Phytoremediation of Salt and Petroleum Hydrocarbon Impacted Soil: An Innovative and Cost Effective Green Technology for Use at Remote Sites

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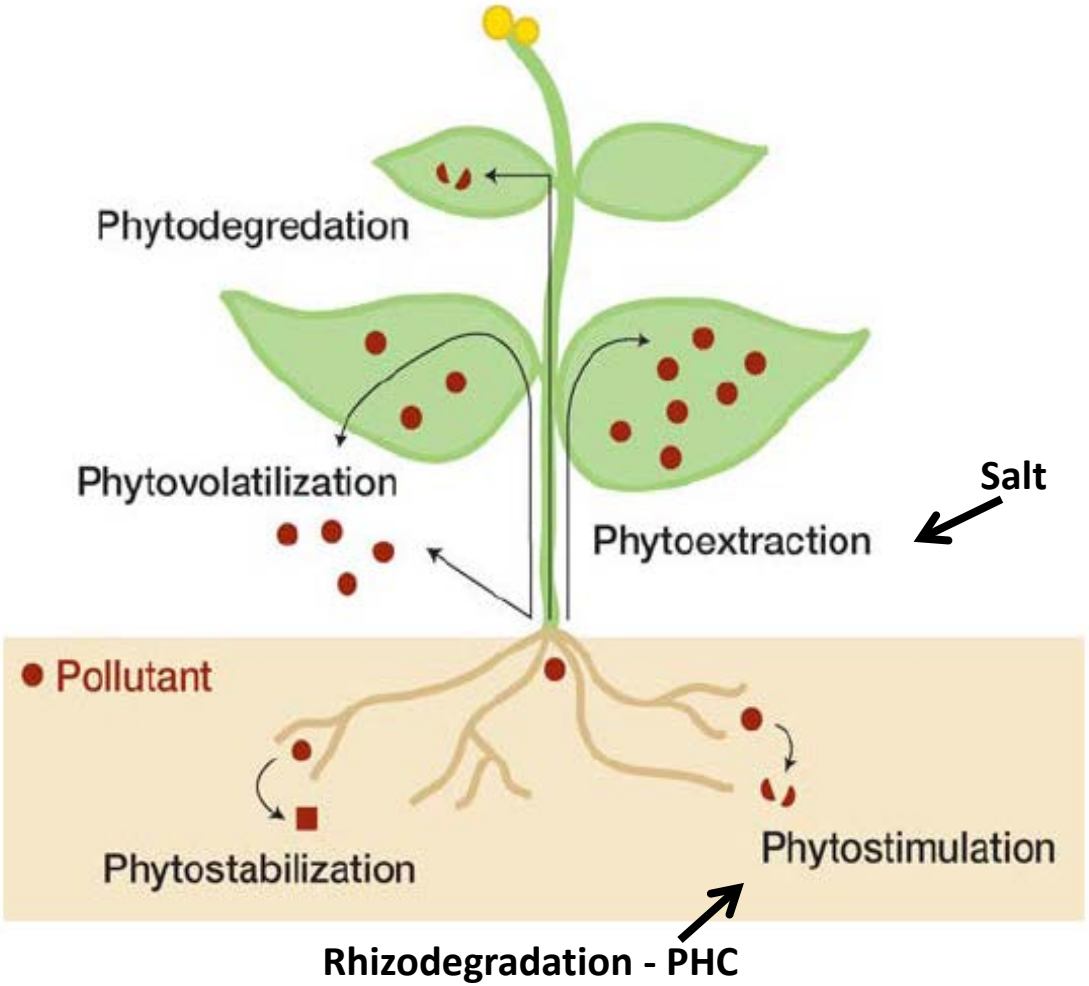
Outline

- Phytoremediation
- PEPS
- Case Study Data – Sahtu Region and Norman Wells Region, NWT
  - Salt (ECe and SAR)
  - PHC F2 and F3 PHC Remediation
  - BTEX Remediation
- Predictive Modeling From Six Alberta Sites
- Costs & Benefits of Phytoremediation

Phytoremediation



- Volatilization
- Phytodegradation
- Plant uptake soil→root
- Rhizosphere processes
- Bioavailability (particle→water)

PEPS

- Plant Growth Promoting Rhizobacteria (PGPR) Enhanced Phytoremediation System - PEPS
- A PROVEN phytoremediation system:
  - Soil treatment area management (amendments, seeding, soil manipulation)
  - Performance measures
  - Final site closure
  - Treats all PHCs (including BTEX, F1 to F4), PAHs and salts

Sahtu Region, NWT

- Two related sites: lease and remote sump located ~170 km northeast of Norman Wells.
- Both sites contained highly saline drilling waste.
- Drilling waste was encapsulated and buried at the remote sump - 3 km from the lease.
- Lab data showed the following exceedances: pH, ECe, SAR, PHC fractions F2 and F3, trace metals at lease site; and pH, ECe, and SAR at remote sump.
- Both sites had areas of poor vegetation growth.
- PEPS was deployed in June 2013 (T=0).

Sahtu Region, NWT

Remediation goals:

- Re-vegetate bare/stressed areas.
- Reduce surface soil salt levels (ECe and SAR) to Alberta Tier 1 guideline values and/or to allow for sustainable plant growth.
- Reduce PHC levels to adhere to CCME residential/parkland and/or industrial guideline values for fine grain surface soil.

Lease Site – Year 1

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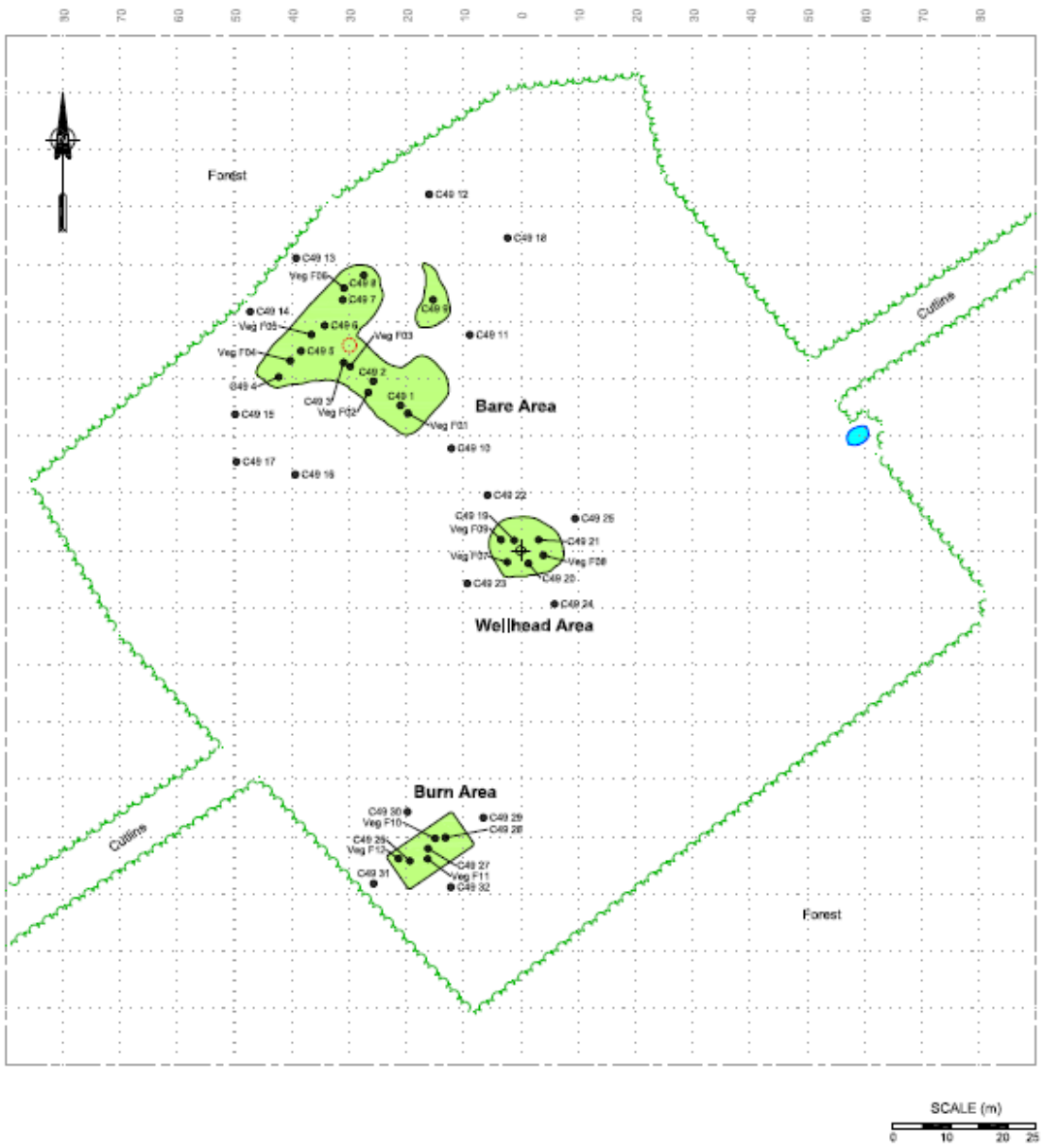
Lease Site – Year 1



Lease Site – Year 1

Lease Site – Year 1

Lease Site – Year 1

Remote Sump Site – Year 1

Remote Sump Site – Year 1

Remote Sump Site – Year 1

Year 1 Summary

- Numerous previous attempts by others to establish vegetation were unsuccessful.
- Plant growth was successfully established on lease site, more work needed on remote sump site.
- Plants were healthy but were heavily grazed by wildlife.
- No significant salt remediation, as expected, in 1st year of PEPS program.
- Good PHC remediation for fractions F2, F3, and F4 was achieved.

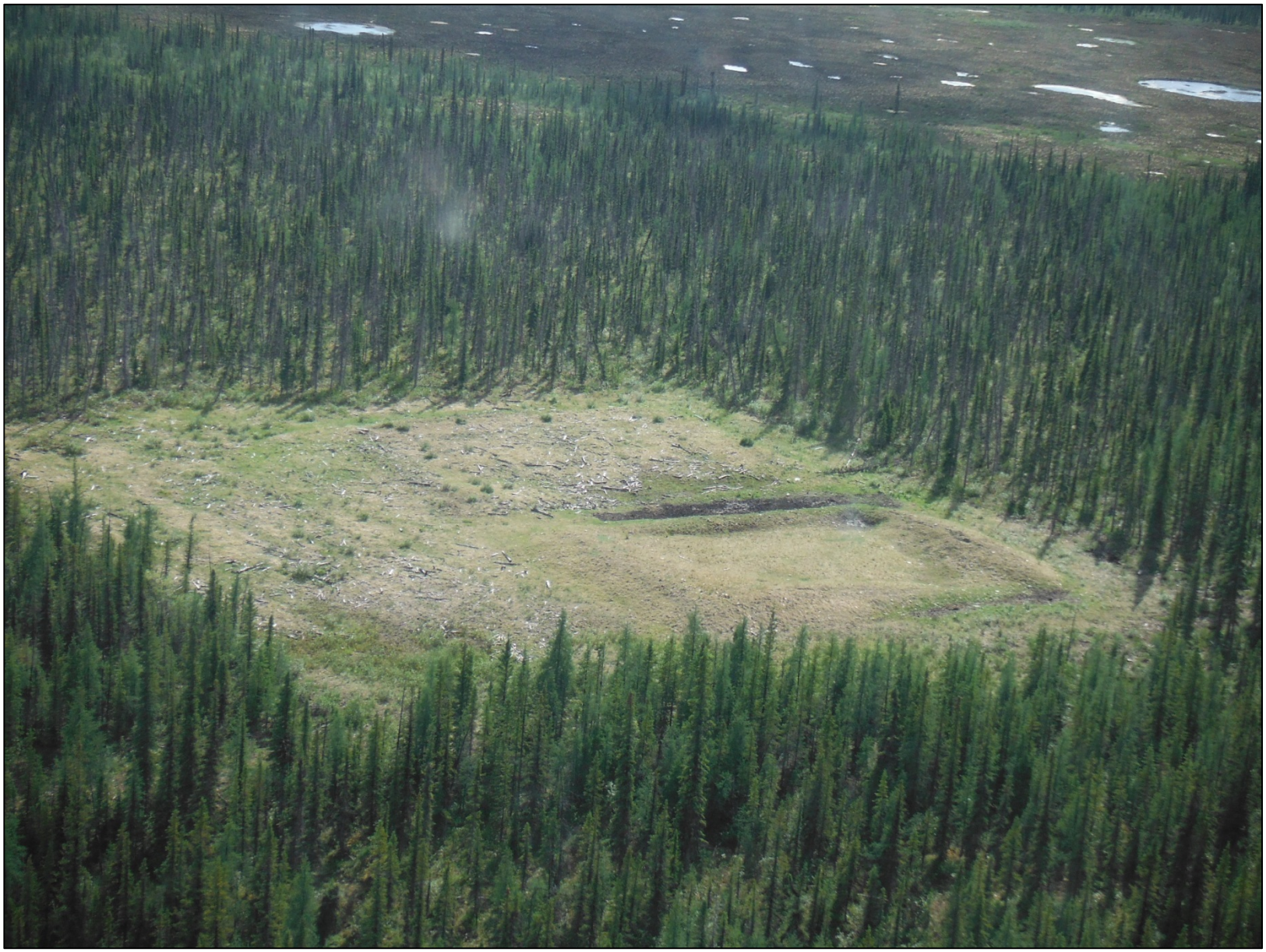
Lease Site – Year 2

Lease Site – Year 2

Lease Site – Year 2

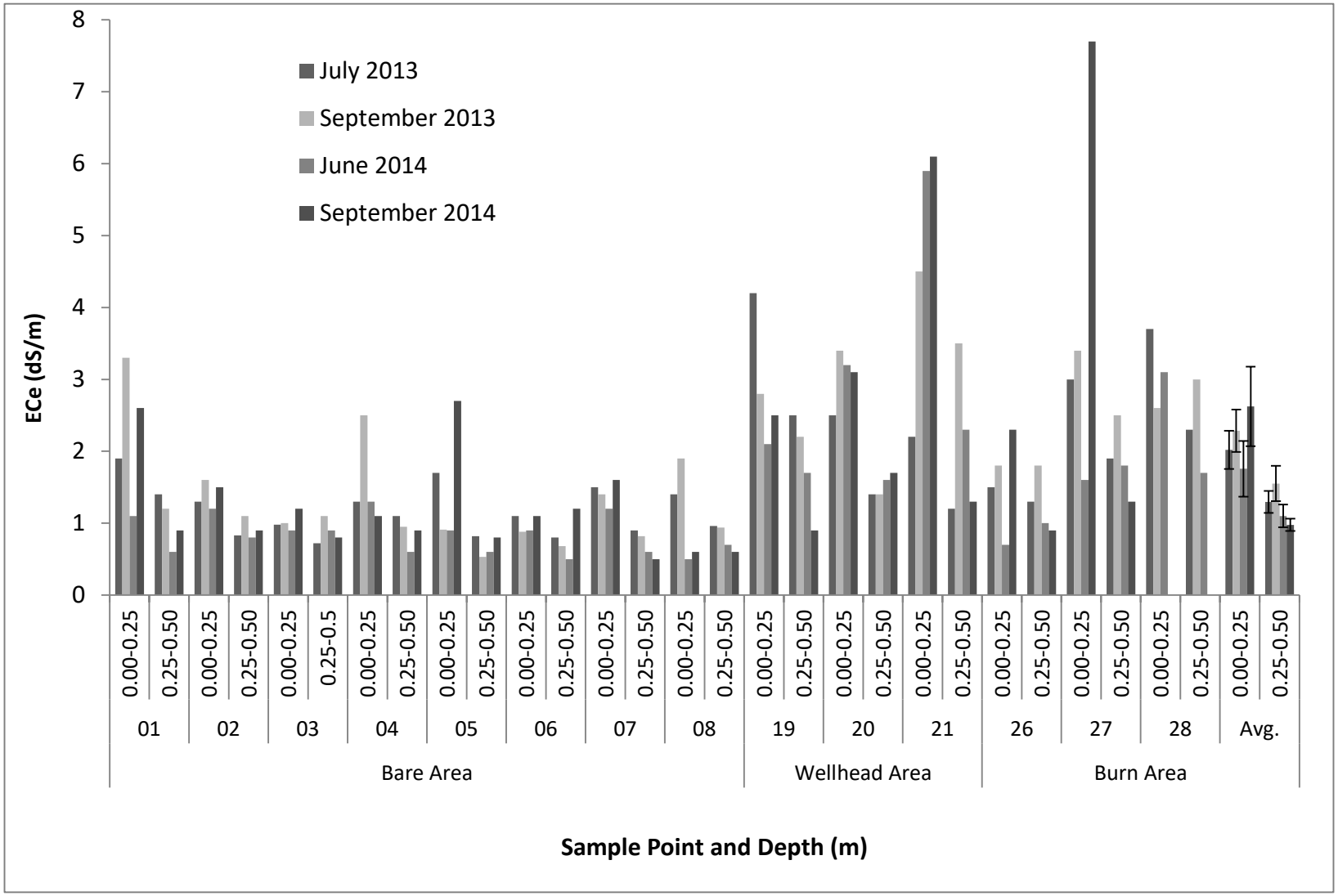
Lease Site – Year 2

Remote Sump Site – Year 2

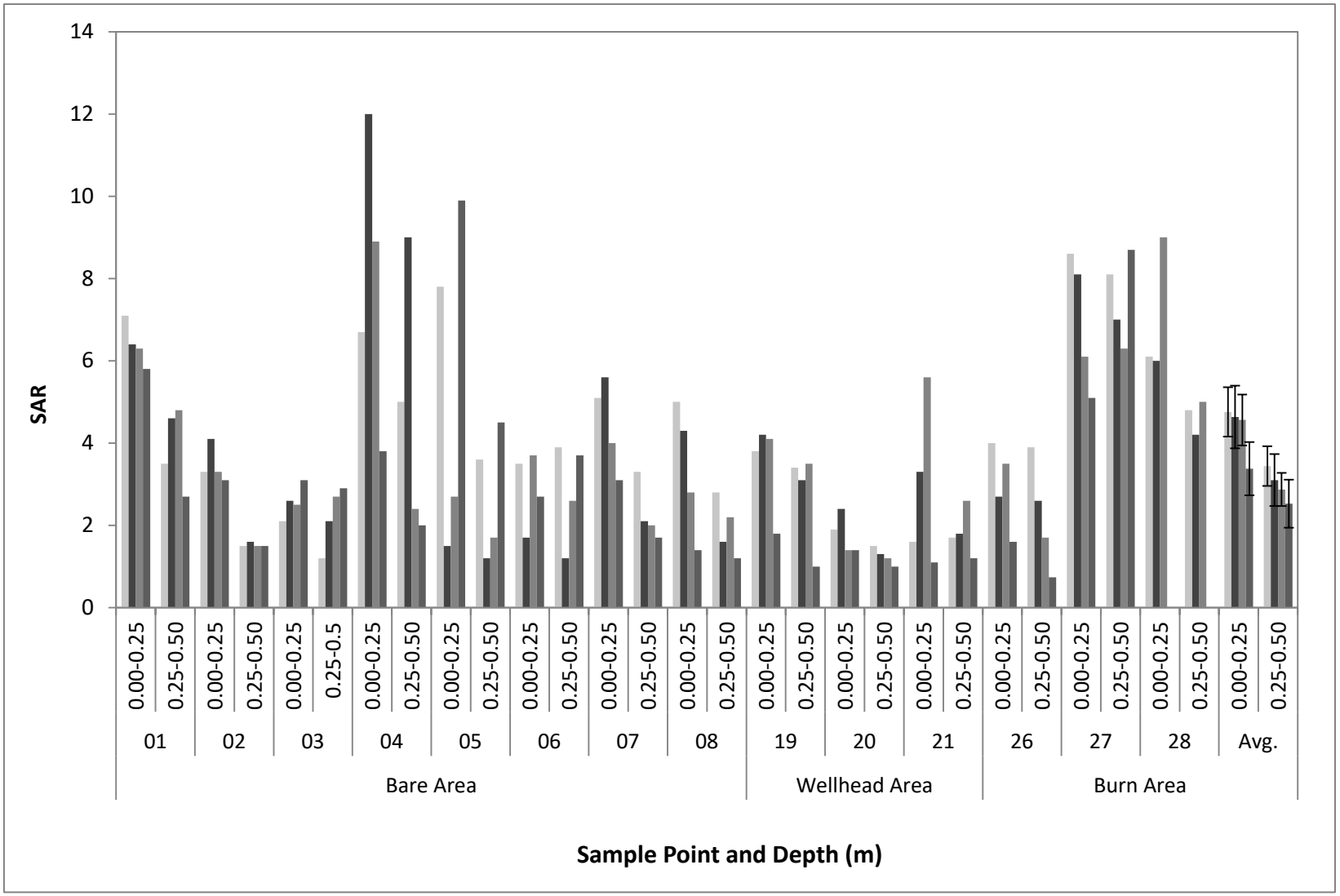


Remote Sump Site – Year 2

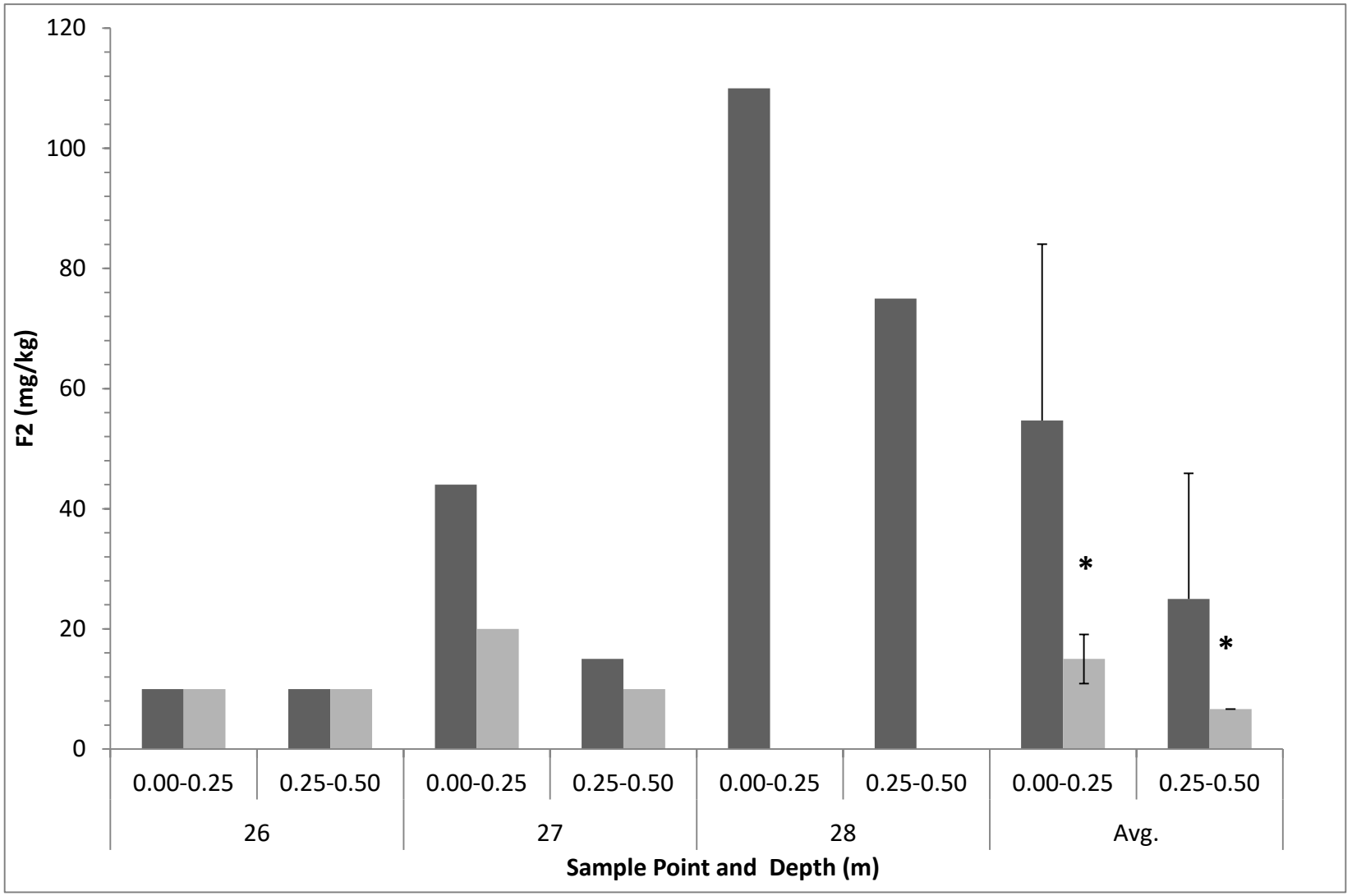
ECe – Lease Site Remediation Progress



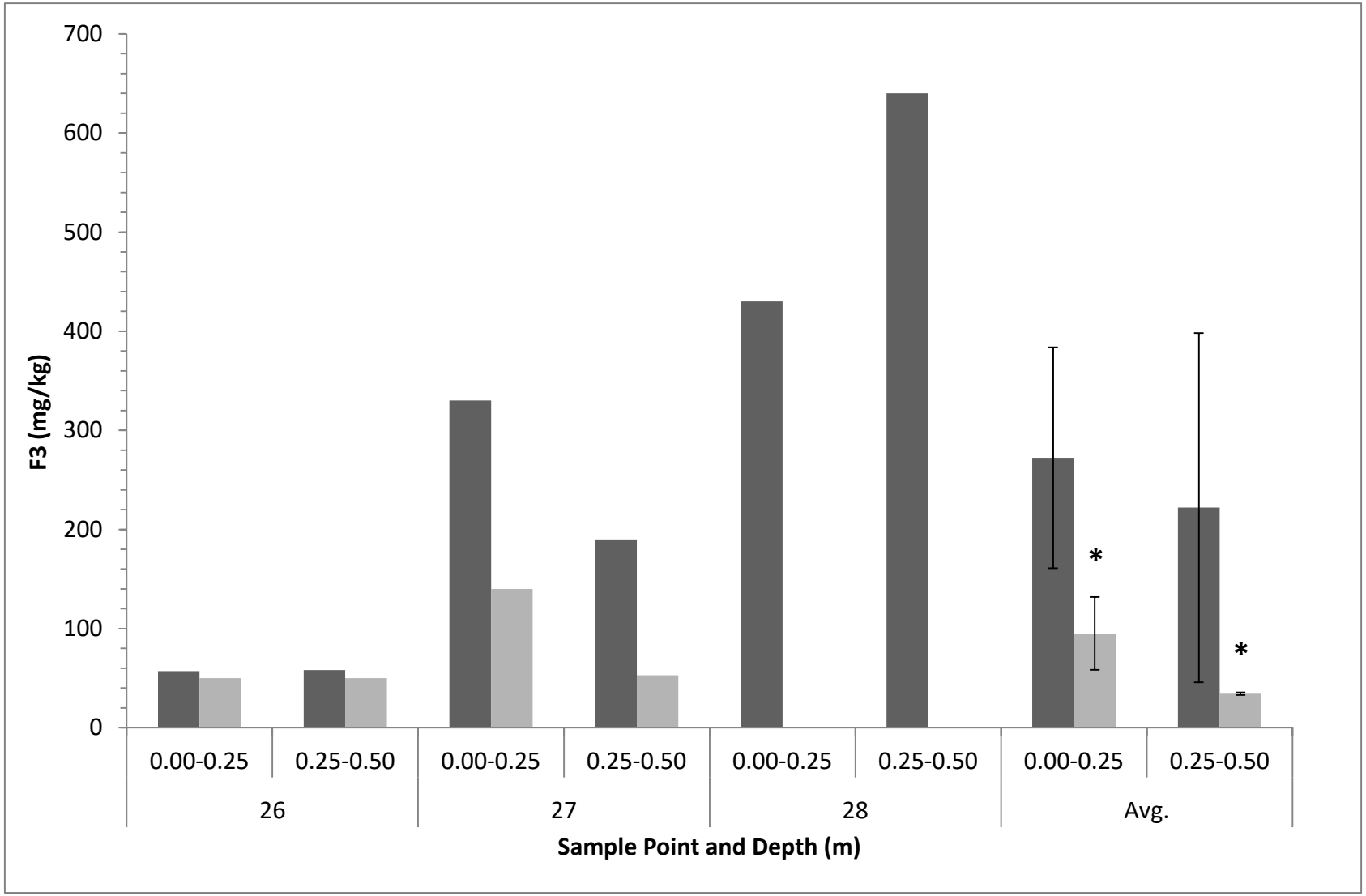
SAR – Lease Site Remediation Progress



F2 – Lease Site Remediation Progress



F3 – Lease Site Remediation Progress

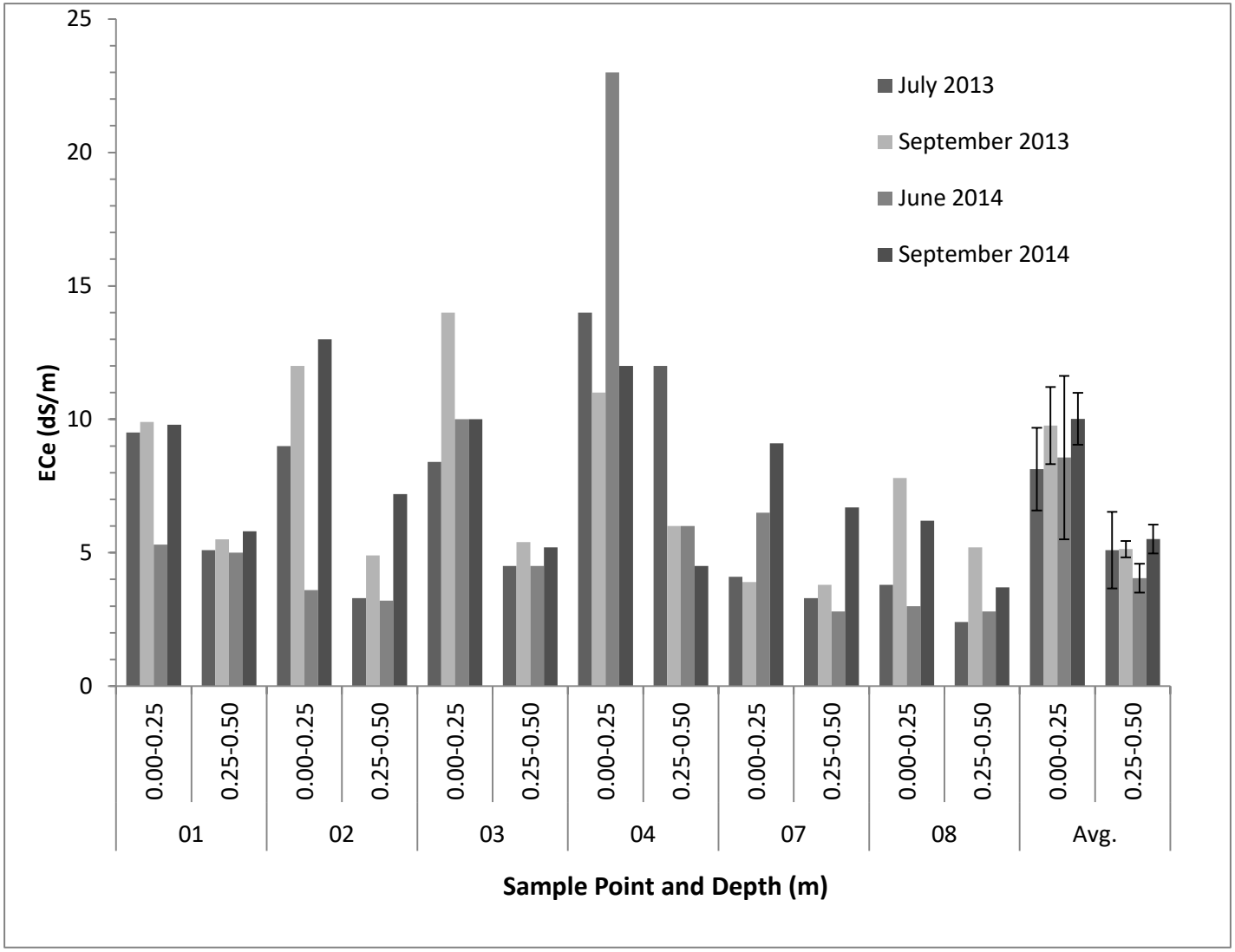


BTEX – Lease Site Remediation Progress

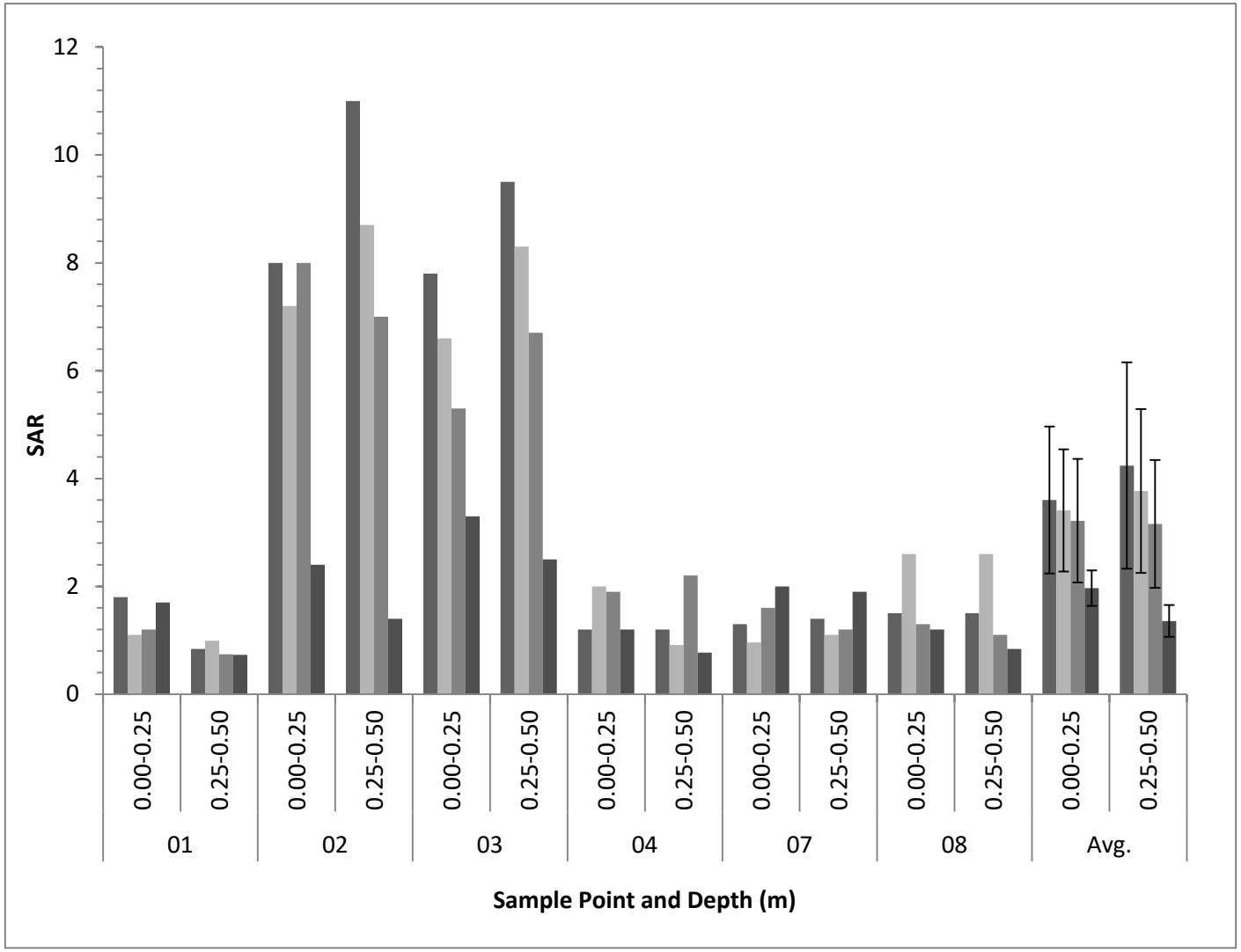
All BTEX concentrations were below guideline values by September 2014.

Sample		Hydrocarbons - mg/kg			
date	depth	benzene	toluene	ethylbenzene	xylenes
Jul-14-13	0.00-0.25	0.021	0.045	0.020	0.16
	0.25-0.50	0.026	0.074	0.080	0.38
	0.50-0.75	0.038	0.110	0.053	0.33
Sep-17-14	0.00-0.25	<0.005	<0.02	<0.01	<0.04
	0.25-0.50	<0.005	<0.02	<0.01	<0.04
	0.50-0.75	<0.005	<0.02	<0.01	<0.04

ECe – Sump Site Remediation Progress



SAR – Sump Site Remediation Progress

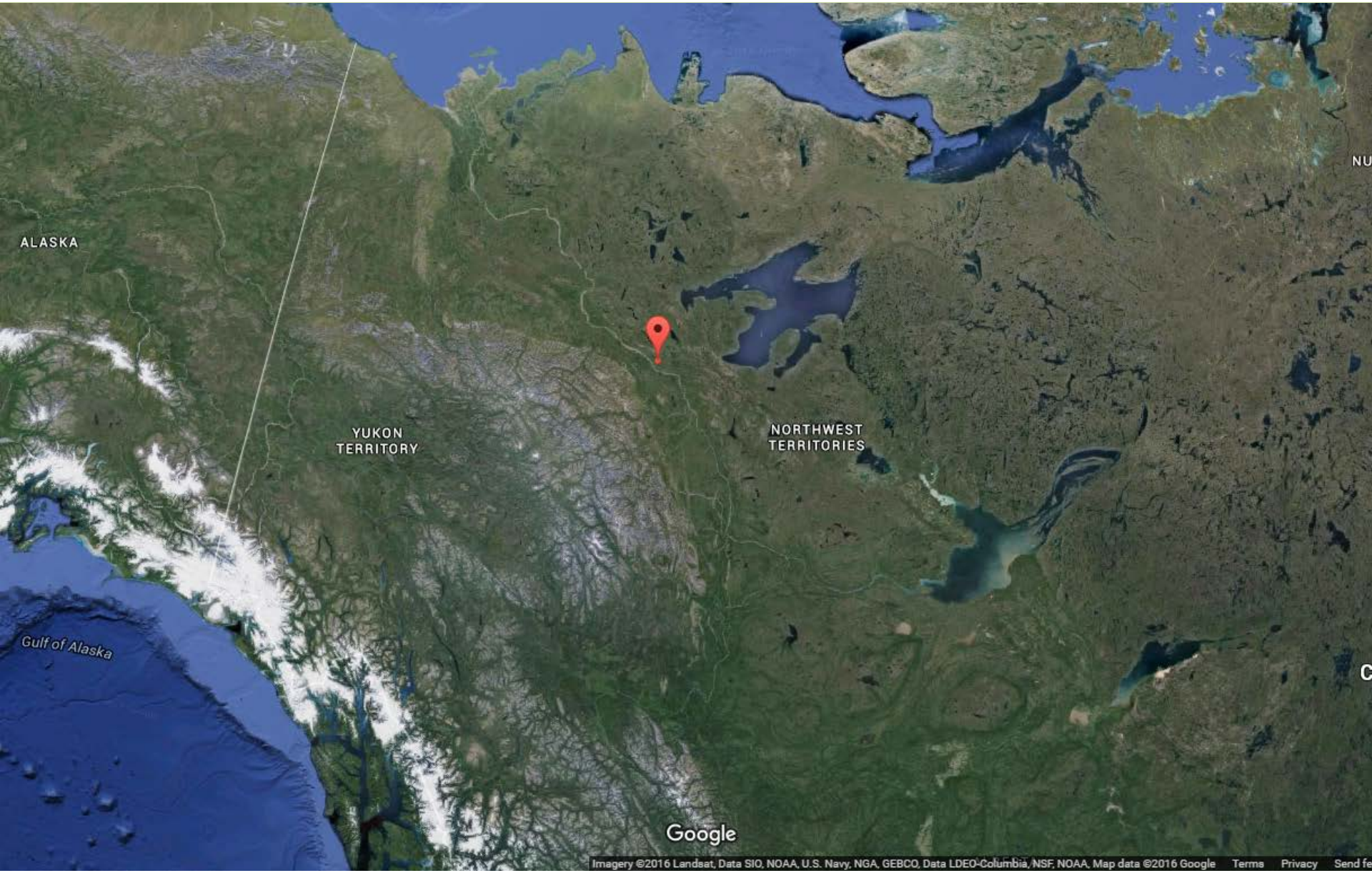


Norman Wells Region, NWT

- Former drill site: located ~30 km southeast of Norman Wells.
- Site contained several sumps and pits.
- Soil contained salts, BTEX, PHC F1 to F4, and metals (Ni and Tl) from drilling activities.
- PEPS deployed to treat surface soil salt in 2008 (Stage 1).
- By the fall of 2010, surface soil salt was remediated to below AB Tier 1 remediation guidelines.

South Site, NWT

- Sumps and pits were excavated in 2011 and a portion of the soil (~2,125 m^3 containing BTEX, PHC F1 to F4, salts, and some metals) was spread over the previously remediated soil (Stage 2).
- PEPS was deployed in 2011 and remediation to applicable remediation guideline values was achieved by the fall of 2013.
- A third lift (~900 m^3 of sump and pit material) was spread on top of the treated soil in 2013 (Stage 3).
- Remediation of PHC fractions F3 and F4 is ongoing. Further impacted material remains onsite for treatment (Stage 4).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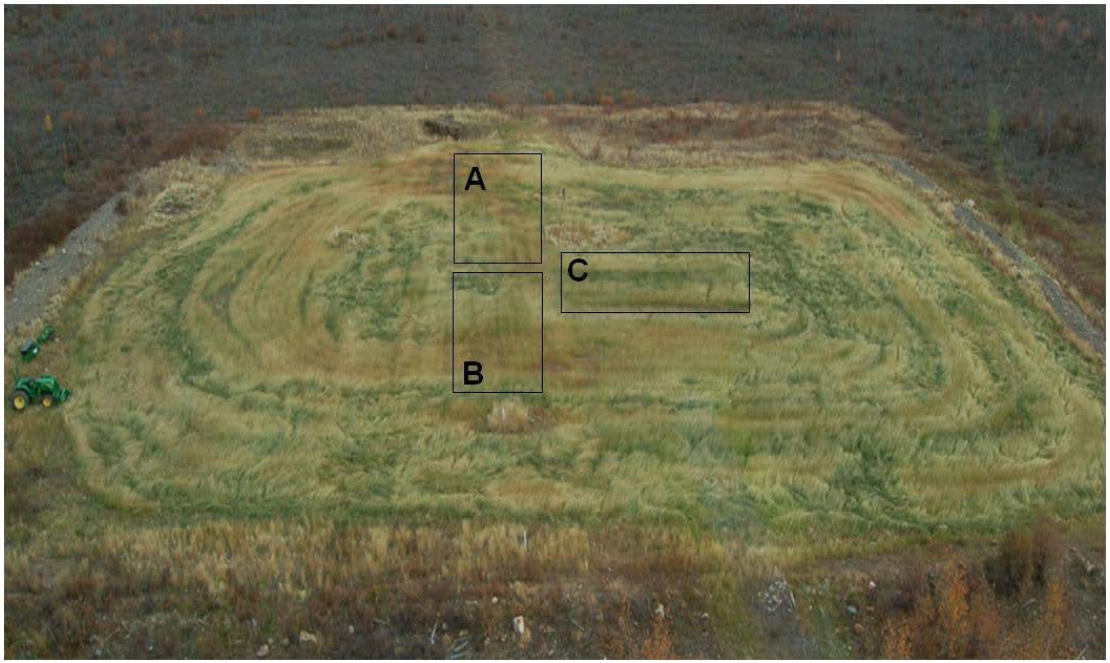
Stage 1: 2008-10

Site prior to PEPS deployment – June 2008

EC average = 10 dS/m

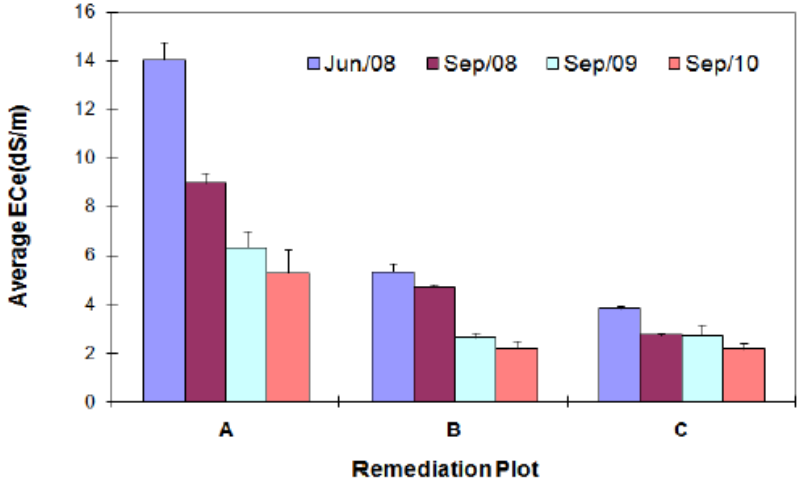
Stage 1: 2008-10

September 2010

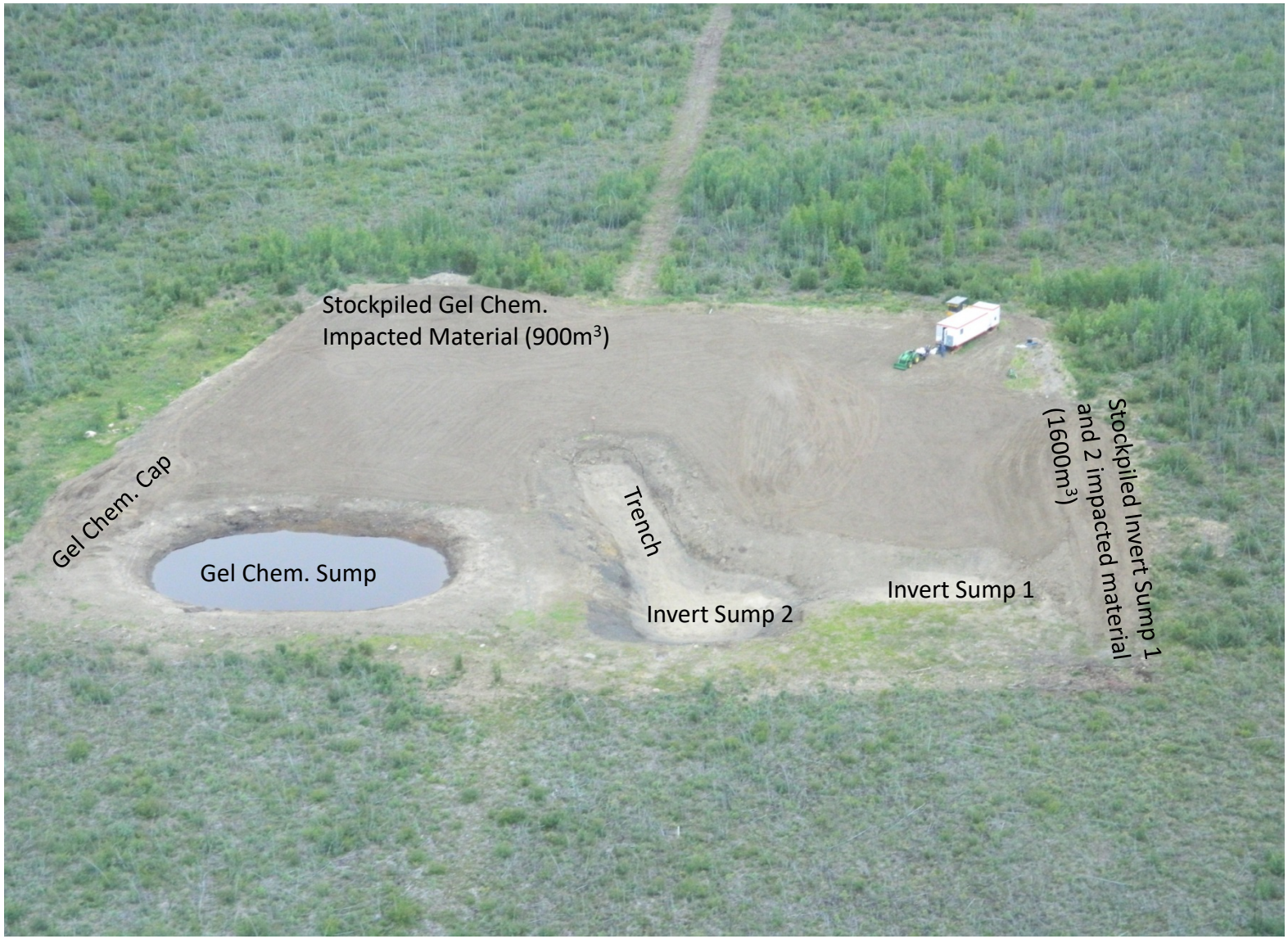


Average EC_e (dS/m)

	2008	2010
Plot A	14.0	5.0
Plot B	5.5	2.0
Plot C	4.0	2.0



Stage 2: 2011-13



July 2011 prior to PEPS deployment

Stage 2: 2011-13

Average values

	July 2011	June 2013	% change
EC dS/m	3.6	2.9	-21
SAR	3.2	1.6	-44
F2 mg/kg	549	84	-84
F3 mg/kg	514	186	-64
F4 mg/kg	70	40	-42

Stage 3: 2013-14

September 2014 – showing mature seed heads of annual ryegrass

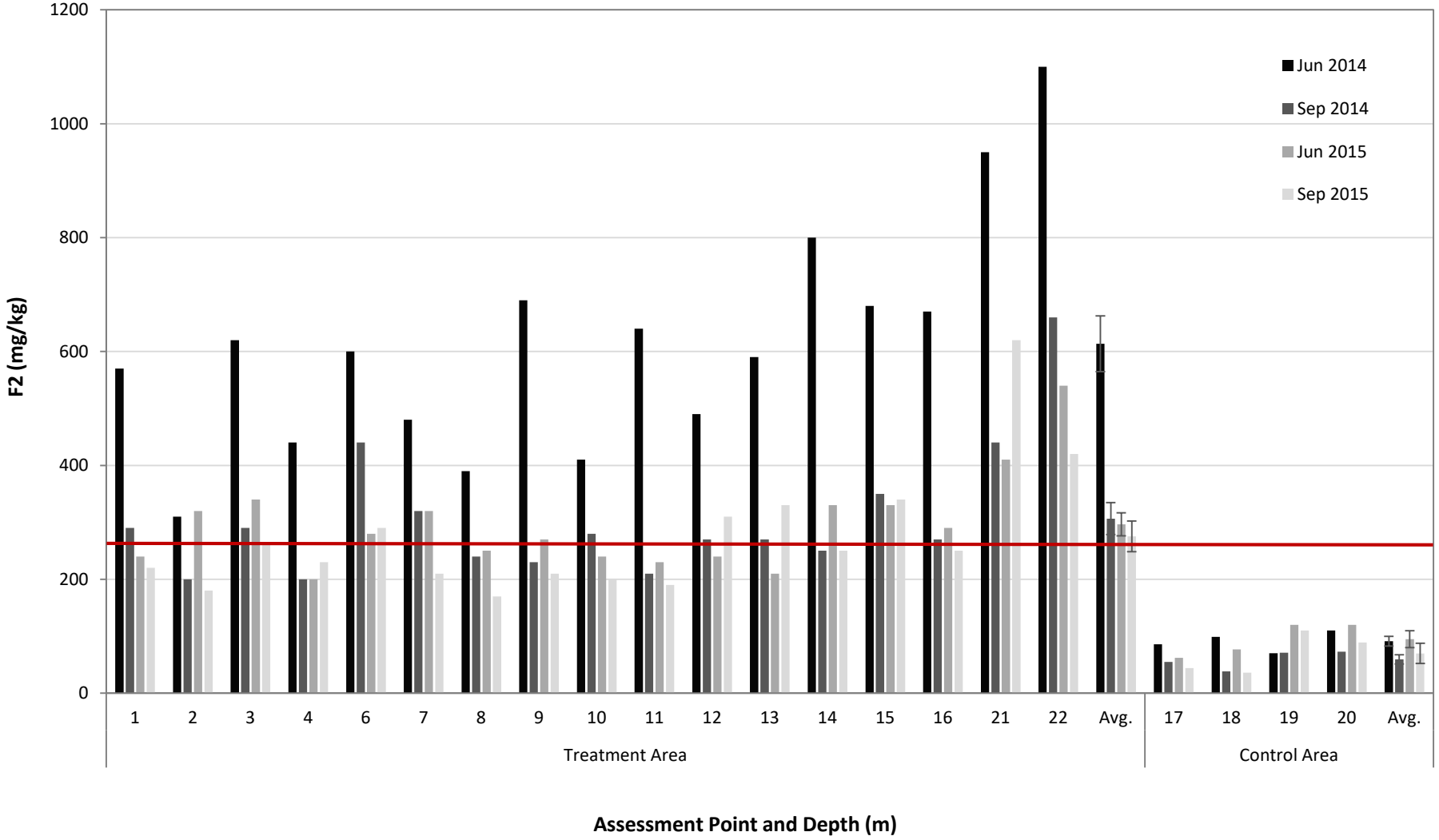
	Sep 2013	Sep 2014	% change
F2 mg/kg	1417	307	-78
F3 mg/kg	694	338	-51
F4 mg/kg	58	49	-16

Stage 4: 2014-15

September 2015 – showing site treatment area growth

	Jun 2014	Sep 2015	% change
F2 mg/kg	614	275	-55
F3 mg/kg	542	413	-24

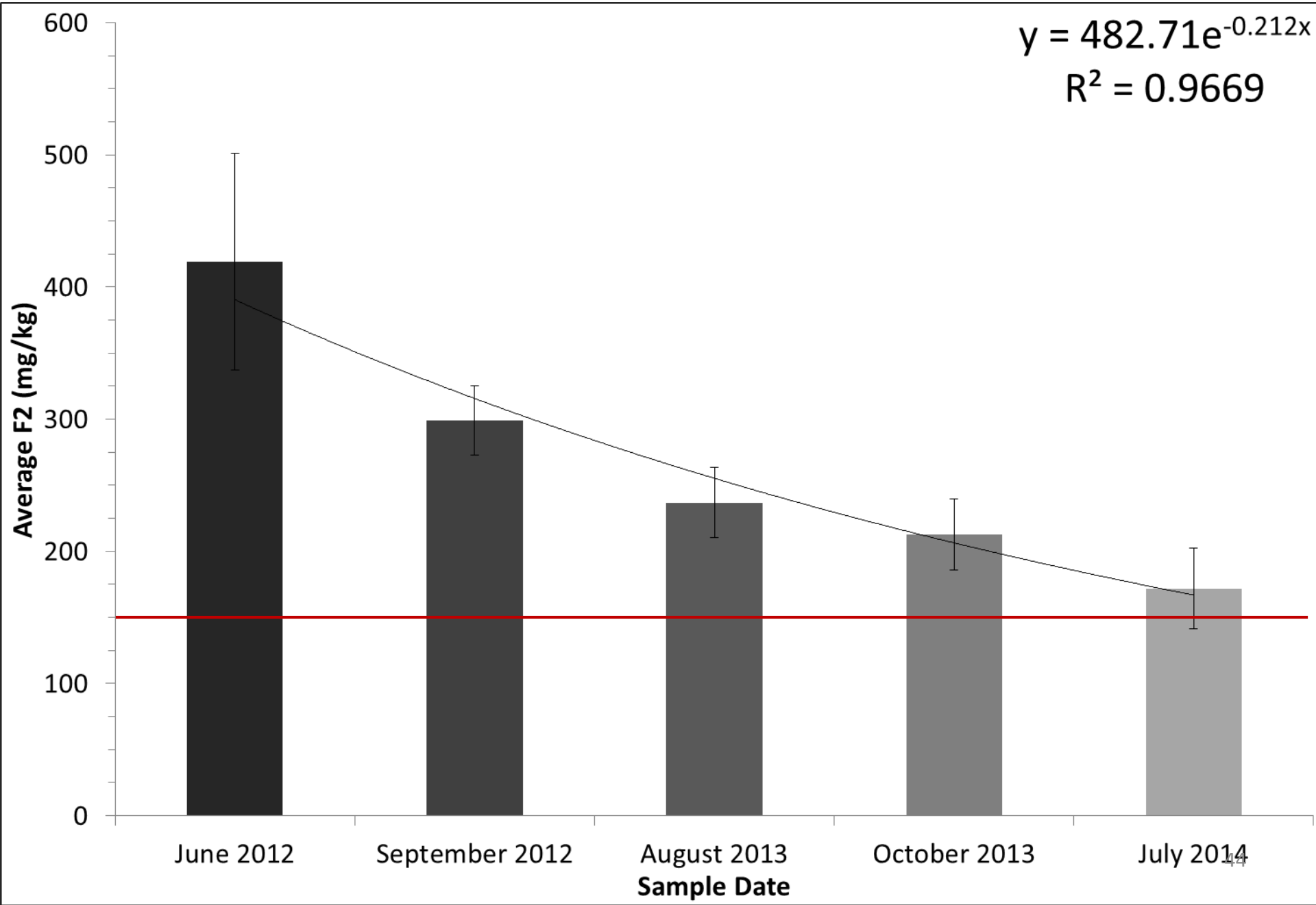
F2 – Lease Site Remediation Progress



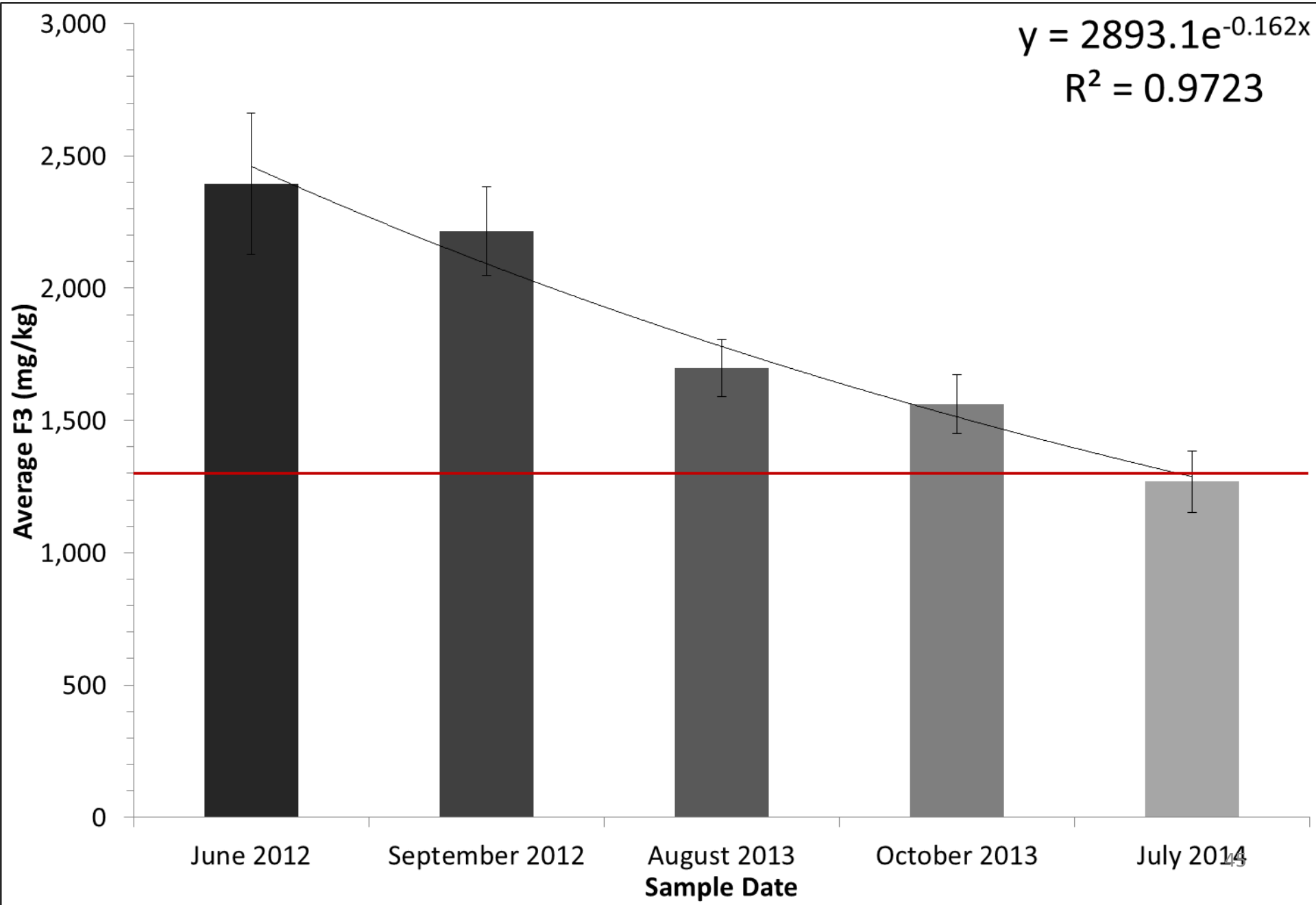
Predictive Modeling

- Model based on data from six phytoremediation sites in Alberta.
- Based on PHC fractions F2 & F3 remediation kinetic data.
- Observed 25-35 % remediation per year for both PHC fractions.
- Indicates continued success in phytoremediation projects.

F2 Remediation Trend



F3 Remediation Trend



Phytoremediation Costs

- PHC F2, F3, and F4, PAH, salt
- The larger the soil volume, the cheaper the unit cost
- $30.00 → $100.00/m³
- Unit costs depend on:
  - Material chemistry and remediation endpoint
  - Site/treatment area conditions
  - Volume of material
  - Geographic location
  - Costs are spread out over multiple years

Phytoremediation Benefits

- GREEN technology
- Soil conservation - eliminates landfilling
- Improved soil quality
- Carbon sink
- Cost effective

Phytoremediation Facts

- 15+ years of research and 10 years full-scale commercial field remediation at > 30 sites
  - 20+ sites completed
- PHC - remediated sites in 7 provinces (since 2004)
- Salt - remediated sites in 4 provinces (since 2007)

Questions?

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