Equilibrium Environmental Inc.

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Onterris™

Identification of Research Gaps in Chloride and Salinity Management in Remediation, Reclamation and Closure

RemTech 2026

Banff, October 15, 2026

Agenda

- Background
- Approach
- Key Gaps
- Example Findings
- Other Jurisdictions
- Next Steps

Project Team

- Key team members:

Equilibrium	Millennium	Onterris
Greg Huber Tony Knafla	Ian Mitchell Emma Stienne	Daniel Pollard Ashley Morgan Bibiana Bartokova

- Industry champion: Steve Kullman (CNRL)
- Engagement and input from EPA & AER

Background

Salt remains a significant challenge for oil & gas remediation, reclamation, closure

Highly mobile, persistent

Can pose environmental risk, but at many sites no adverse effect has occurred

Necessary conservatism in screening guidelines, but this has consequences:

- Unnecessary remediation → potential adverse effect
- Finite resources → need to focus on actual risk



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Background

- As a result, there is need for:
  - A comprehensive framework and guidance for decision-making
  - Toolbox for assessment, remediation, management, monitoring, reclamation and closure
  - Increased consistency and certainty in management strategies
  - More effective use of resources, improved environmental outcomes



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Approach

Objectives and Scope

- Goal: Improved management of salinity in Alberta
  - Environmental, economic and sustainable outcomes
- Reach alignment on direction of future work regarding salinity and chloride management
- Develop catalogue of literature, data, research and best practices in Alberta and other jurisdictions
- Identify/classify broad gaps, limitations, opportunities, and rank/prioritize
  - Environmental significance
  - Economic significance
  - Regulatory factors
  - Existing work
  - Feasibility

Deliverables

Annotated Inventory of Relevant Research

Comparative Analysis of Jurisdictions

Gap Analysis Report

Recommendations for Future Research



Key Gaps

Identifying, Ranking, and Validating Data Gaps

Initial brainstorming of potential data gaps

Data gaps ranked based on a combination of potential impact and potential for practical implementation

Ranked from 3 to 1 (highest to lowest priority):

2.5-3	**highest**
2-2.5	**medium-high**
1-2	**low-medium**

27 data gaps identified and ranked:

- 6 of highest priority
- 4 of medium-high priority
- 17 of lower priority

Preliminary and follow-up discussions with stakeholders (May through Sept 2026) regarding identified data gaps and rankings to ensure alignment and completeness

Highest Priority Data Gaps for Further Evaluation

Number	Data Gap Description	Ranking
1	Data gaps related to the Alberta Tier 1 chloride delineation criteria of 100-120 mg/L saturated paste, and whether some sets of site conditions (based on texture, distance to aquatic receptor etc) would be relevant to an alternate delineation criteria (such as 100 mg/kg as per the SST) in some cases.	3.00
2	Data gaps related to which wetland classifications (as defined in the Alberta Wetland Classification System) should be considered to be 'freshwater aquatic life receptors' when implementing any sort of Tier 2 approach where FAL distance is an important parameter (PHC's, PAH's, chlorides, etc).	2.86
3	Guidelines gaps pertaining to chloride toxicity to aquatic life with the consideration of water hardness	2.57
4	Data gaps related to how peatlands are treated in terms of FAL receptor status. Data gaps in AB specific guidance on sampling / analytical / assessment methods in organics.	2.50
5	Guidelines gaps pertaining to chloride toxicity to aquatic life with the consideration of background salinity (TDS, sulfate, etc)	2.50
6	Need for appropriate management and monitoring guidance where chloride mass removal is not feasilbe or desirable and is therefore managed in place.	2.50
7	Data gaps related to the Tier 1 chloride irrigation guideline (nominally listed as 100 mg/L) and resolution of inconsistencies between the Tier 1 EC irrigation guideline (1 dS/m) and other chloride values listed in the surface water guidelines (100-700 mg/L).	2.36
8	Data gaps related to model assumptions of where irrigation water is sourced from (DUA? dugout? irrigation water aquifer?)	2.21
9	Lack of guidance on methods for evaluating current and future risks to vegetation from salinity within the root zone above Tier 1 EC and SAR guidelines at non-native prairie sites as part of SSRA.	2.14
10	Data gaps related to the assessment and management of PAR (Potassium Adsorption Ratio) or SPAR (Sodium Potassium Adsorption Ratio)	2.00

Complete list of all 27 data gaps presented at AUPRF Remediation, Reclamation & Ecological Forum (June 26, 2026 - Calgary)
Further details provided at PTAC.org

Example Findings

Data Gap 4a: How peatlands are treated in terms of FAL receptor status



Organic soils (peat/muskeg) are a precluding condition for Tier 1. Approximately 20% of Alberta has peatlands.

Limited clear guidance for how to address this at Tier 2

Limited guidance on when peat must be treated as a freshwater aquatic life receptor



Compiled information from Tier 1 and Tier 2 guidelines, SCARG, SST user manual, ESA Standard, BiC scale, surface water quality guidelines, peatland reclamation criteria

Data Gap 4a: How peatlands are treated in terms of FAL receptor status

Key gaps:

- Accepted Tier 2 approaches
- Analytical approaches (peat is not soil!)
- Tier 1 chloride guideline based on species not typically present in peatlands
- Limited guidance on remediation methods (non-destructive)
- Limited guidance on when FAL guidelines apply
- Lack of guidance on how to consider reclamation activities/criteria during contaminated site assessment



Data Gap 4a: How peatlands are treated in terms of FAL receptor status

- Jurisdiction Review – only BC guidance found:
  - BC CSAP Society – A Review of Analytical Methodologies and Interpretation of Analytical Results in Peat (2017)
  - Draft Alternative Salt Guidelines for British Columbia Boreal Peatland Release (2017)
    - Not adopted but have been approved by BCER as alternate standards with caveats as part of risk assessment
  - Site Remediation and Restoration Manual includes guidance relating to classification of peatland as an aquatic receiving environment

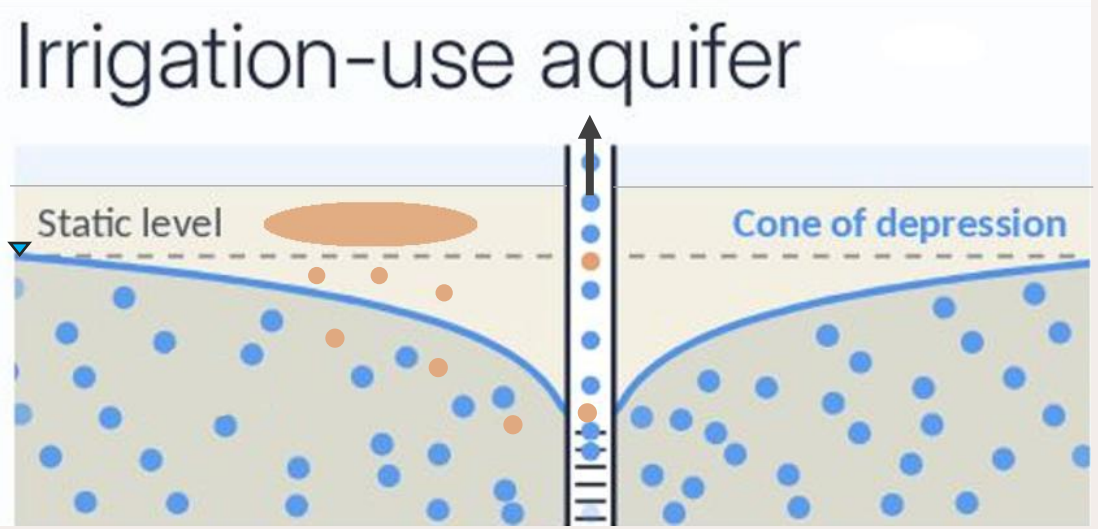
Data Gap 4a: How peatlands are treated in terms of FAL receptor status

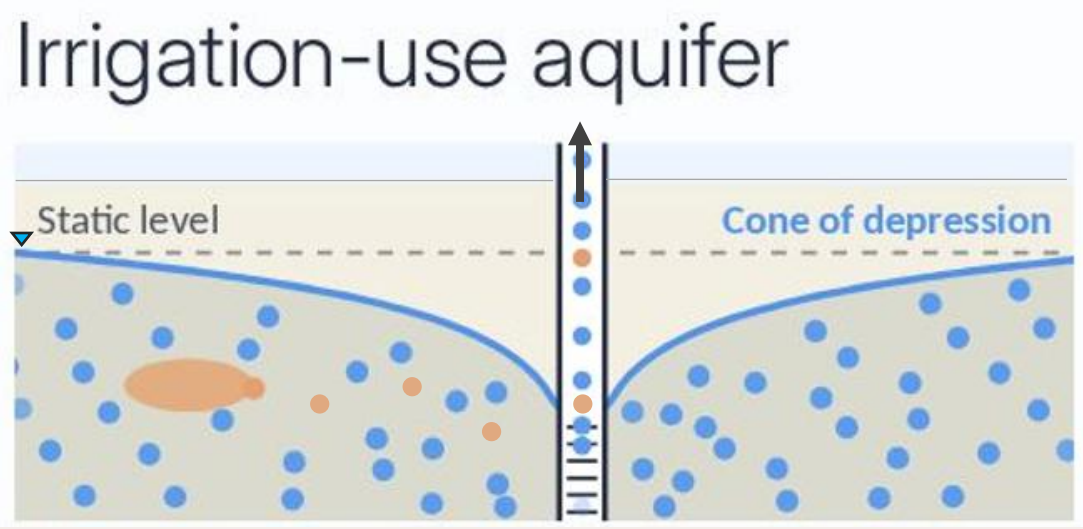
- Opportunities:
  - Decision tree/clear guidance for screening peat sites, identifying aquatic habitat, determining reclamation requirements
  - Review Alternative Salt Guidelines for British Columbia Boreal Peatland Releases for potential portability to Alberta
  - Potential guidelines for peatlands without open-water habitat
  - Toolbox for Tier 2/risk assessment and risk management of peatland
  - Framework for evaluating salinity management of peatland considering adverse effects of salinity and adverse effects of remediation

Data Gap 8: Sources of Irrigation Water

- Irrigation pathway can be sensitive since a relatively low chloride irrigation guideline
- Alberta Tier 1 guidance assumes an 'irrigation use aquifer', with minimal detail
- Impacts can potentially be above or below the water table (or both) with different implications for dilution / modeling

> *"For irrigation, the compliance point is everywhere within the irrigation-use aquifer, where applicable." ... "the Tier 1 guideline for groundwater applies at any point in the aquifer, regardless of current water use."*
>
> **Alberta Tier 1 & Tier 2 Guidelines (2024)**





Impacts above water table

Some dilution into groundwater via DF3

No clear adjustment for pumping rate / drawdown

Impacts below water table

No additional dilution into groundwater

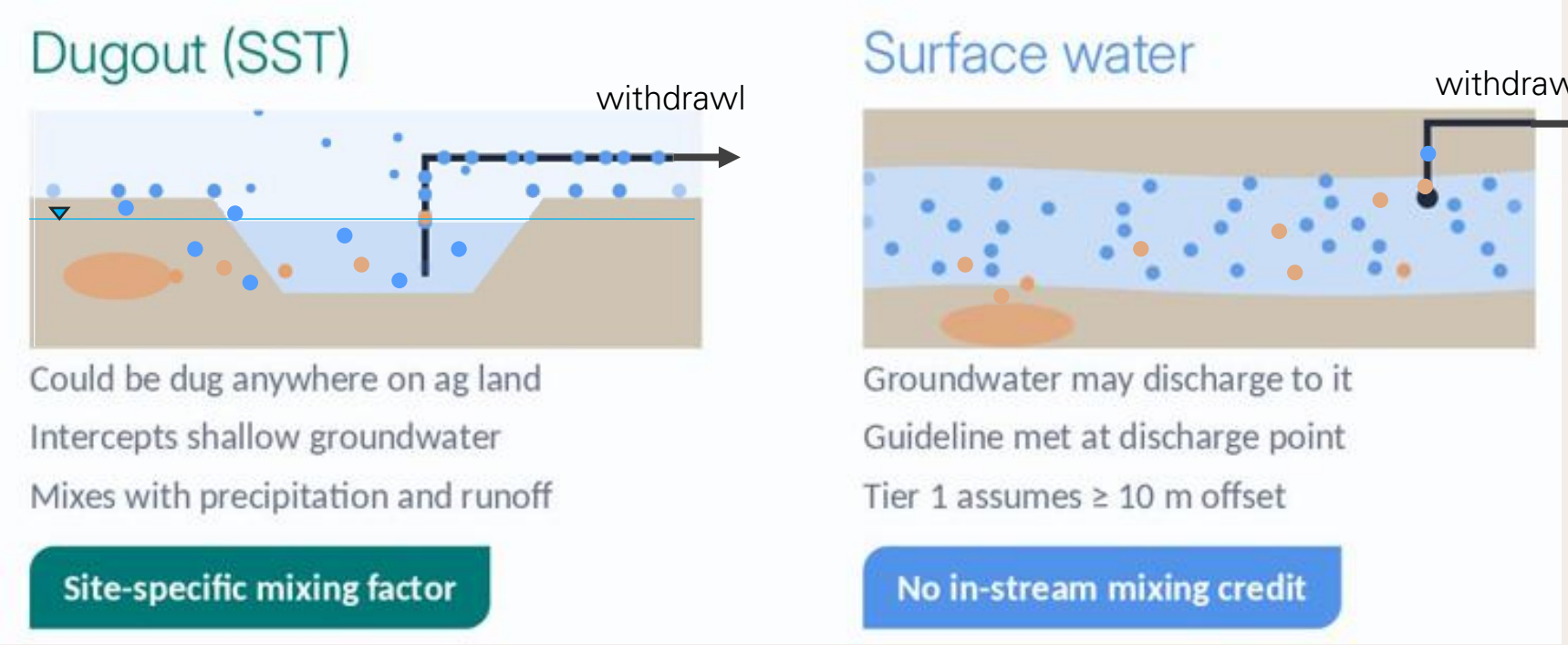
Pumping may dilute impacts with clean groundwater

Data Gap 8: Sources of Irrigation Water

- Other potential sources of irrigation water are referenced in both CCME guidance and SST protocols (dugout and surface water)

- **Different assumptions about irrigation sources, different assumptions about dilution calculations**

> *"Contaminated groundwater could potentially be accessed via a water well, a dugout, or after discharge to a surface water body and used for agricultural purposes (livestock watering or irrigation)."*
>
> **CCME (2015) Groundwater Quality Guideline Protocol**



Data Gap 10: Potassium Adsorption Ratio (PAR)

- Sodium has well-known potential adverse effects on soil structure via clay dispersion / swelling
- Expressed via SAR: a modified ratio between sodium (monovalent) and calcium plus magnesium (divalent) – all on a meq/L basis
- Elevated potassium (also monovalent) may be introduced and potentially cause similar risks
- Potassium-based (eg, KCl) mud additives can be present in drilling waste.
  - Fertilizer, manure, road salt, natural formations are also possible non-oil-and-gas sources
- Labs do not currently calculate PAR or SPAR values, but can be done analogously with SAR
- Provides an initial diagnostic for further risk considerations (including considering background PAR/SPAR)

SAR — Sodium Adsorption Ratio

all ions as meq/L

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

PAR — Potassium Adsorption Ratio

$$PAR = \frac{K}{\sqrt{(Ca + Mg)/2}}$$

SPAR — Sodium + Potassium Adsorption Ratio

$$SPAR = \frac{Na + K}{\sqrt{(Ca + Mg)/2}}$$

BH ID	Na (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	K (mg/kg)	SAR	PAR	SPAR
Sample A	**303**	**421**	**94**	**290**	**4.0**	**2.27**	**6.31**
Sample B	**325**	**658**	**<3**	**480**	**3.48**	**3.02**	**6.51**
Sample C	**434**	**398**	**137**	**861**	**5.45**	**6.36**	**11.81**

- In general, elevated PAR poses less soil structure risk than equivalent SAR
- Differences can be taken into account using techniques such as “CROSS” equation

Data Gap 1: Chloride Delineation Criteria

- High-priority data gap with high levels of practical, technical, and regulatory importance
- Multi-faceted topic with wide range of previous and ongoing research:

Evaluation of Soil Chloride Delineation Requirements.
Onterris (Matrix/Montrose). RemTech, Banff. October 17, 2024.

Complications with Chloride Delineation and the Influence of Non-Oil-and-Gas Sources.
Equilibrium Environmental. CLRA AGM & Conference, Edmonton. March 6, 2025.

High Potential-Risk Subsoil Salinity Tool (SST) Scenarios Where More Stringent Chloride Delineation Criteria Are Required.
Equilibrium Environmental. CLRA AGM & Conference, Edmonton. March 6, 2025.

Evaluation of Chloride Soil-Groundwater Partitioning, in Support of Guideline Updates.
Onterris. RemTech, Banff. October 15, 2026. (**coming up next!**)

Other Jurisdictions

Other Jurisdictions

Other jurisdictions outside Alberta have been reviewed to determine which have useful approaches that might be relevant

Candidate jurisdictions selected based on oil & gas development or other salinity-related issues

Other jurisdictions drawn from:

- Canada
- United States
- International



Complete list of all other jurisdictions presented at AUPRF Remediation, Reclamation & Ecological Forum (June 26, 2026 - Calgary)
Further details provided at PTAC.org

Example: Saskatchewan

Several similarities with Alberta

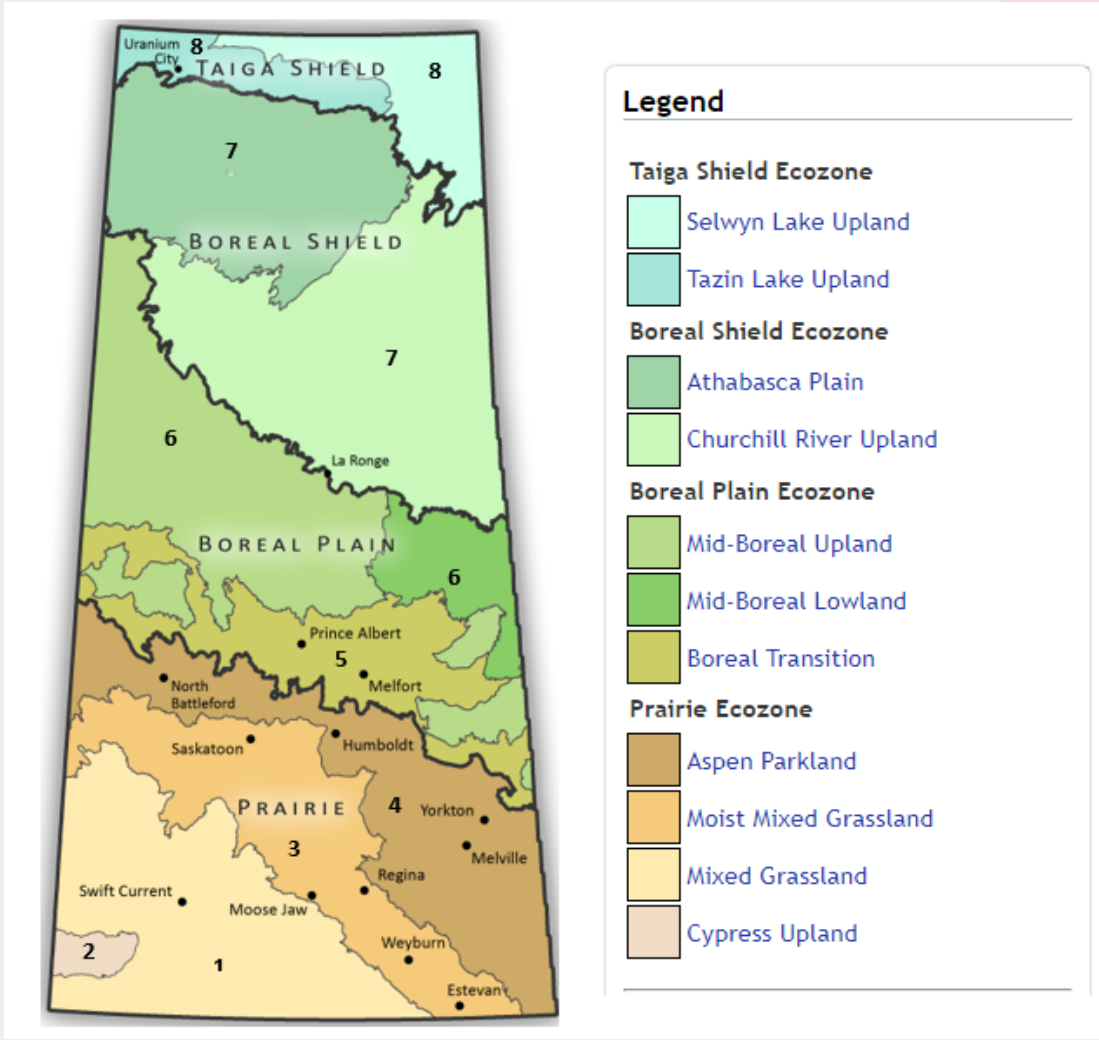
- Climate
- Background salinity
- Produced water issues
- Broad regulatory framework

Some differences in underlaying guidelines

- SPIGEC vs SCARG

Some approaches drawn from Alberta

- SST incorporated into PNG045 using variety of post-modifications and look-up tables
- Climate / natural subregion cross-references with SST subregions from Alberta



Example: Canadian Federal



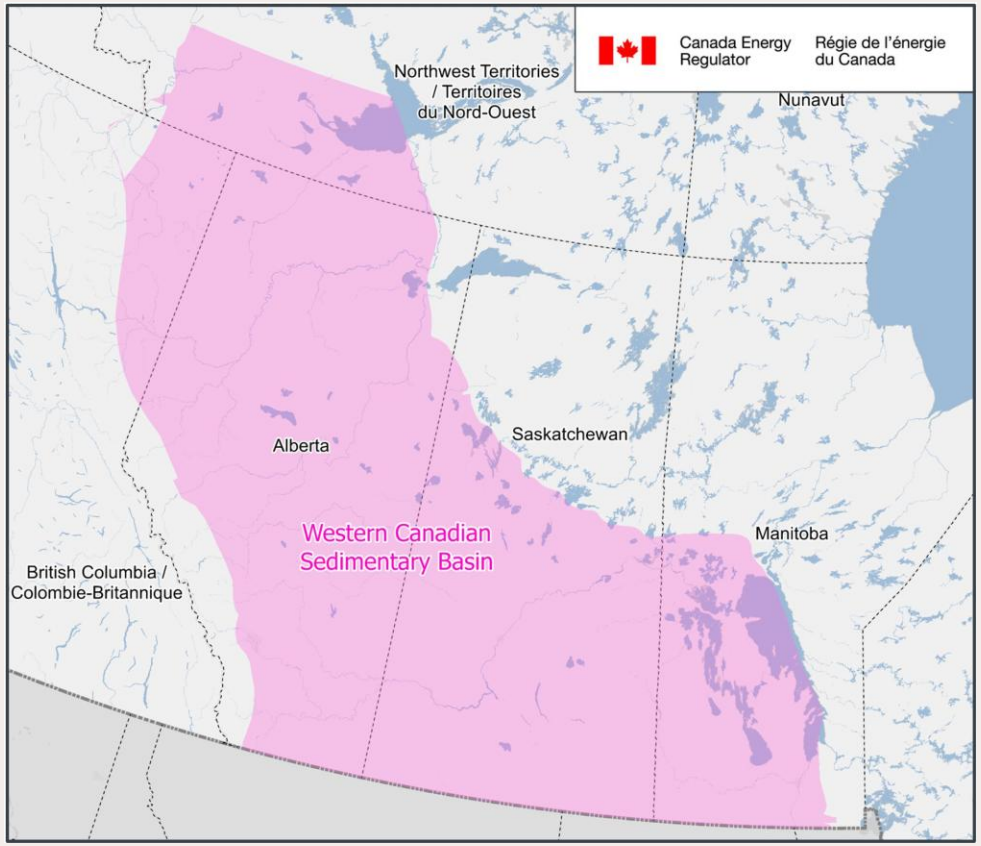
Canadian federal guidelines generally determined by CCME, Health Canada, or other federal organizations

Some provinces selectively adopt CCME salinity guidelines, or generate their own

- Soil, groundwater, surface water

Indian Oil and Gas Canada (IOGC) draws heavily on CCME guidelines, with additional considerations for First Nation sites

- Generally more conservative of provincial and federal guidelines used
- Some approaches currently being considered to apply the SST to chloride-impacted IOGC sites
- Majority of relevant sites (though not all) located in Western Canadian Sedimentary Basin
- May involve additional conservatism being incorporated via post-adjustments to guidelines and protocols



Example: Texas

Intensive oil and gas development within Permian Basin in northwest Texas (and into New Mexico)

- Produced water impact issues similar to Alberta

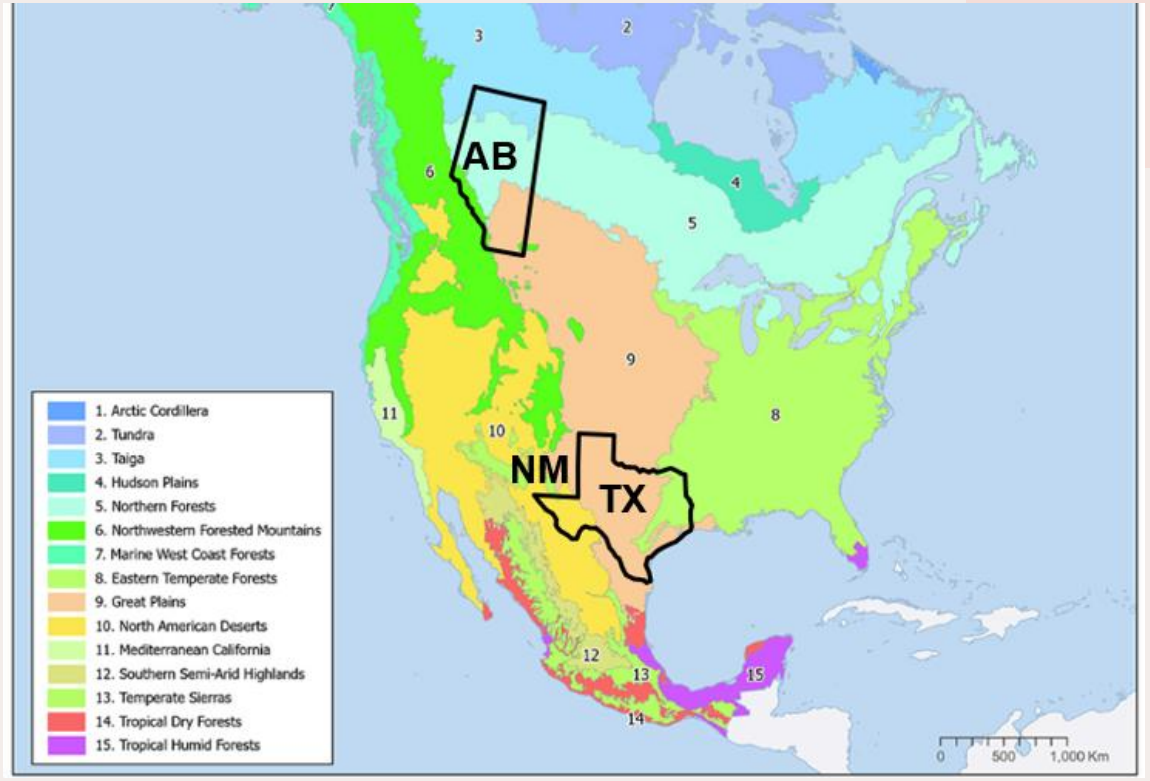
Some climate similarities between TX and NM to southeast Alberta and south Saskatchewan

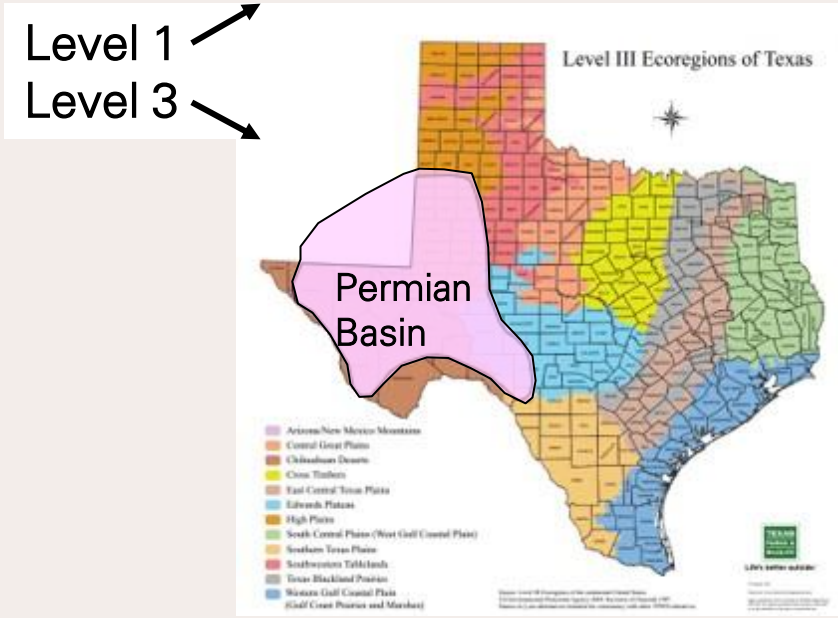
- "Great Plains" Ecoregion extends through parts of both states and both provinces

US EPA Ecoregion maps (different 'Levels') allow some climate comparisons between jurisdictions

- Permian Basin primarily located in "Great Plains" and "North American Deserts"

Climate / precipitation plays a role in some Texas-specific risk calculations (next slide)





Example: Texas

Some relevant protocols for assessment and salinity management from:

- Texas Railroad Commission (TRRC)
- Texas Commission on Environmental Quality (TCEQ)

Tier 2 Soil-to-Groundwater PCL Equation

$$^{GW}\text{Soil} = \frac{(\text{Groundwater PCL}^{*}) \cdot \text{LDF}}{K_{sw}} \cdot \frac{L_2}{L_1}$$

Cascading dilution factors

Simplified DF2

*Critical groundwater PCL as determined in accordance with §350.78.

$$K_{sw}\left[\frac{(\text{mg / L - } H_2O)}{(\text{mg / kg - soil})}\right] = \frac{\rho_b}{\theta_{ws} + K_d \rho_b + H'\theta_{as}}$$

← Similar to DF1

$$\text{LDF [dimensionless]} = 1 + \frac{U_{gw}\,\delta_{gw}}{I_f\,W_s}$$

← Similar to DF3

$$\delta_{gw}\,[\text{m}] = (2\alpha_v\,W_s)^{0.5} + b_{gw}\left[1 - \exp\left(\frac{-I_f\,W_s}{U_{gw}\,b_{gw}}\right)\right]$$

← Mixing thickness

I_f Net infiltration rate of water through soil (cm/yr)

Upper bound: $I_f \leq K_{vs}$ (3.15 x 10^7 s/yr)

- sand $0.0018(P)^2$
- silt $0.0009(P)^2$
- clay $0.00018(P)^2$

Draft TRRC screening guidance:

"Soils with a maximum concentration of 3,000 mg/kg chloride or 8 mmhos/cm EC are generally expected to be protective of groundwater based on the assumption of a complete soil leaching or runoff pathway with a 10 fold dilution of leachate in the receiving aquifer or surface water body."

*Less regulatory emphasis on root-zone / vegetation than Alberta

Example: Other International Jurisdictions

Reviews performed for other relevant countries across the globe. Eg:

- United States (federal, and other states)
- United Kingdom
- Mexico
- Brazil
- Norway

Some relevant regulations / guidelines from some of these countries, but in general, Alberta appears to be a world-leader in the realm of chloride-salinity management



Next Steps

Next Steps



Follow-up discussions with AER (Alberta Energy Regulator) and EPA (Alberta Environment & Protected Areas) on data gaps



Finalize literature review and review of other jurisdictions



Complete write-up of data gaps and other jurisdiction review for inclusion in final report

Questions?