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Saskatchewan

Collaboration For Closure of Salt Affected Well Sites in Saskatchewan Using Tier 2 Pathway Modification

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Outline

- Risk and NaCl
- New MER Directive
- Case Study
- Liability Reductions

Acknowledgement of Reclamation for Sodium Chloride Impacted Sites

- To provide guidance for an **environmentally responsible** path to obtain Acknowledgement of Reclamation (AOR) for sites that have NaCl concentrations exceeding the generic criteria established in the Directive PNG033: *Phase II Environmental Site Assessment* (PNG033) and the *Saskatchewan Environmental Quality Standards* (SEQS).
- Methods adopted are harmonized with the Saskatchewan Environmental Code (Code).
- A risk-based approach that manages NaCl, often referred to as “salinity impacts” or “produced water impacts”, using site specific criteria or risk assessment.

Into Con't

Historical actions have presented unacceptable environmental and economical risk to the Saskatchewan Oil and Gas Orphan Fund (SOGOF) due to;

1. Incomplete assessment of the risks associated with historical salt impacts;
2. Limited technical understanding of NaCl related adverse effects;
3. Lack of a reasonable closure process for NaCl impacted sites; and
4. High cost of remediating to Tier 1 numerical closure targets

Implications of 1 to 4 have resulted in efforts to minimize remediation spending by implementing monitoring programs and inefficient systems until a practical path to AOR approval is understood.

- Large, surface excavations in order to satisfy Saskatchewan's Salinity and Sodicity numerical Remediation Criteria (Appendix 1 of PNG033) and/or criteria supplied in SEQS where a clearer understanding of receptor risks may have been warranted.
- Landowners are not receptive to remedial excavations due to the size, location and extending over areas of productive agricultural land.

How Long Can He Go!!!!

Fact: NaCl can present limited risk to ecological receptors relative to natural conditions, thus;

- Industry needs to reconcile performing large, expensive, intensive remedial programs to meet Tier 1 numerical criteria that too often excludes consideration of the significant carbon footprint costs or wetland rehabilitation times;
- ER desires to encourage that the **net environmental benefits be understood** prior to embarking on large excavations of salt impacted sites; and
- Commencing perpetual or indefinite monitoring programs that have no articulated regulatory closure plan may not equate to a reduction in total liability or site closure.

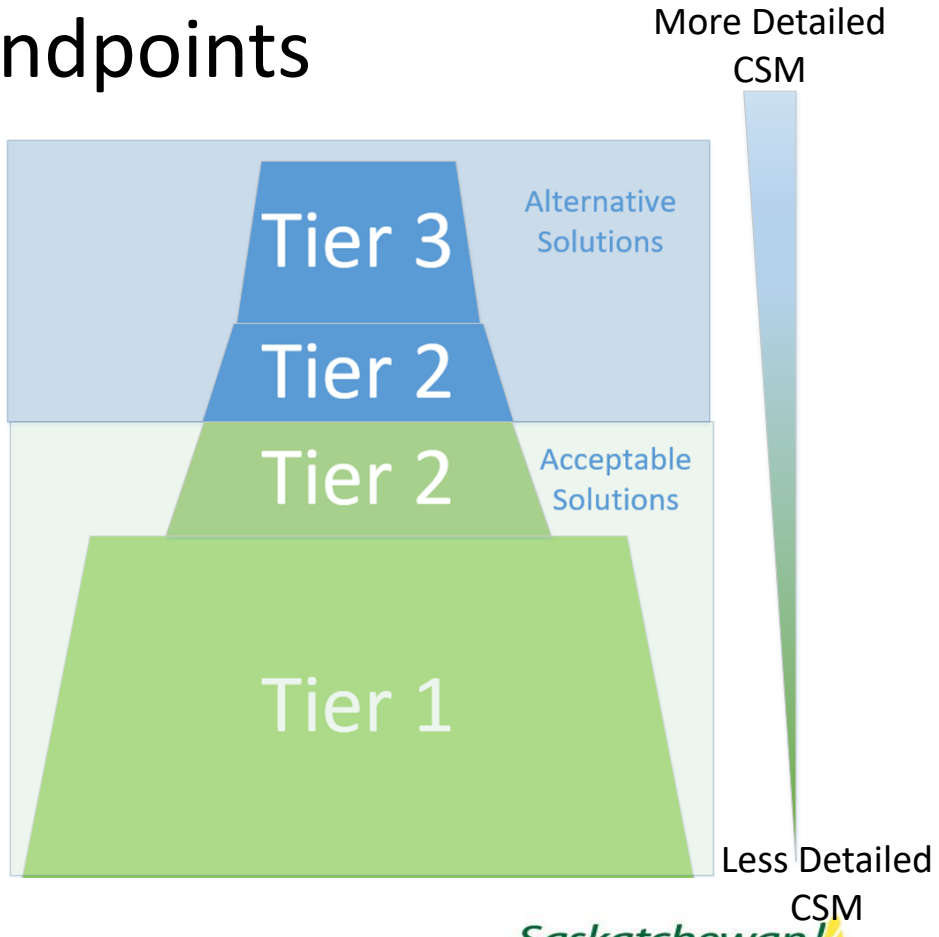
This new Directive enables industry to better understand the balance between cost, liability and effective effort while **ensuring environmental sustainability and responsibility**.

What is Risk?

- Risk is the chance or probability that the environment will be harmed or experience an adverse effect if exposed to a contaminant.
- There is also a risk that if we do not develop a pragmatic method to remediate NaCl impacted sites that they will not be cleaned up before oil and gas is no longer on the landscape

Tiered Endpoints

- **Tier 1** = Generic guidelines obtained from PNG 033
- **Tier 2** = Two options; an increased numerical criteria for soil and a structured pathway modification for other environmental receptors
- **Tier 3** = Risk Assessment. Endpoints are developed by the environmental practitioner



Tier 2

- Developing a Site-Specific Standard Based on Background Data
- Pathway Modification
  - Transport Calculations and Modelling
  - Looking at individual receptors
    - Surface Soil
    - Potable Water Aquifer
    - Dugout/irrigation
    - Fresh Water Aquatic Live

Surface Soil as an Example

- Use a buffer calculation of Buffer = Tier 2 Acceptable EC – surface soil EC
- Chart developed through the Subsoil salinity tool.
- Top of Impact as measured via Phase 2 ESA
- Drainage rates calculated from groundwater monitoring data or from the Native Prairie Protocol method

FINE	Surface Soil Guideline (mg/kg chloride)				
Surface soil drainage rate	Top of impact	Surface soil EC buffer (dS/m)			
(mm/yr)	(m)	1	2	4	6
1↑	1.5	410	830	1700	2500
	2	490	980	2000	2900
	3	720	1400	2900	4300
	4	1200	2300	4700	7000
1↓	1.5	540	1100	2200	3300
	2	680	1400	2700	4100
	3	1100	2200	4400	6600
	4	1900	3900	7700	10000
3↓	1.5	680	1400	2700	4100
	2	900	1800	3600	5400
	3	1600	3200	6400	9700
	4	3100	6200	10000	10000

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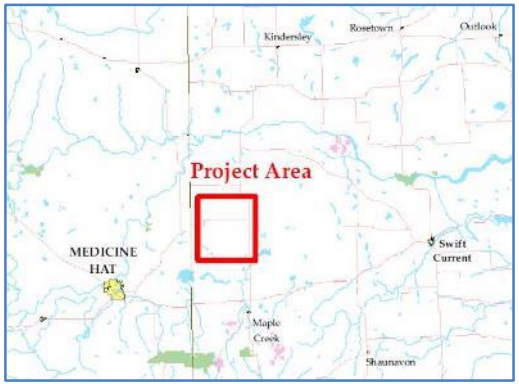
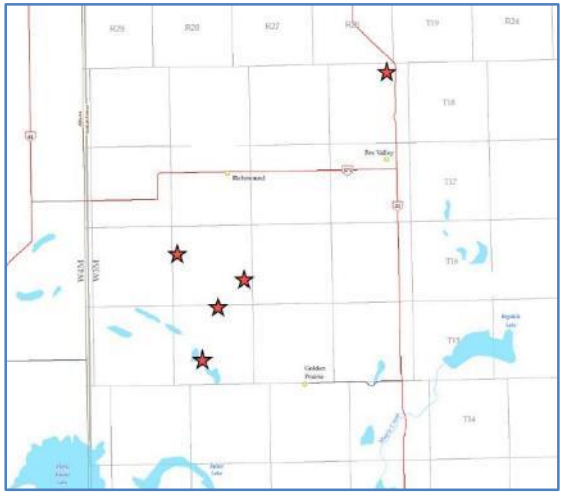
Case Study

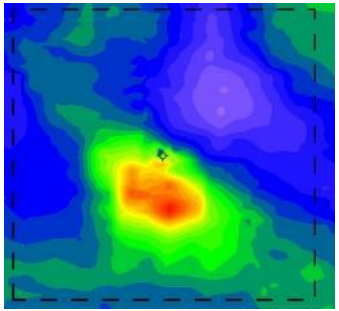
- Sites located in SW Sask.
- Current land use is Agricultural; Cultivated and Pasture / Grazing / Native Prairie.
- Mixed Grass Ecoregion





Site Histories

- Shallow gas wells drilled in the mid 1980's
- Drilled with KCl based drilling fluid
  - Shallow on site DWDA at 0.8 to 1.5 m
- Other APECs (Well Centre and EM anomalies)



Site Histories

- Production has ended and well bores abandoned 2015 - 2017
- Background Soil Quality – moderately saline
  - Sodium Sulphate
  - EC to 8.5 dS/m
  - SAR to 9
  - Some pH values 8 to 9
  - Chlorides to 154 mg/kg

Soil Quality

Shallow soil with elevated salinity > Tier 2 Endpoints

- EC elevated relative to generic guidelines (to 17 dS/m)
- SAR values 10 to 35
- Chloride ranges (~450 to 2,130 mg/kg)
  - Shallow Zones typically < 0.75 m thickness (DWDA)
  - Chloride above BG to 4 to 5 m below surface
- Sites historically at various assessment stages, with multiple historical assessments conducted

Typical Approach

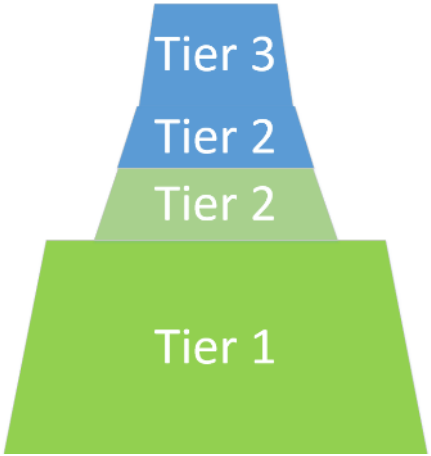
Soil salinity > guidelines typically remediated through excavation and off-site disposal

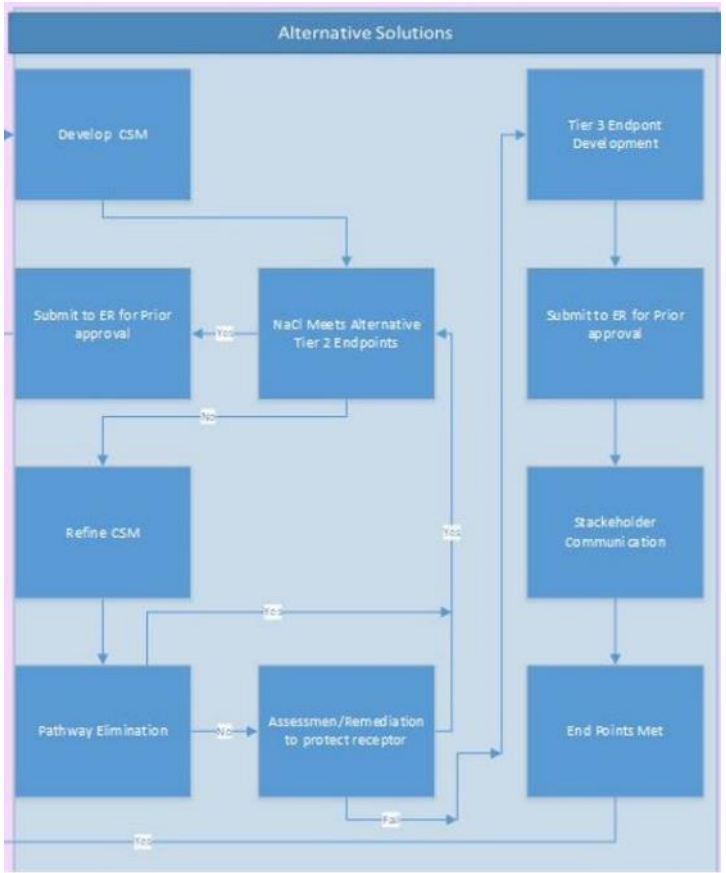
- Remediation will always have an adverse effect
- Remediation is destructive to a site and causes unnecessary ecosystem disturbance
- Increases the time to obtain a AOR and does not remove the environmental liability.
- Increased environmental footprint through obtaining backfill and increased greenhouse gases

New Approach

An Alternative Solution was desired

- Assurance with MER on the Sites was desirable for client before proceeding with reclamation work scopes
- Ongoing collaboration with MER





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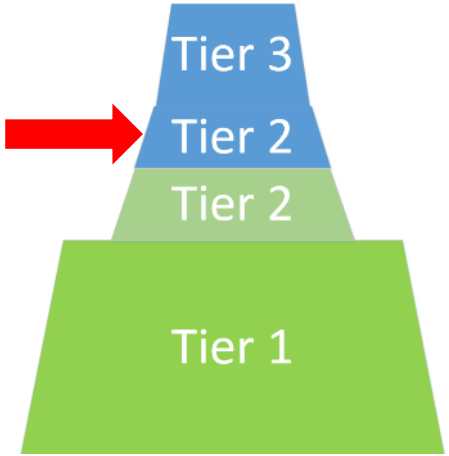

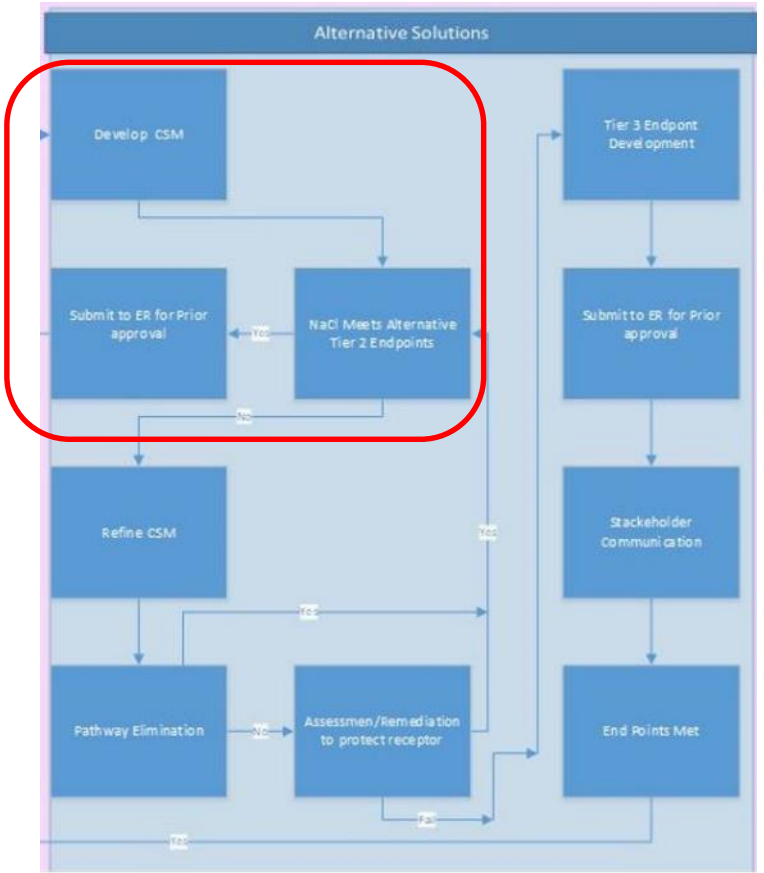

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Alternate Solutions

Main COPC at the Sites;

- Salinity (EC , SAR, pH) in rooting zone / topsoil
- Chloride in rooting zone / topsoil to 1.5 m and in subsoil >1.5m

Although not fully reclaimed the vegetation appeared robust and not impacted

Alternate Solutions

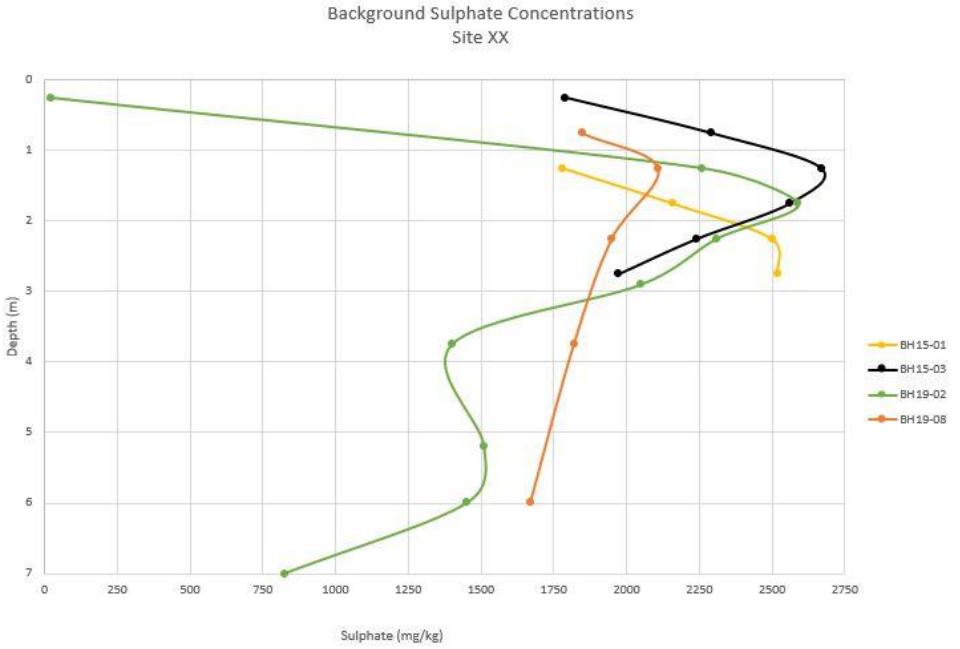
EC / chloride in rooting zone

- Adaptation of the ***Native Prairie Protocol*** (AEP 2019)
- Baseline Veg. assessment – No current Adverse Effect
- Future DSA will confirm – No Current Adverse Effect

Alternate Solutions

EC / chloride in rooting zone - ***NPP***

- Evaluation of Natural Sulphate Profile
  - No potential for future upward salt migration



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Alternate Solutions

Chloride in subsoil

- Adaptation of the *Subsoil Salinity Tool*
  - Adjustment for site locations
  - All other input parameters would be considered “normal” application
- All sites were within the chloride guidelines

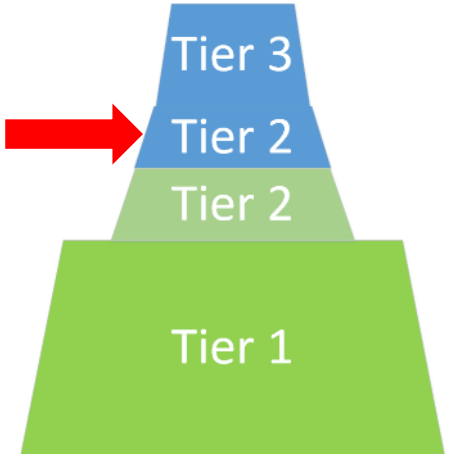
Alternate Solutions

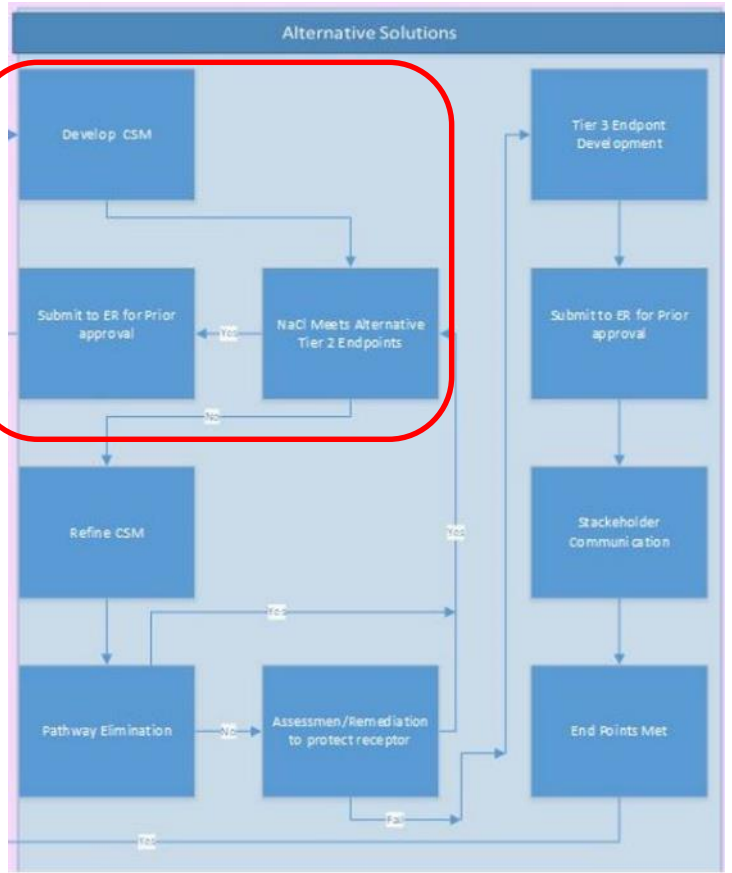
SAR and pH - Professional justifications

- SAR
  - < may cause clay dispersion…, < may cause impermeable layer…, < may cause restrictive layer…, < may cause perched water table…, < may cause vegetation impairment...
  - No change in soil structure
  - Deep water table
- pH
  - Below the active rooting zone.

Alternative Solutions

Final Step was submission to MER for review and Approval





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Liability Reduction

This method for 5 Sites in the study area with a soil volume > generic guidelines of 2,350 m^3

- Alternate Solutions reduced remediation volume to 0.
- Represents > 20X savings multiplier per dollar spent

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Lessons Learned

- New Directive
  - **Environmentally Responsible** path to obtain AOR
  - Enables industry to better understand the balance between cost, liability and effective effort while **ensuring environmental sustainability and responsibility.**
- Collaboration with all parties is essential
- Risk Based Closure

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Questions?

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