PEPS – Scientifically and Field Proven Phytoremediation Systems for Petroleum and Salt Impacted Soil

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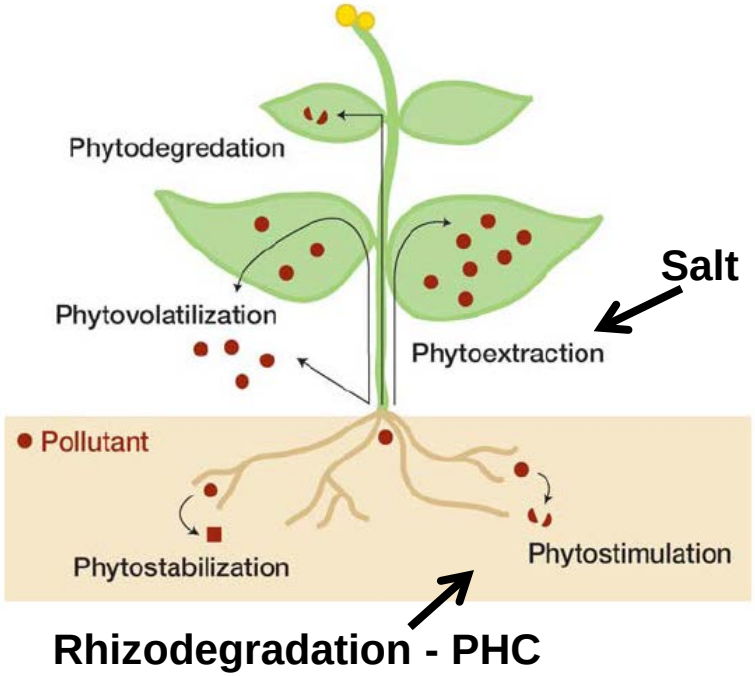
Partners: ConocoPhillips, Lone Pine, Baytex, TransEuro, Shell, Devon, Legacy, Tundra, Enbridge, Seaway Energy Services, NSERC

Presentation Outline

- Phytoremediation
  - What it is
  - How it works
- PEPS phytoremediation systems
  - Science behind PEPS
  - Commercial activities - laboratory and field
- Advantages of PEPS

Phytoremediation

Phytoremediation is the use of plants to extract, degrade, contain and immobilize chemicals, including salt, from the soil.



Rhizosphere processes create contaminant bioavailability

- Plant uptake soil → root
- Translocation: root symplast → xylem
- Chelation/compartment in leaves or roots

Phytoremediation

- One of the remedial techniques for treatment of contaminated soils
  - Dig and dump
  - Soil washing/flushing
  - Thermal desorption
  - Oxidation
  - Conventional Bioremediation (i.e. landfarming)
  - **Phytoremediation**

PEPS - **P**lant growth promoting rhizobacteria (PGPR) **E**nhanced **P**hytoremediation **S**ystems

- PGPR applied to seeds prior to planting
- PGPR – natural, non-pathogenic strains; usually Pseudomonads
- Isolate PGPR from all soils (ON, AB, SK, NWT)
- Not bioaugmentation

Science Experience Results

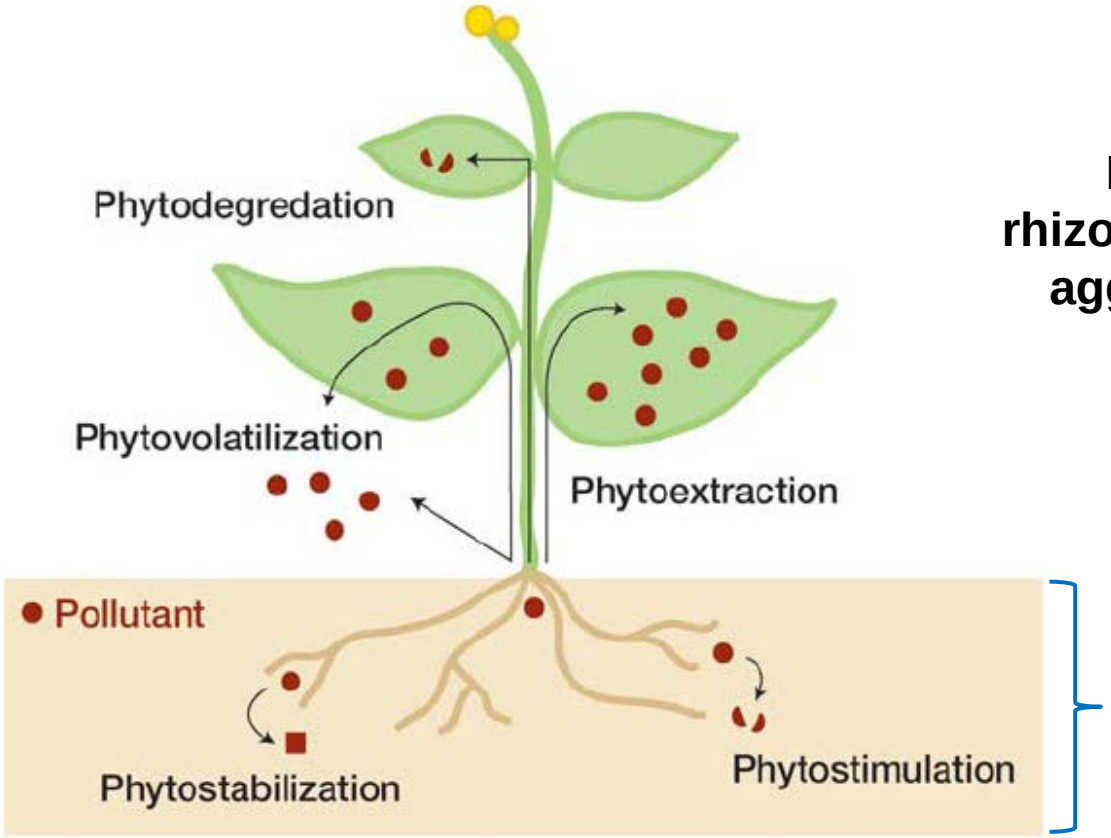
PEPS

- Thirteen years of lab and field research
- Full scale commercial remediation for >7 years
- Successfully deployed at >30 sites
  - 10+ sites remediated
  - PHC in AB, BC, MB, NWT, QC and ON
  - Salt sites in SK, AB, MB and NWT
- Research to continually improve the systems

Science Experience Results

The Science Behind PEPS

PEPS



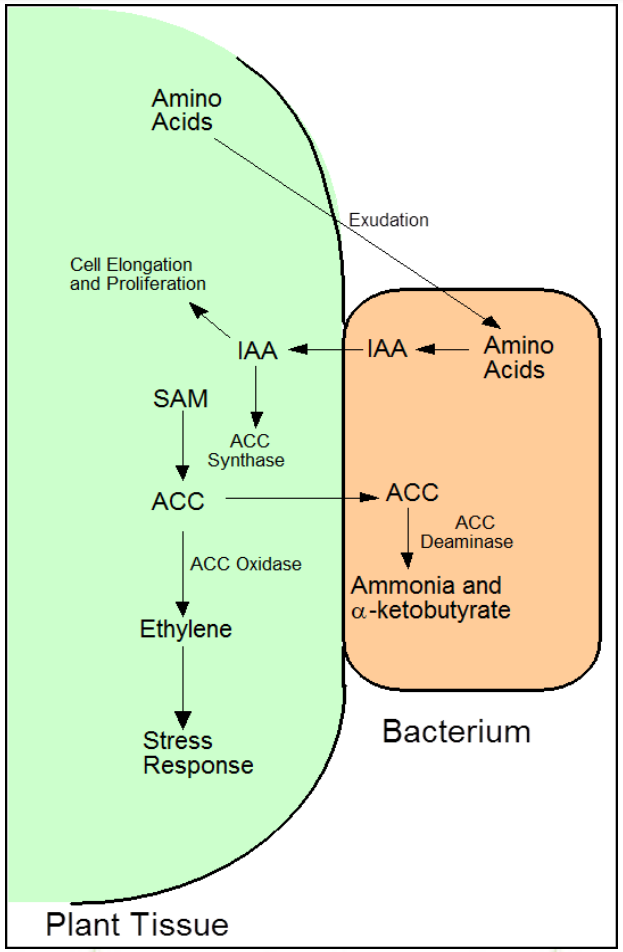
PEPS improves the rhizosphere which results in aggressive plant growth

Remediation

Rhizosphere consists of:

- Soil
- Organic matter
- Bacteria
- Water
- Roots
- Contaminants

Interaction of a PGPR Containing ACC Deaminase with a Root



Stress ethylene

Plant vigor

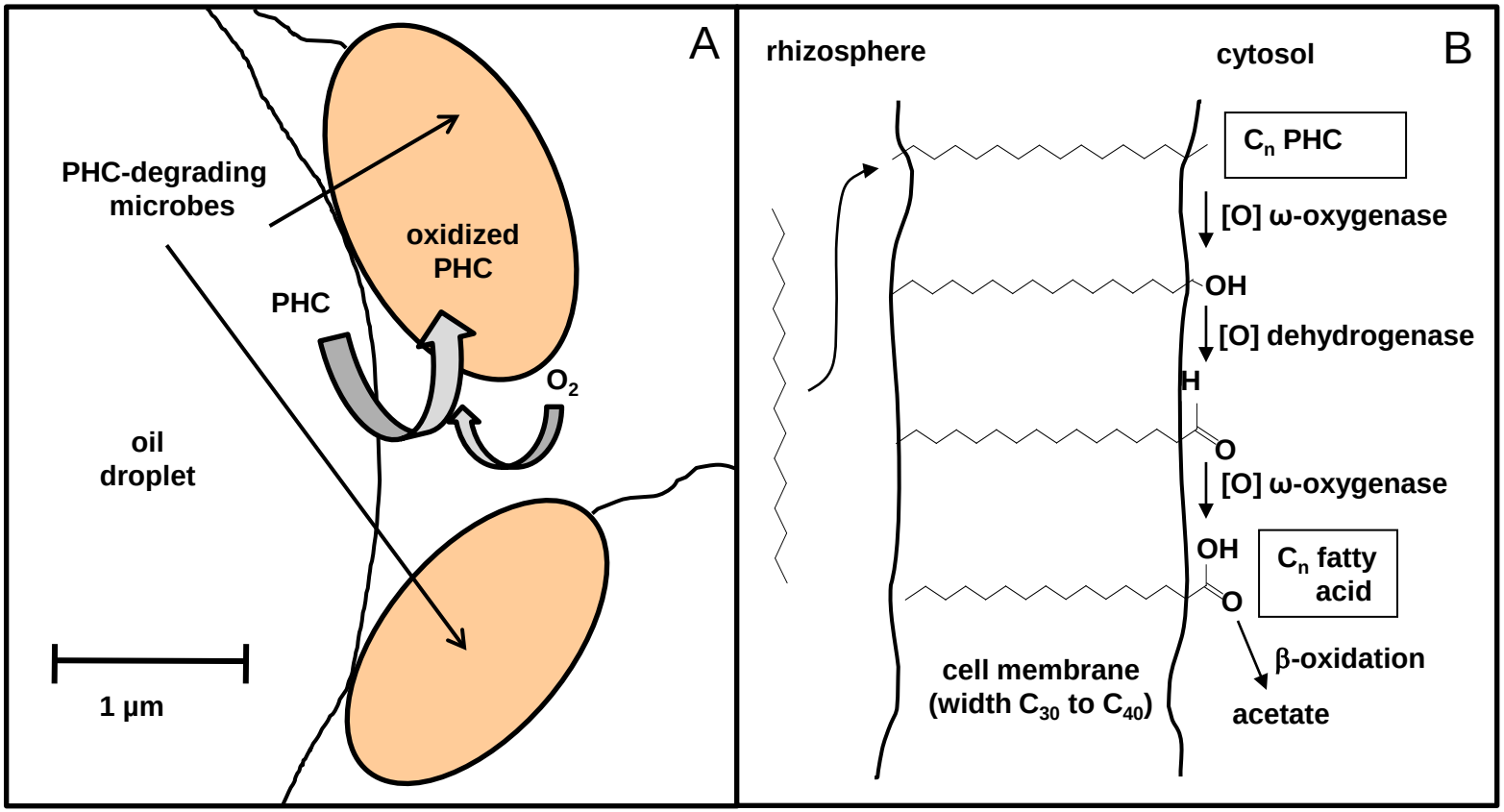
Root development

Rhizobacteria → Consumption of PHC

Leaves → Salt and metals uptake

- Active rhizosphere
- Partitioning of contaminants

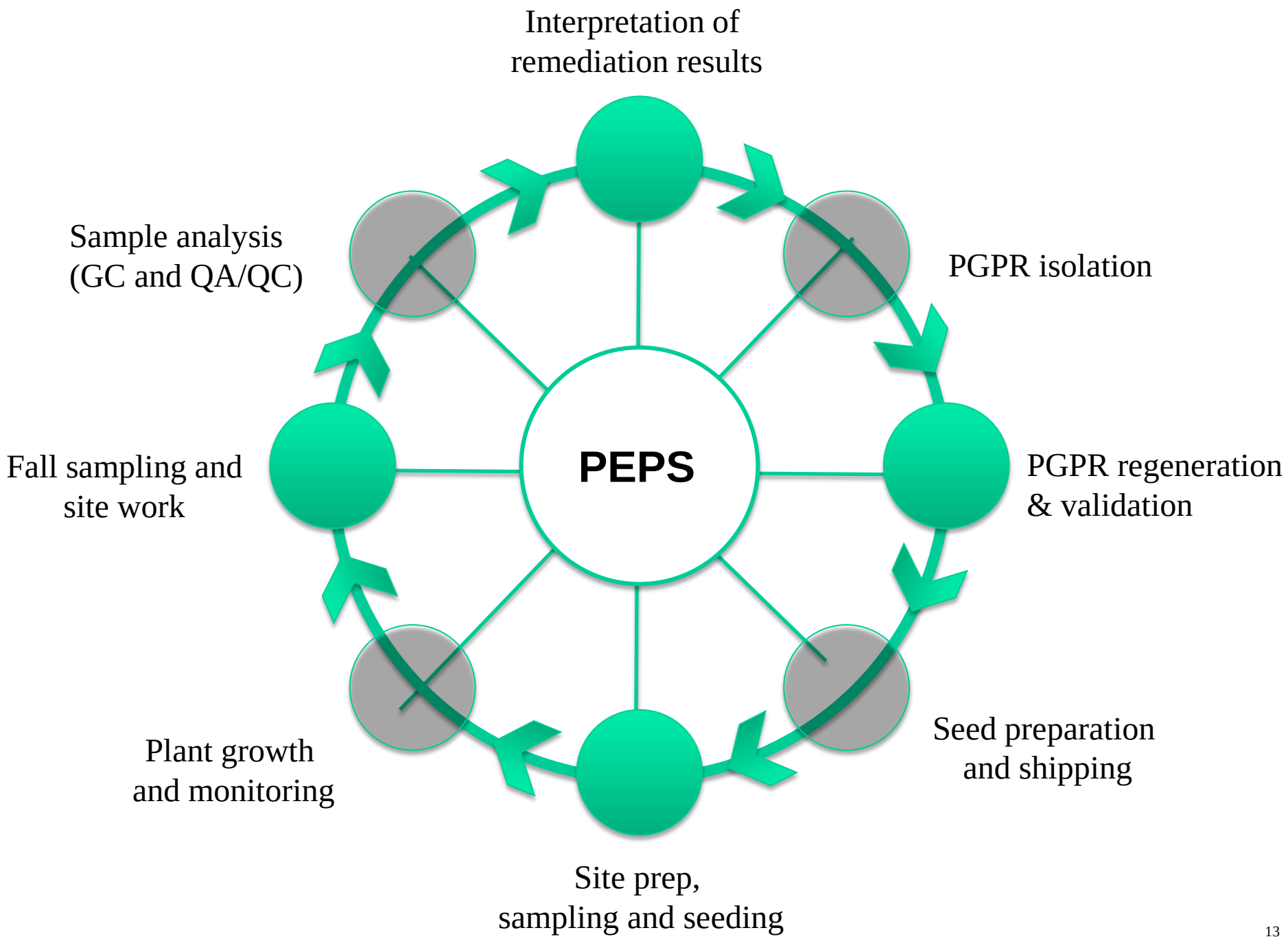
PHC Metabolism

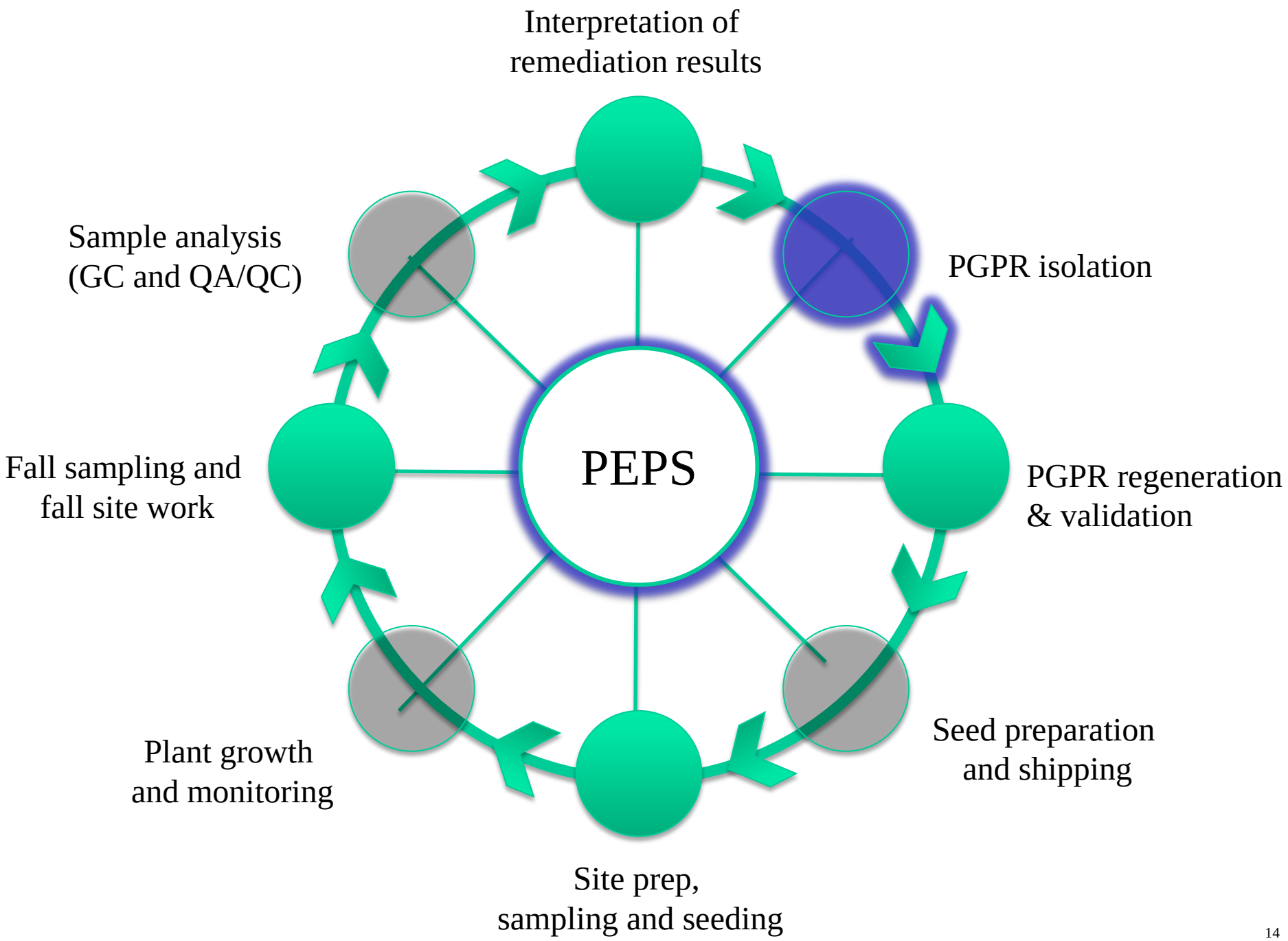


PEPS Performance

- PEPS creates abundant plant shoot and root growth
- Greater than 2X more plant biomass due to PGPR
- Very healthy rhizosphere – microbe level 10-100X greater
- Effective partitioning of contaminants
- PHC degraded in the soil
- PHC remediation - 30 to 40% per year
- Salt uptake – 0.5 – 1.5 dS/m per year

Commercial Projects
Laboratory and Field


Interpretation of remediation results
PGPR isolation
PGPR regeneration & validation
Seed preparation and shipping
Site prep, sampling and seeding
Plant growth and monitoring
Fall sampling and site work
Sample analysis (GC and QA/QC)
PEPS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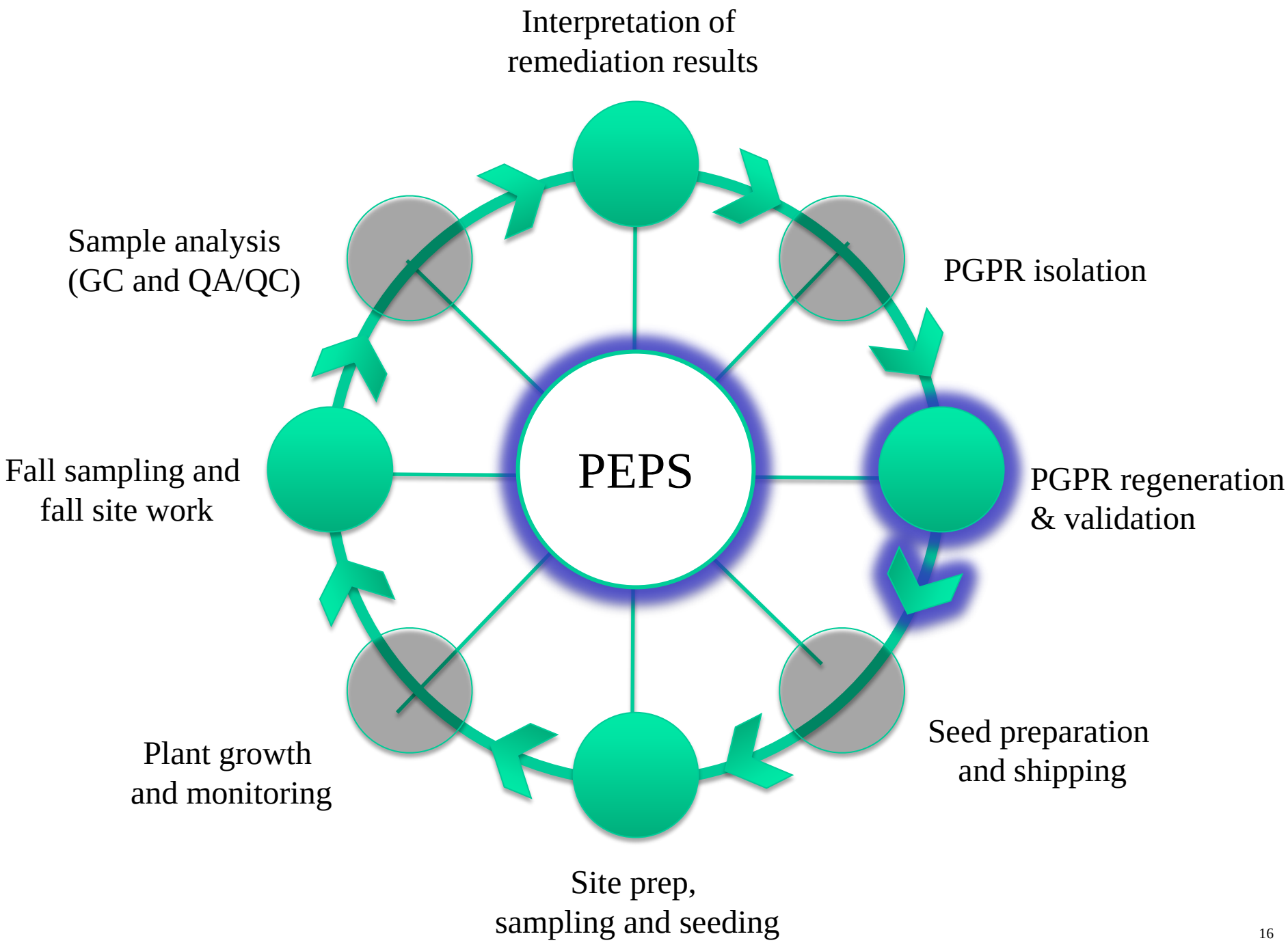
PGPR Isolation

- Naturally occurring
- Isolated from site rhizospheres – adapted to impacted soils
- Continually isolating new strains
- DNA sequencing to identify them
- Biosafety Level I
- Non-GMO
- Currently have >10 strains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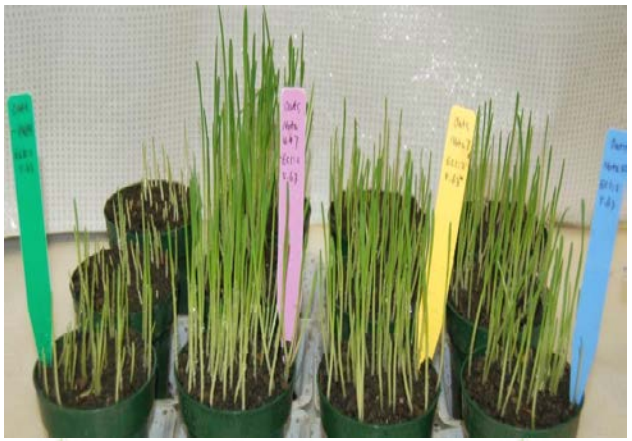
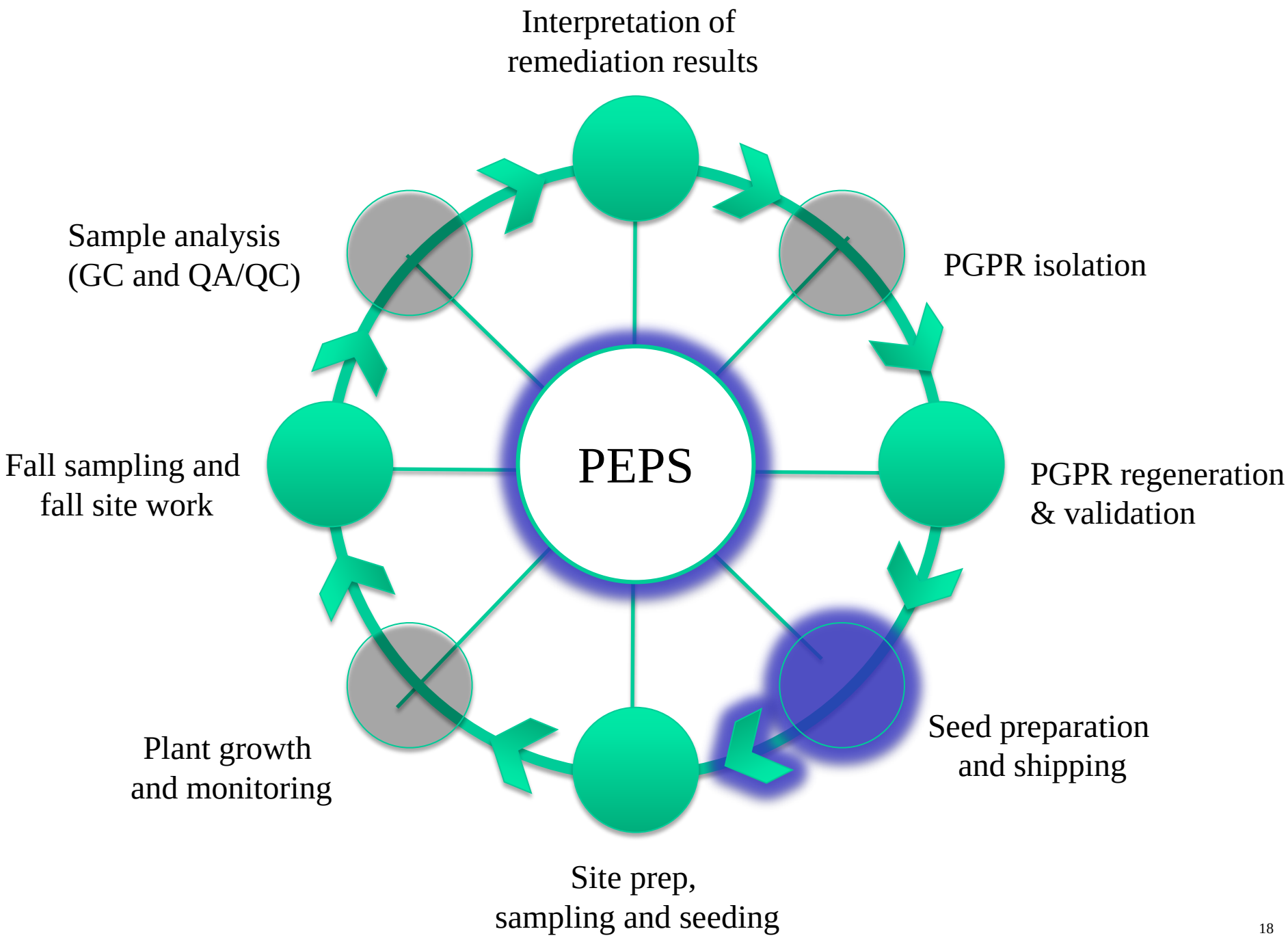
PGPR Regeneration & Validation



- Regenerate proven PGPR isolates for field use
- Confirm PGPR are healthy and retain key biological activities
- Assay for ACC deaminase
- Assay for auxin production
- Assay for plant growth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Seed Treating

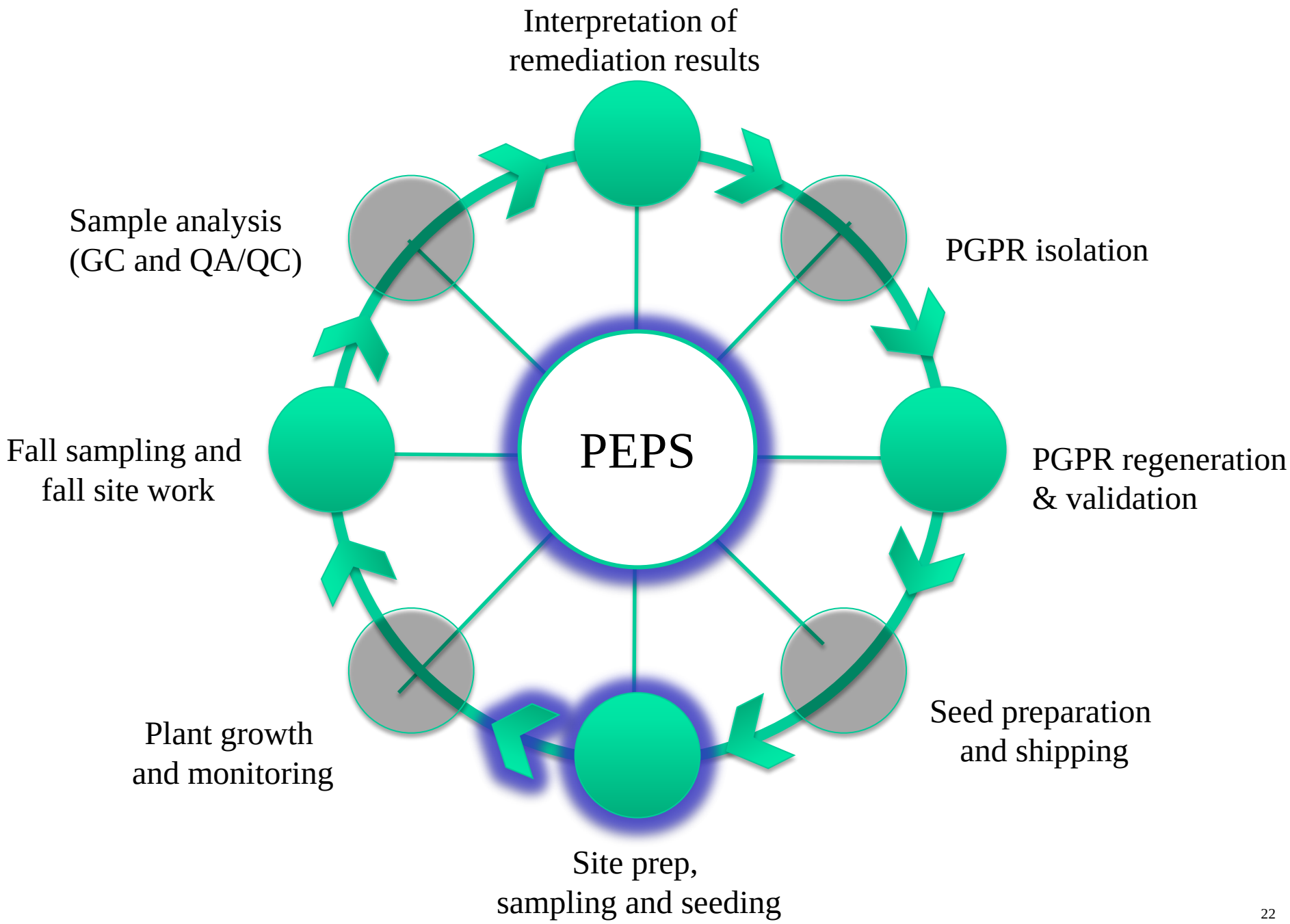
- Treat seeds with proven and regenerated PGPR
- Only proven grass and cereal species are used
- Mechanical seed treater efficiently and evenly coats the seeds

PGPR Seed Treatment QA/QC

- Aliquots of PGPR-treated seeds assayed for plant growth enhancement

Shipment

- Treated seeds shipped to sites after QA/QC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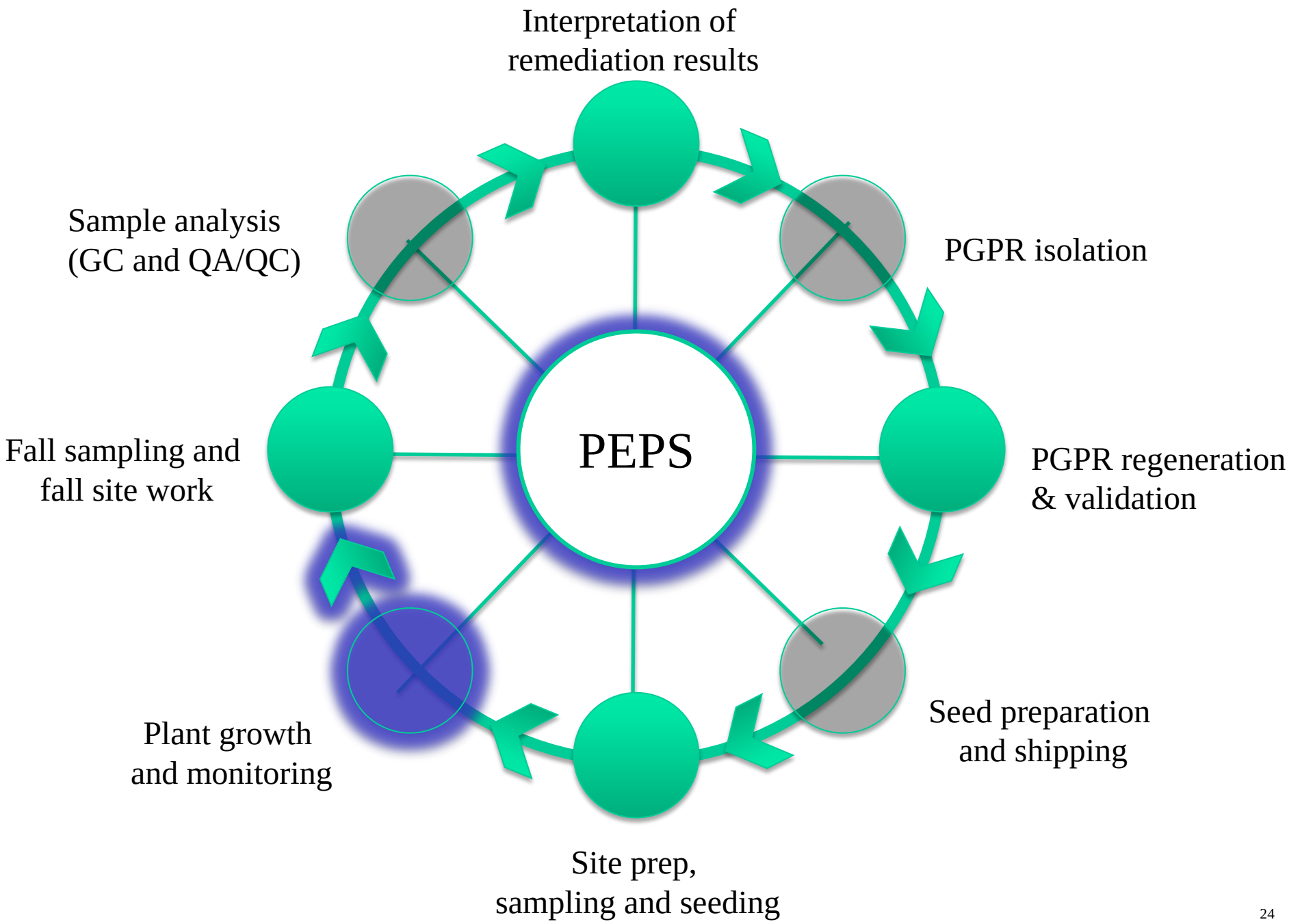
Compacted Clay Liner Construction

Seed Bed Preparation & Amendment Application

Sampling

Sow PGPR-treated Seed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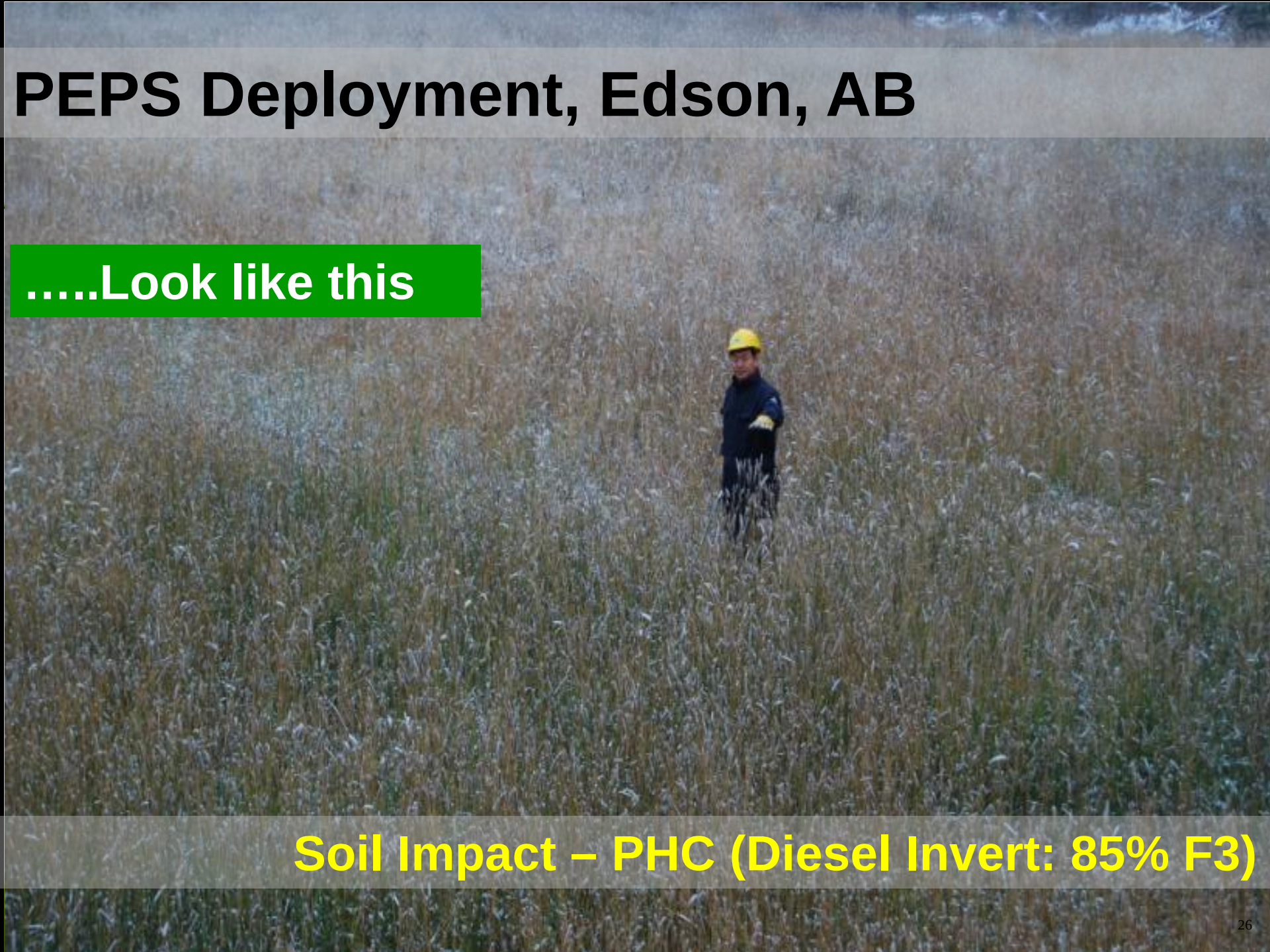
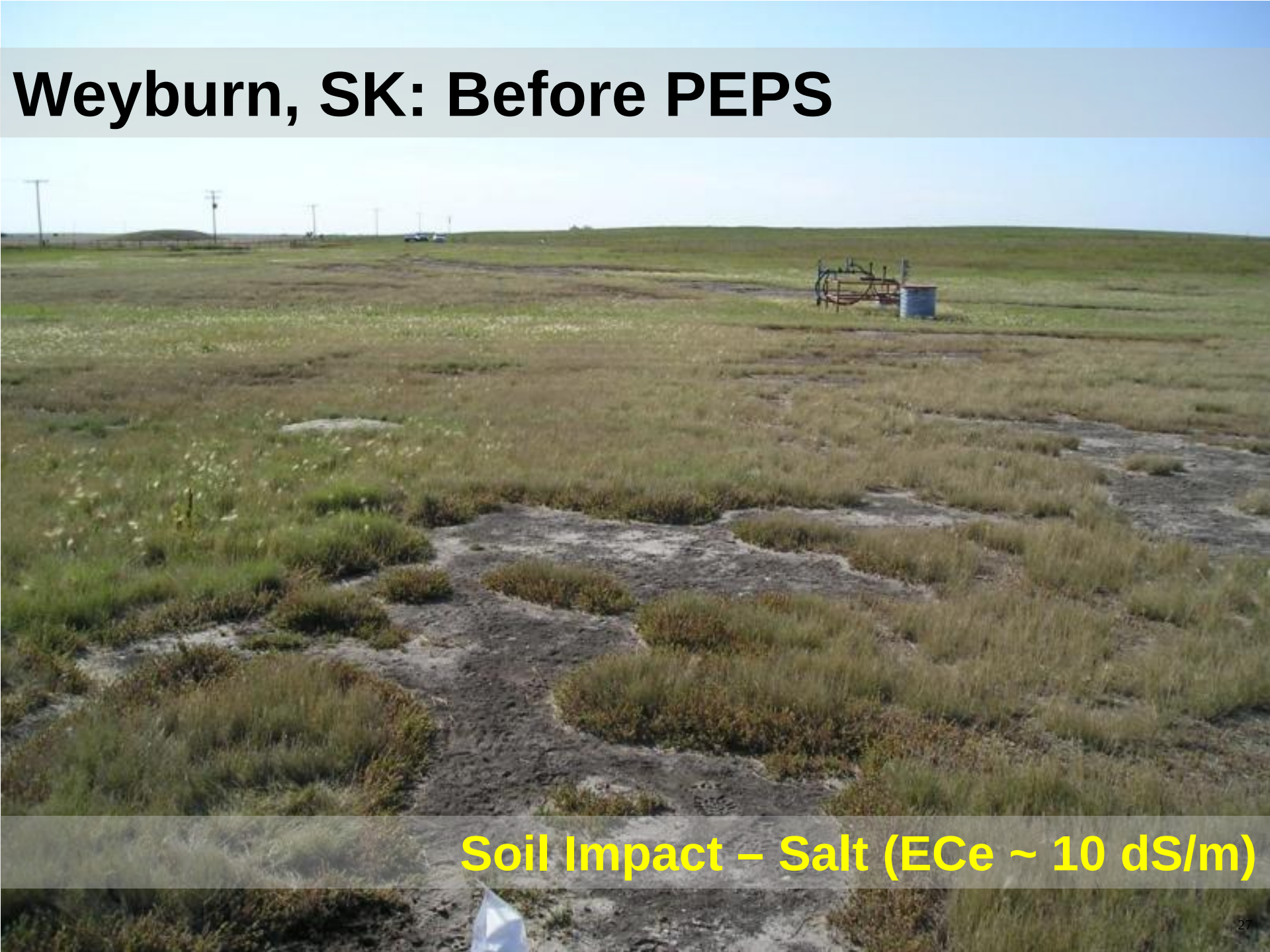
Edson, AB – Before site prep and seeding

PEPS Deployment, Edson, AB

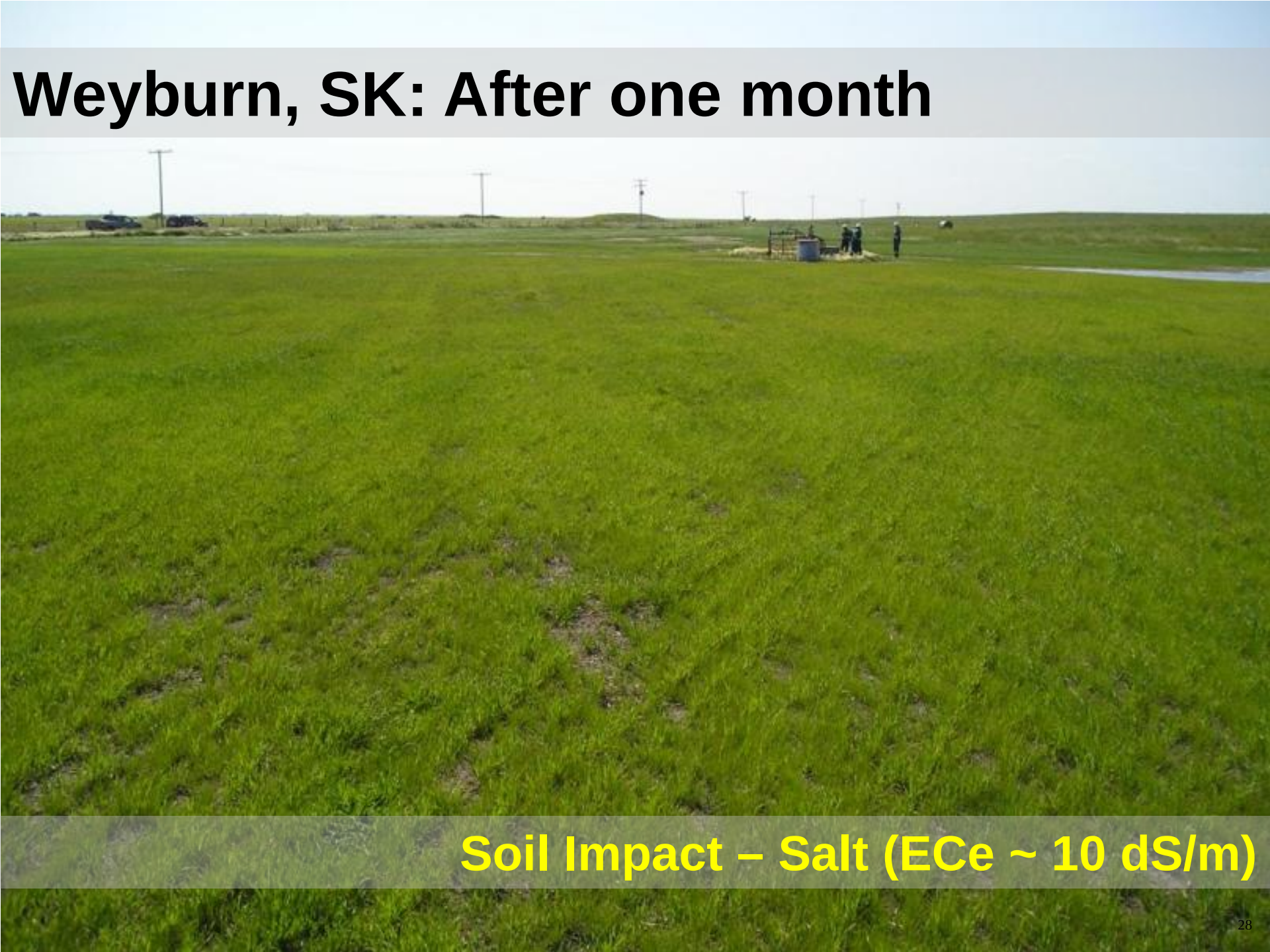


Weyburn, SK: Before PEPS



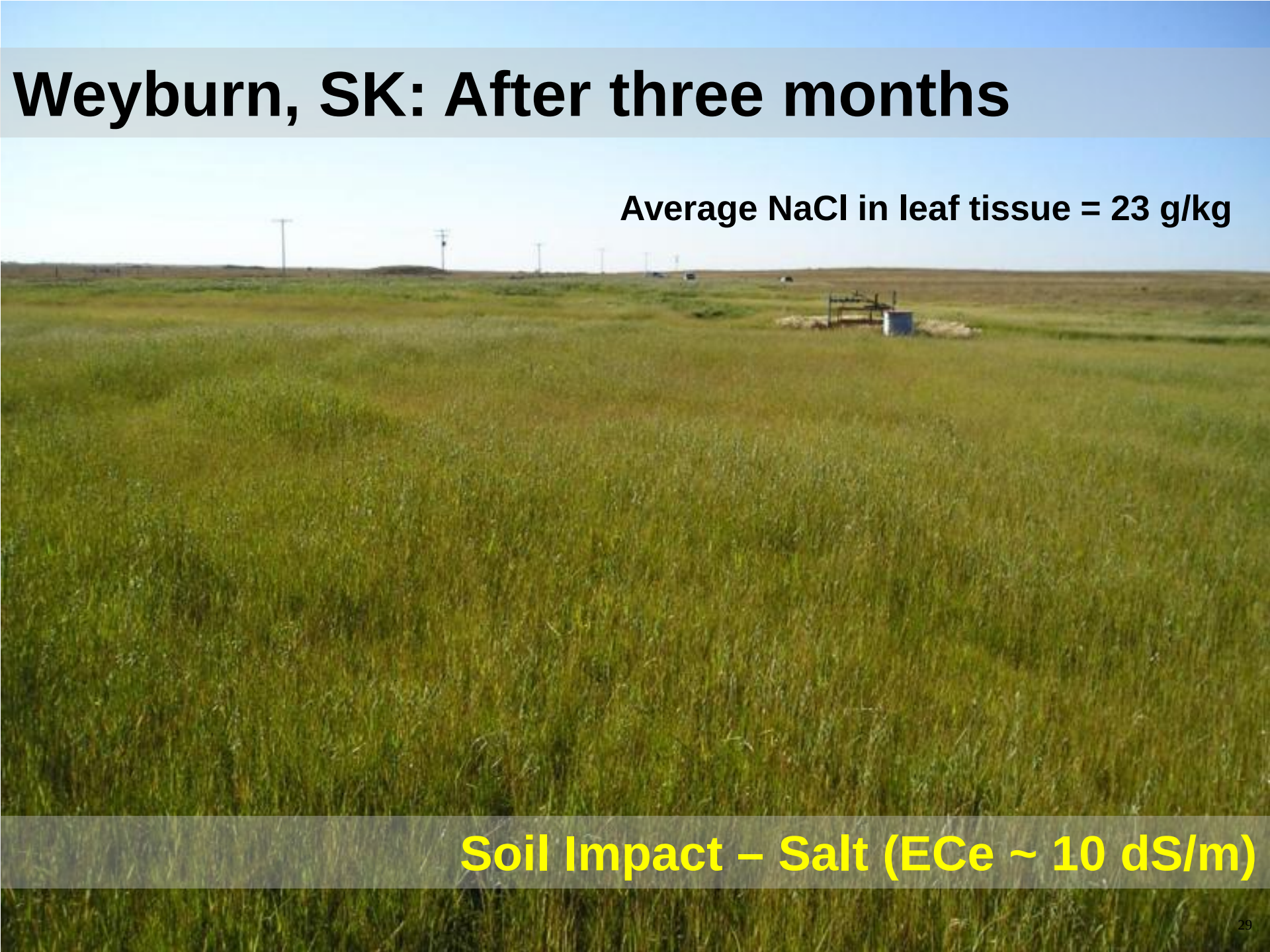
Soil Impact – Salt (ECe ~ 10 dS/m)

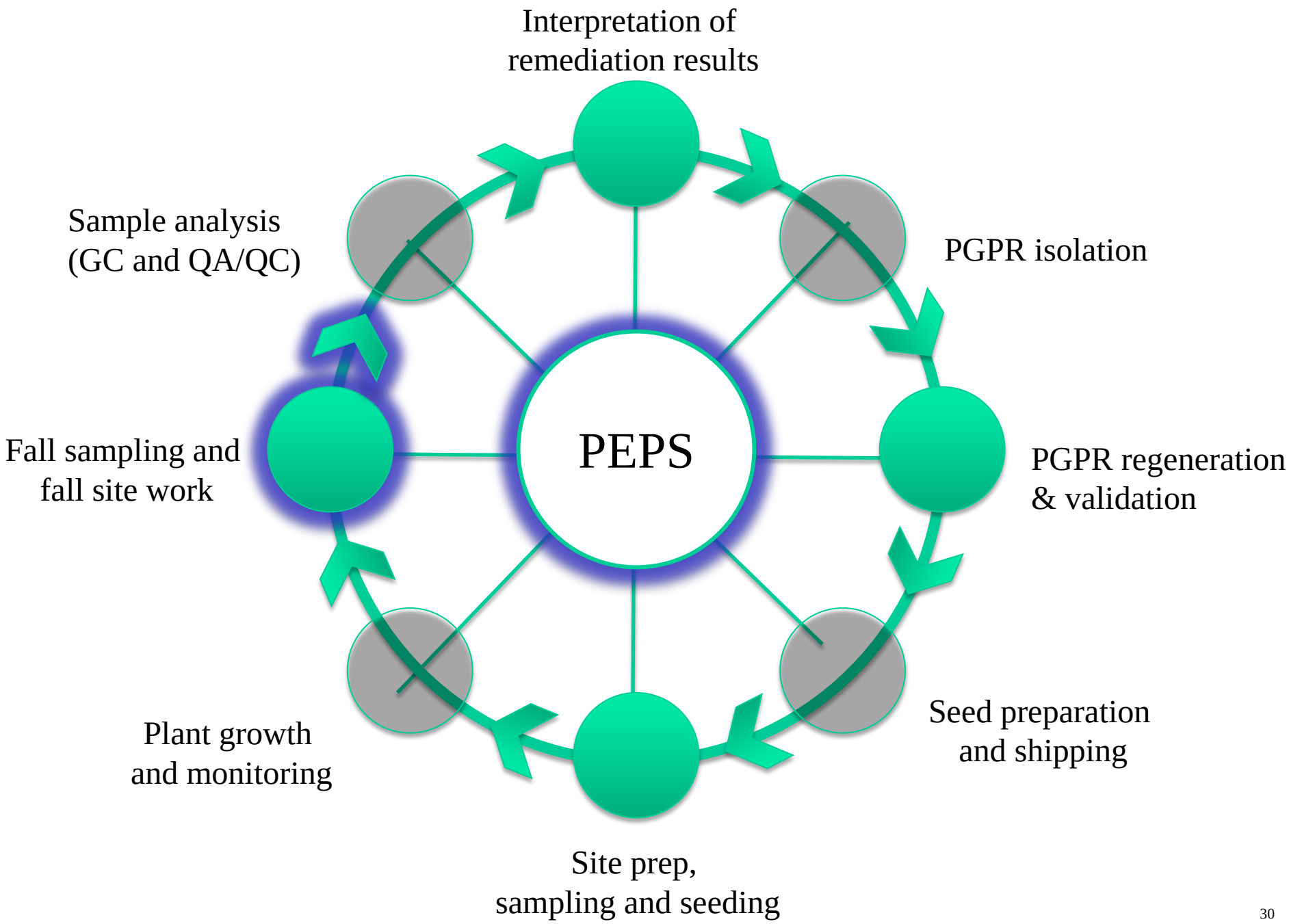
Weyburn, SK: After one month



Soil Impact – Salt (ECe ~ 10 dS/m)

Weyburn, SK: After three months

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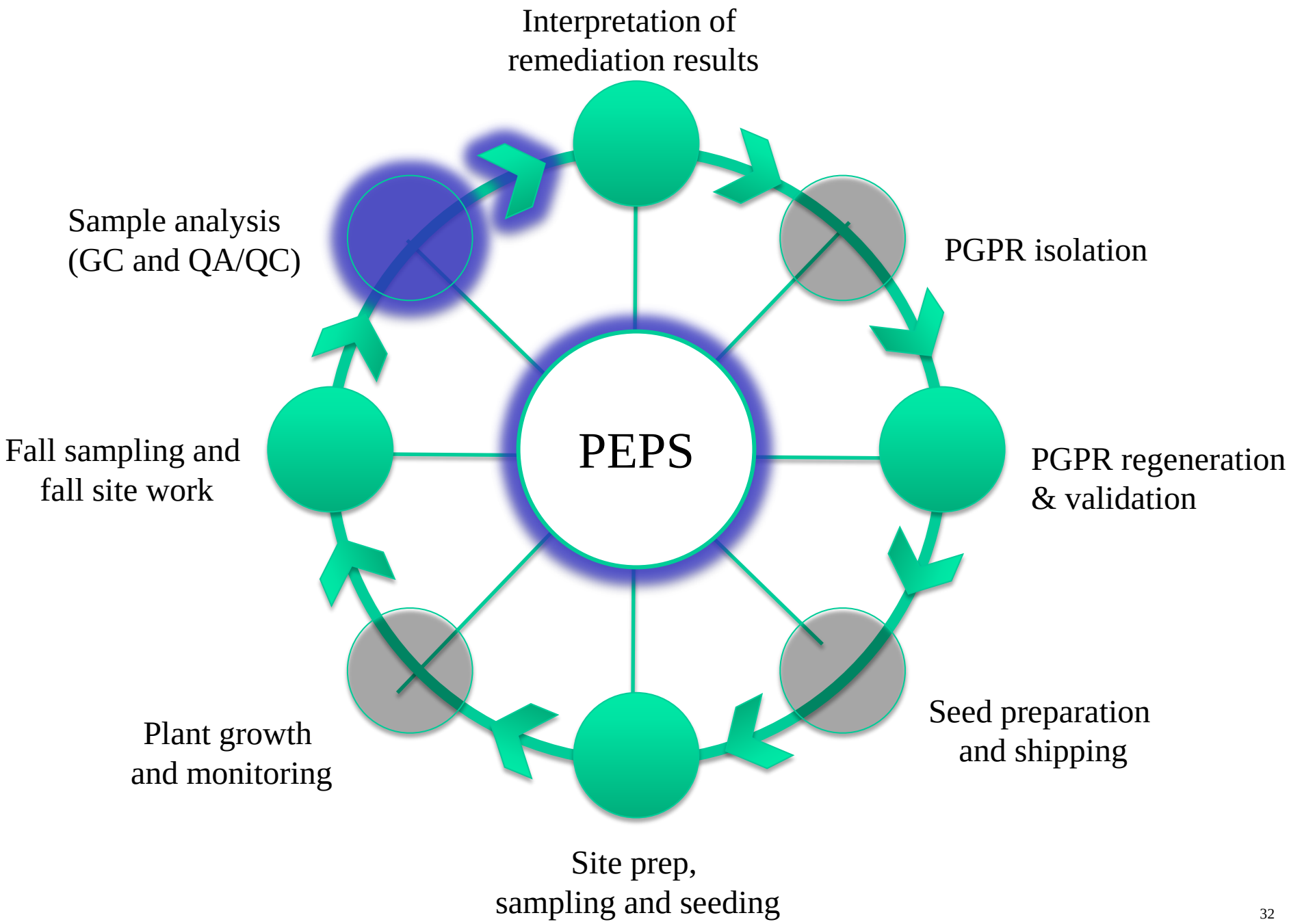
Swathing/Mowing

Baling

Fall Sampling and Site Work

At Salt Sites, Cut Grass is Removed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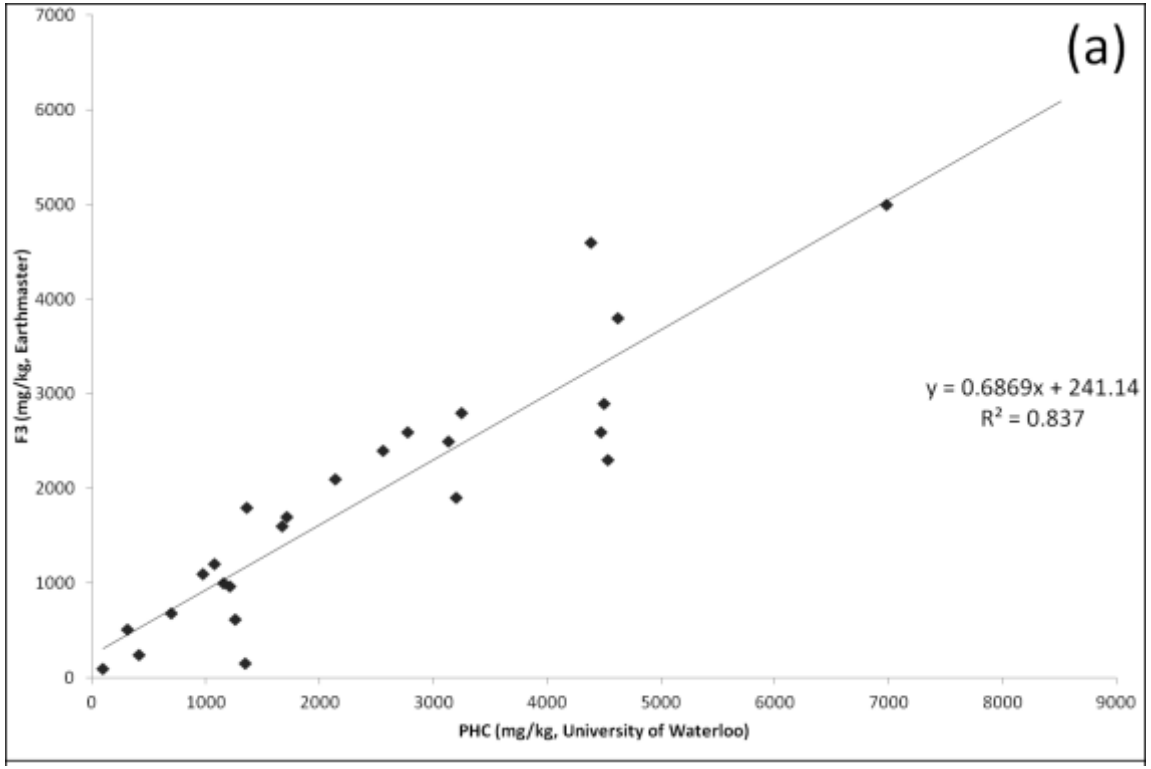
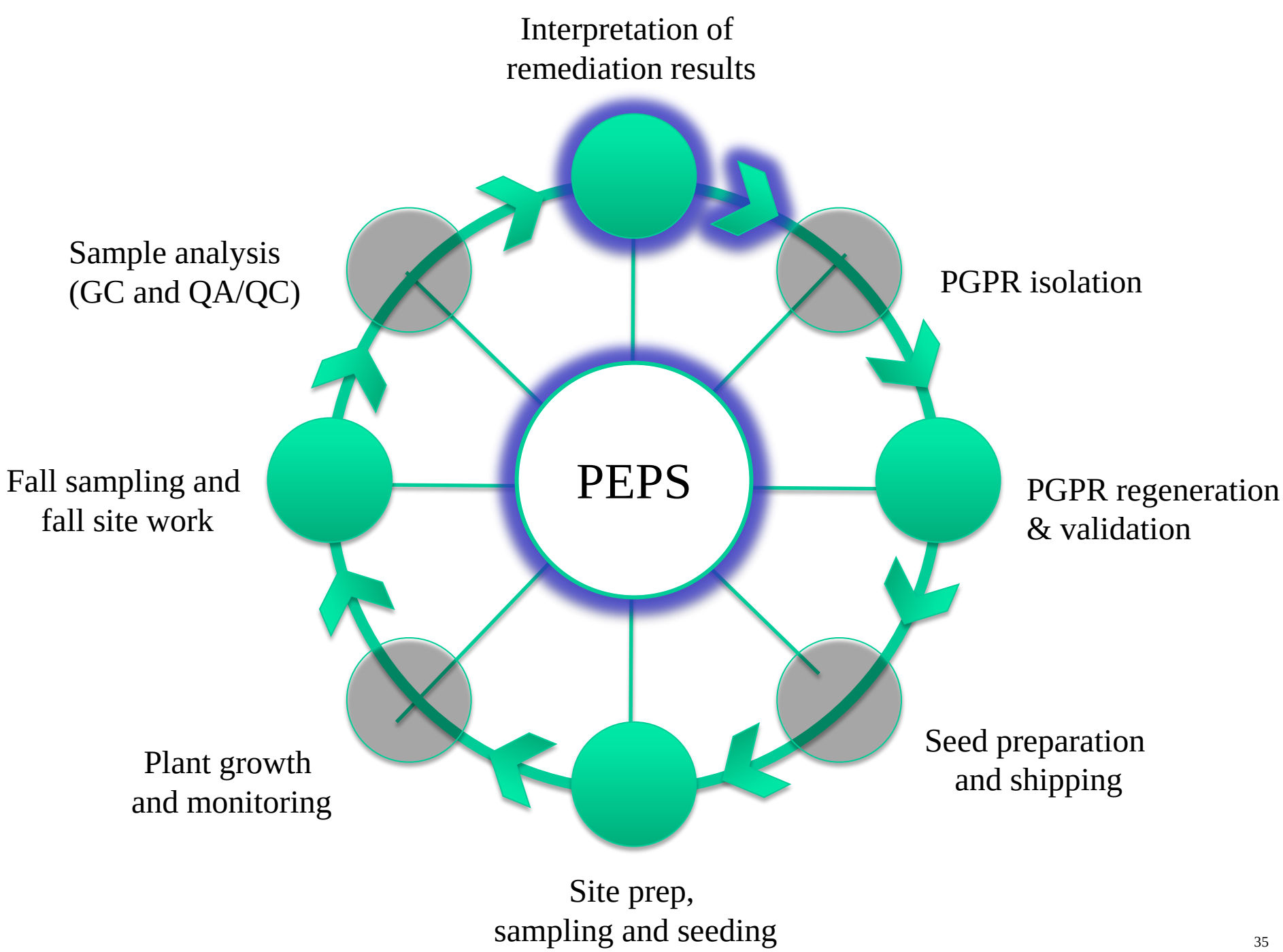
Sample Analysis

- Analysis of PHC and salt impacted soils
- Soil PHC – CCME GC method
- Soil Salt – ECe, SAR, Na and Cl
- Tissue Salt – Analysis of plant samples to assess plant uptake of salt

QA/QC Analysis



- PHC and/or salt samples are analyzed in at least two laboratories
- Data sets compared to assure data quality
- Data correlations are reviewed to determine data acceptance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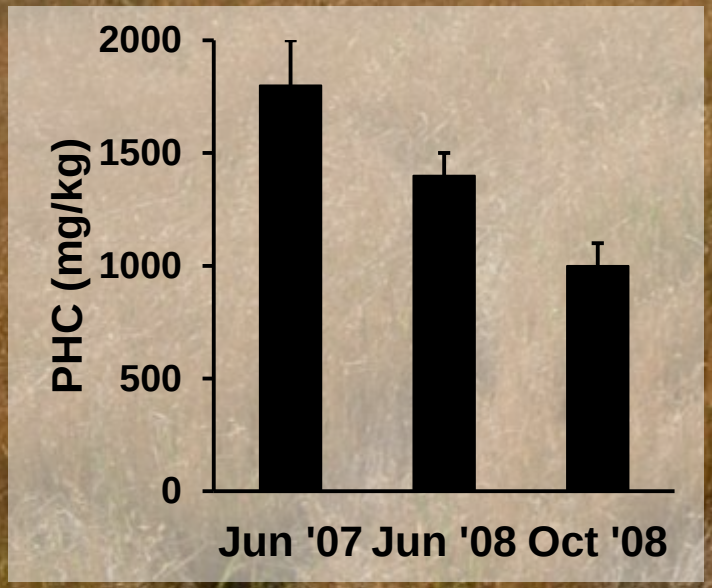
PEPS Deployment at Edson, AB

After PEPS



All 10 sampling points below criteria after remediation

Average 1500 mg/kg F3 to 1000 mg/kg in 2 years

Full Scale PEPS Deployment at Typical PHC Sites

Site	Analysis	Date	Average (mg/kg)	% Remediation	Notes
Completed Sites - 1st Generation					
Edson	CCME F3	Spring 2007	1500	33.33%	5 of 10 sample points above Tier 1 criteria
	CCME F3	Fall 2008	1000		All sample point met Tier 1 criteria
Hinton 2	CCME F3	Spring 2007	900	44.44%	6 of 15 sample points above criteria
	CCME F3	Fall 2008	500		All sample point met Tier 1 criteria
Dawson 1	EPH(C10-19)	Spring 2009	6500	91.54%	12 of 12 sample points above Tier 1 criteria
	EPH(C10-19)	Fall 2011	550		1 of 12 sample points above Tier 1 criteria
	EPH(C19-32)	Spring 2009	2500	72.00%	11 of 12 sample points above Tier 1 criteria
	EPH(C19-32)	Fall 2011	700		All sample point met Tier 1 criteria
Peace River	F3	Spring 2007	900	78.89%	4 of 11 sample points above Tier 1 criteria
	F3	Fall 2008	190		All sample point met Tier 1 criteria
Quebec City	F3	Spring 2009	550	49.09%	3 of 3 sample points above criteria
	F3	Fall 2009	280		All sample point met Tier 1 criteria
Sites in Progress - 2nd Generation					
Hinton 1	CCME F2	Spring 2010	1100	77.27%	10 of 10 sample points above Tier 1 criteria
	CCME F2	Fall 2010	250		6 of 10 sample points above Tier 1 criteria
	CCME F3	Spring 2010	3200	56.25%	9 of 10 sample points above Tier 1 criteria
	CCME F3	Fall 2010	1400		3 of 10 sample points above Tier 1 criteria
Swan Hills	CCME F2	Spring 2009	1400	78.57%	8 of 8 sample points above Tier 1 criteria
	CCME F2	Fall 2010	300		4 of 8 sample points above Tier 1 criteria
	CCME F3	Spring 2009	2550	64.71%	7 of 8 sample points above Tier 1 criteria
	CCME F3	Fall 2010	900		1 of 8 sample points above Tier 1 criteria
Dawson 2	EPH(C10-19)	Spring 2009	6500	46.15%	15 of 15 sample points above Tier 1 criteria
	EPH(C10-19)	Fall 2011	3500		8 of 15 sample points above Tier 1 criteria
	EPH(C19-32)	Spring 2009	700	42.86%	3 of 15 sample points above Tier 1 criteria
	EPH(C19-32)	Fall 2011	400		All sample point met Tier 1 criteria
Dawson 3	EPH(C10-19)	Spring 2009	7000	81.43%	11 of 12 sample points above Tier 1 criteria
	EPH(C10-19)	Fall 2011	1300		5 of 15 sample points above Tier 1 criteria
	EPH(C19-32)	Spring 2009	3500	57.14%	12 of 12 sample points above Tier 1 criteria
	EPH(C19-32)	Fall 2011	1500		6 of 12 sample points above Tier 1 criteria
Beaver River	EPH(C10-19)	Spring 2010	1600	25.00%	8 of 20 sample points above Tier 1 criteria
	EPH(C10-19)	Fall 2010	1200		6 of 20 sample points above Tier 1 criteria
	EPH(C19-32)	Spring 2010	850	35.29%	8 of 20 sample points above Tier 1 criteria
	EPH(C19-32)	Fall 2010	550		3 of 20 sample points above Tier 1 criteria

Average Remediation = 34 % per year

Full Scale PEPS Deployment at Typical Salt Sites

Site	Analysis	Date	Average (dS/m)	% Remediation
Completed Sites – 1st Generation				
Nota	ECe ECe	Spring 2008 Fall 2010	7.7 2.3	70.13%
Provost	ECe ECe	Spring 2009 Fall 2009	14.5 8	44.83%
Sites in Progress – 2nd Generation				
Weyburn	ECe ECe	Fall 2010 Fall 2011	13.5 10.5	22.22%
Weyburn	ECe ECe	Fall 2010 Fall 2011	6.9 5.9	14.49%
Weyburn	ECe ECe	Fall 2010 Fall 2011	13.5 12.1	10.37%
Weyburn	ECe ECe	Fall 2010 Fall 2011	14.3 12.6	11.89%
Red Earth	ECe ECe ECe ECe	North, Sp 2010 North, F 2011 South, Sp 2010 South, F 2011	5.2 4.5 4.2 3.8	13.46% 9.52%
Kindersley	ECe ECe	Spring 2008 Fall 2009	5.5 4	27.27%
Cannington Manor	ECe ECe	Spring 2007 Fall 2008	17.6 11.8	32.95%

Approximately 1 ECe unit per year

Conclusions for Salt Remediation

Parameter	Value
Annual Drop in Soil EC_e	10% to 20%
NaCl Uptake into Foliage	29 g/kg dry weight
NaCl removed from the field in foliage	150 kg/ha
Change in EC_e accounted for by foliar uptake of salt	0.95

Data derived from 12 commercial research project sites

Research Initiatives = Innovation

- NSERC: Optimization of PHC analysis for phytoremediation
- NSERC: Establishing Tier 2 SOPs for site closure
- ISTP: Phytoremediation of salt impacted soils in China
- IRAP: Product development platform for improved PEPS

Why Use PEPS?

- Peer reviewed science and performance
- Proven for PHC and/or salt impacted sites
- PHC - PEPS meets Tier I or II
- Salt – PEPS re-vegetates impacted sites & reduces soil salt levels to guideline values
- 100 % success rate at >30 sites
- Liability is reduced, not transferred and maintained
- Regulator support

Why Use PEPS?

- Environmentally responsible
  - Green technology
  - Driven by solar energy – northern vs. southern
  - Soil is conserved
  - Soil quality is improved
  - Greenhouse gas storage
- Cost effective
  - More cost effective at remote sites
  - Sites with large soil volumes – half the cost of landfilling
  - Costs spread out over 2 – 3 years
- It works!

Thank you

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