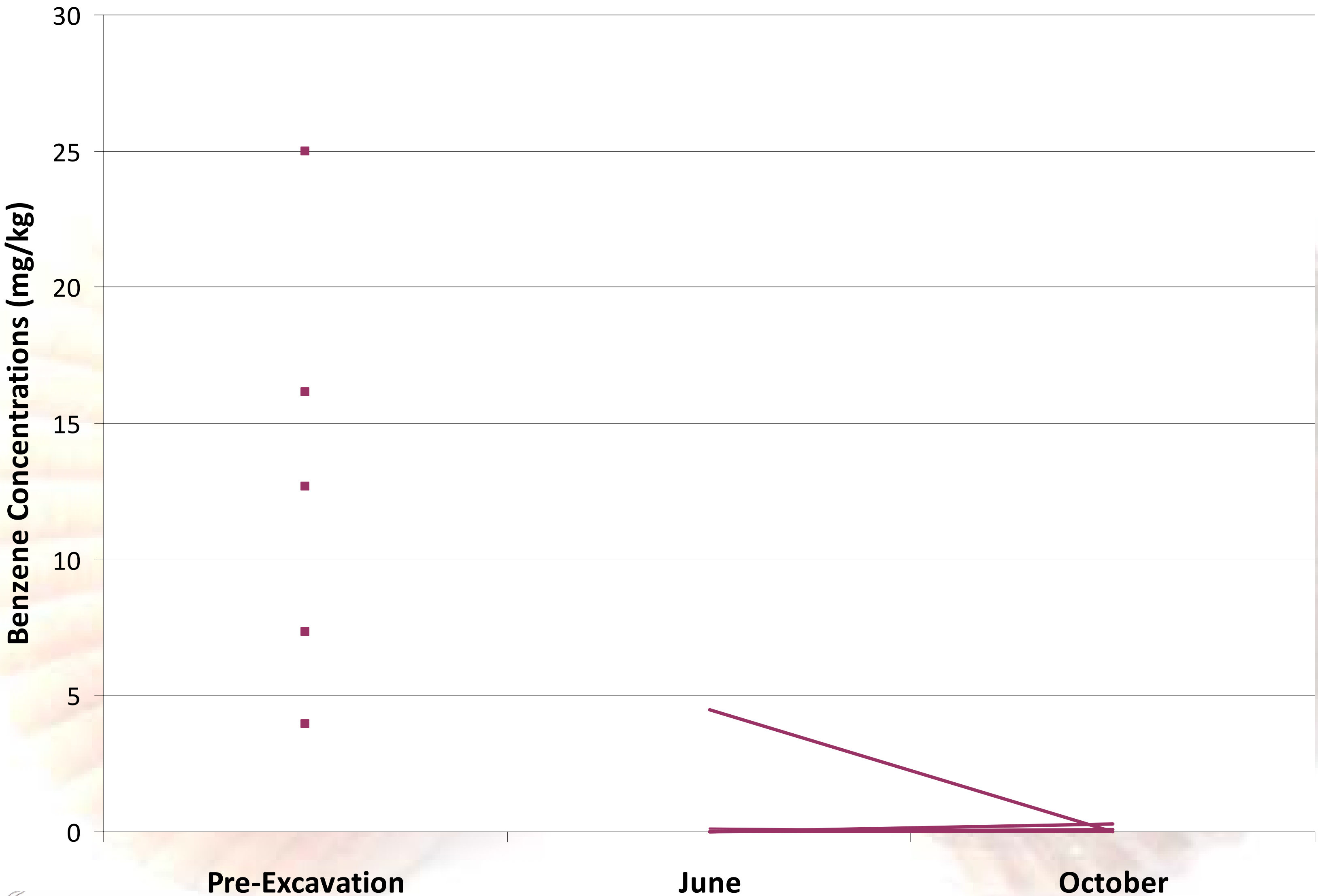
Remediation Progress

- Soil samples collected from 12 sections of the treatment area.
- Samples collected in June 2007 immediately following planting of grass and in October 2007 to determine progress of remediation.

Remediation Progress



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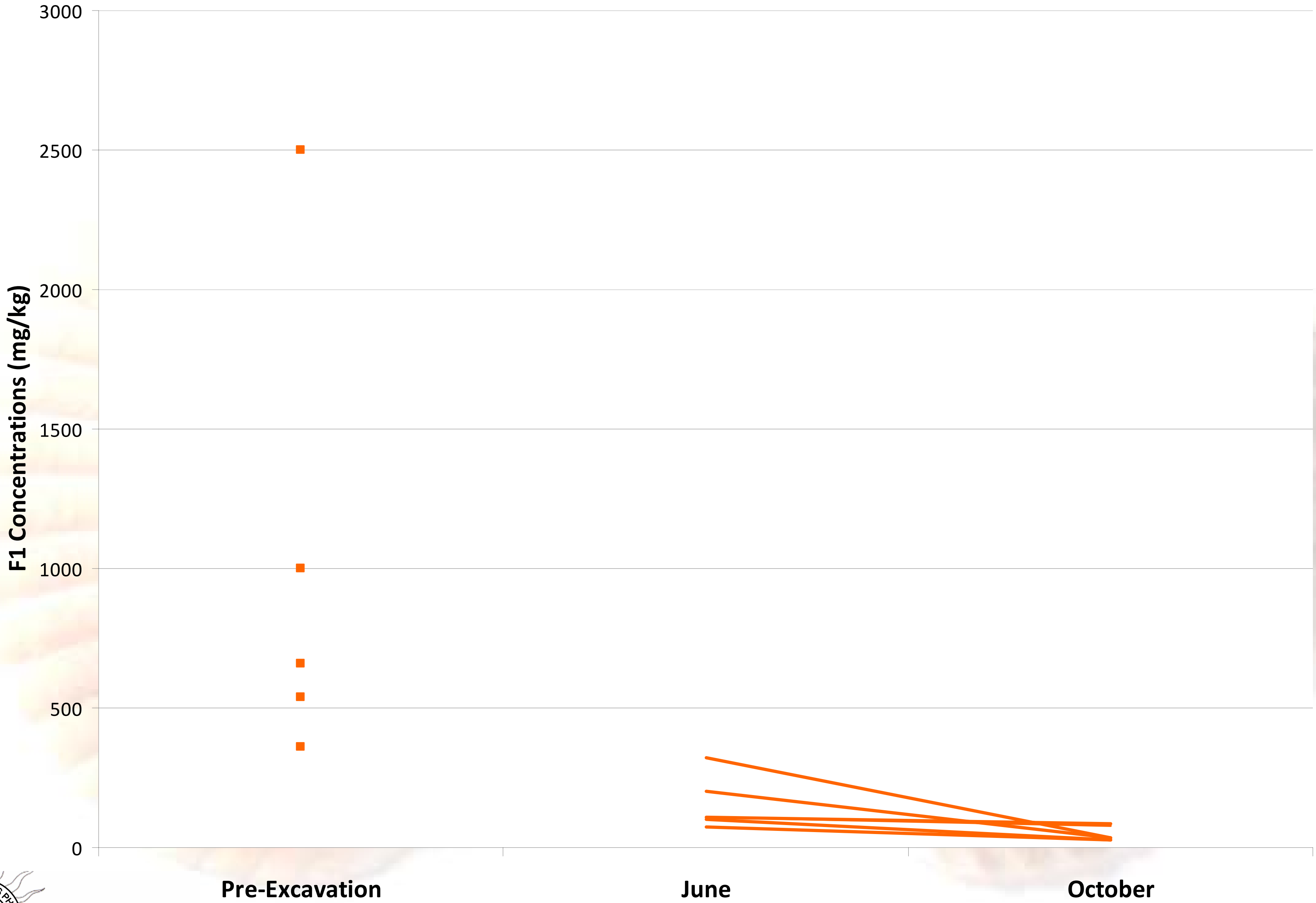
Remediation Progress



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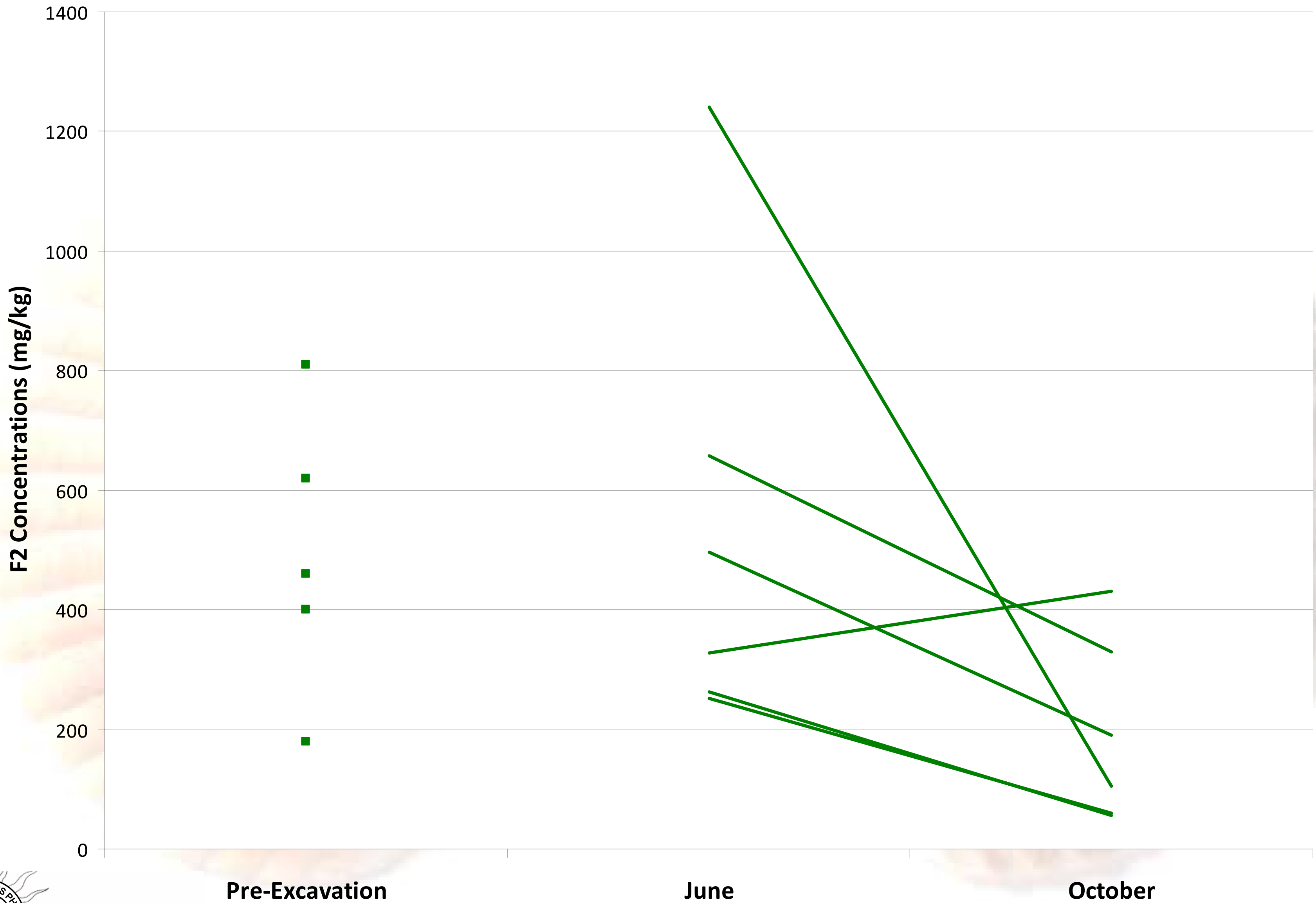
Remediation Progress



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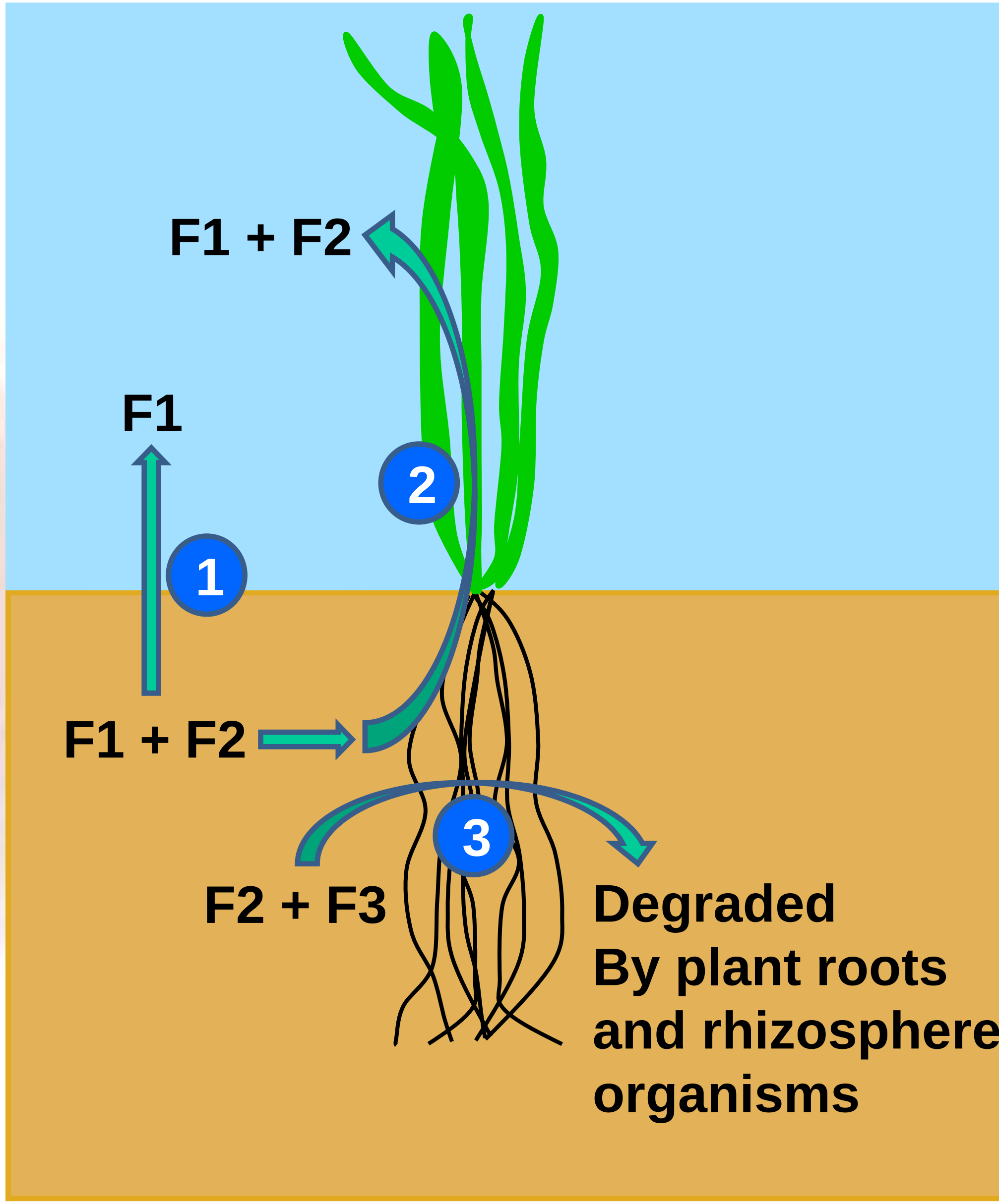
Mechanism of Remediation

1. **Direct volatilization: Probably only occurred when the sub-soil was excavated and spread – an odor associated with F1 and F2 was not detected**

2. **Phytovolatilization: Likely a relatively minor pathway due to hydrophobic nature of petroleum**

3. **Phytodegradation and rhizodegradation: Major pathway once plant growth begins – we have demonstrated active degradation of F2 and F3 by roots and soil microbes**



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Benefits of this Process

- Remediation completed in a timely fashion
- No soil disposal costs
- 5400 tonnes of impacted soil was not sent to the landfill
- An equal amount of virgin soil was not needed to be taken from a greenfield for backfilling
- Approximately 7900 L of diesel fuel was saved by not trucking the soil to a landfill

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Benefits of this Process

- Approximately 300 hours of trucking on highways was not required, greatly reducing the likelihood of motor vehicle accidents
- Impacts were remediated, and not just hauled to another location
- No “back-end” costs – onsite remediation pad did not need to be decommissioned, and the process turned the sub-soil into topsoil
- Cost for entire remediation project was $320,000

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Outcomes

- Site remediated in less than 1 year
- Achieved cost savings as compared to traditional soil disposal
- Reduced greenhouse gas emissions
- Reduced loading of landfill
- Reduced impact to local roads
- Reduced risk to health and safety
- Provided the community with an aesthetic site during remediation

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