Wellsite Salt Remediation: Subsoil Salinity Tool vs. Site-Specific Salt Risk Assessment?

Erik J. Martin, Ph.D., DABT

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Co-Authors

David Alberti, M.Sc., P.Geol. Stantec David.Alberti@stantec.com

Mike Callaghan, M.Sc., P.Eng.

Salt Impact Management mvcallaghan@shaw.ca



Outline of Presentation

- 1. Site Background
- 2. Regulatory Context
- 3. Subsoil Salinity Tool
- 4. Site-Specific Salt Risk Assessment
- 5. Compare SST & SRA
- 6. Conclusions
- 7. Questions / Discussion





1. Site Background

- Abandoned upstream oil wellsite (●) located in central Alberta near Hay Lakes.
- Agricultural Land Use and fine-grained soil.
- Sodium chloride (salt) and petroleum hydrocarbon (PHC) impacts at the site.
- AENV Tier 1 soil & groundwater exceedances.





2. Regulatory Context

Under the Alberta framework, three options are provided for management of contaminated sites:

- Tier 1: Remediation of a site to generic guidelines
- Tier 2: Remediation of a site to modified guidelines
- Exposure Control Risk Management





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3. Subsoil Salinity Tool

- The Subsoil Salinity Tool (SST) is a software program for developing Tier 2 soil remediation guidelines for chloride (CI⁻)based salt contamination below the root zone (>1.5 mbg).
 - Soil within the root zone must be remediated to meet salinity guidelines in the Alberta Tier 1 Remediation Guidelines.
- SST-derived Tier 2 remediation guidelines are protective of groundwater uses (drinking water, irrigation and livestock watering), surface water (aquatic life), and the root zone.
- SST is essentially a Cl⁻ mass balance calculator
 - Estimates the redistribution of Cl⁻ impact over time to determine present day Cl⁻ concentrations that are not predicted to result in current day or future adverse effects to receptors.



Tier 2A vs. Tier 2B vs. Tier 2C

- Moving from Tier 2A to Tier 2C, the quantity of site-specific information that is considered in modeling increases.
- SST Tier 2A is intended to provide a rapid screening method for developing guidelines that rely on minimal site data.

> No monitoring wells or groundwater information

- SST Tier 2A relies on a number of conservative assumptions and thus guidelines may be more conservative.
- SST Tier 2B considers a number of site-specific parameters and allows for more refined predictions of risk.
- Tier 2C, essentially site-specific risk assessment, is generally applied at large and complex sites and incorporates the most site-specific information.



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SST at Subject Site

Based on available information, initially generated Tier 2B guidelines for the site.

Reasons to use Tier 2B:

- Existing groundwater information available
- Large volumes of salt impacted soil
- Salt impacts below 1.5 mbg







Conceptual Model for Salt Exposure – SST Tier 2B

Receptor	Pathway	Point of Exposure	Transport Distance
Humans	Drinking water	DUA	Vertical from impact down to potential DUA
Plants	Soil water	Rooting zone	Vertical from subsoil upwards to rooting zone
Plants	Irrigation from dugout	Dugout	None, dugout is assumed to be placed in area of impact
Livestock	Watering from dugout	Dugout	None, dugout is assumed to be placed in area of impact
Aquatic Life	Groundwater discharge to surface water	Surface water body	Lateral distance from nearest edge of impact to edge of surface water body

Notes:

DUA - Domestic Use Aquifer

Receptors based on agricultural land use scenario



Parameters for SST Tier 2B

Site Information

- Agricultural land use
- Central Parkland Sub-region
- Source length parallel to GW flow = 70 m

Shallow Groundwater Information

- Water table depth = 3 m
- Background Cl⁻ in shallow GW = 17 mg/L
- Background TDS in shallow GW = 1,350 mg/L
- Lateral hydraulic gradient = 0.09 m/m
- Lateral hydraulic conductivity = 1.4 x 10⁻⁷ m/s
- Calculated lateral GW velocity = 2.0 m/year



Parameters for SST Tier 2B

DUA Information

- Depth = 14 m (maximum depth drilled)
- Background Cl⁻ in DUA = 50 mg/L
- Lateral hydraulic gradient = 0.028 m/m (default)
- Lateral hydraulic conductivity = 1.0×10^{-6} m/s (default)

Soil Information

- Root zone background salinity data (e.g., EC, SAR, pH)
- Soils type: fine
- Depth of impact: 1.5 to 6.0 mbg



Results of SST Tier 2B

Pathway	Chloride Guideline (mg/kg)	Breakthrough Time (years)
Root Zone:	910	203
Livestock Watering:	2400	3
Irrigation Watering:	460	3
Aquatic Life:	60	3 Shallow Groundwater Table
		8.1 Aquatic Life Receptor Location
DUA:	750	529
Minimum Chloride G	uideline (mg/kg): 60	
Shallow Groundwate	r Guideline (mg/L): 260	

- SST Rule of Thumb: Soil Cl⁻ concentration of 100 mg/kg used to determine whether soils are classified as impacted or un-impacted.
- AENV Tier 1 guideline for protection of freshwater aquatic life (FAL) = 230 mg/L and DUA = 250 mg/L.

4. Site-Specific Salt Risk Assessment – Tier 2C

- As excavation progressed, the complexity of the residual impact increased, motivating the move to a Tier 2C-type evaluation.
- Conducted a site-specific salt risk assessment (SRA) to develop site-specific remediation guidelines for salinity-related parameters in soil and groundwater.
- Why SRA?
 - > Allow for use of additional site-specific information
 - Introduce more realism to shape/profile of chloride impact
 - Deal with impact in a stratified manner
 - **Overall Objective:** Minimize the removal of marginally impacted soils to the landfill and conserve soil as a resource.



Conceptual Model for Salt Exposure – Tier 2C

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Aquatic Life	Groundwater discharge to surface water	Surface water body	Lateral distance from nearest edge of impact to edge of surface water body
Subsoil hydraulic conductivity	Soil water	Subsurface in subsoil	None, the location of elevated SAR is assumed to be the location of maximum hazard

Notes:

DUA - Domestic Use Aquifer

SAR - Sodium Adsorption Ratio



Applicable Generic Salinity Guidelines

Criteria for the Protection of:	Rooting Zone ¹	Potable water ²	Aquatic Life ²	Irrigation ³	Livestock ²
EC, dS/m	3.0 (soil)	-	-	1.0, 2.5, >2.5 (water)	-
SAR (soil)	4.0	-	-	-	-
Chloride, mg/L (water)	-	250	230	-	-
TDS, mg/L (water)	-	500	-	-	3000

Notes:

- 1. A subsoil criterion of 3.0 dS/m, saturated paste extract electrical conductivity (EC) and a sodium adsorption ratio (SAR) of 4 correspond to the "Good" soil quality rating (AENV, 2010a).
- 2. Alberta Tier 1 Soil and Groundwater Remediation Guidelines (AENV, 2010a).
- 3. Procedures Manual for the Classification of Land for Irrigation in Alberta (AAFRD, 2004). Ranges in irrigation water EC correspond to the "Safe", "Possibly Safe", and "Hazardous" irrigation water quality categories.



SRA - Infinite Source Scenarios

- Initially, site-specific remediation guidelines were calculated for exposure scenarios where an infinite source was assumed:
 - Livestock watering from a dugout
 - Irrigation from a dugout
 - > Protection of rooting zone
- Here, the calculation of guidelines is not dependent on the initial mass of salt present, only on the concentration.
- Thus, the guidelines would apply on a site-wide basis.



SRA - Salt Guidelines for Infinite Source

Criteria for the Protection of:	Lowest	Rooting Zone	Potable Water	Aquatic Life	Irrigation From Dugout	Livestock Watering from Dugout	Subsoil Hydraulic Conductivity
Chloride, mg/kg	700	NR	See Note 1	See Note 1	700	1,910	NA
SAR	11	NR	NA	NA	NA	NA	11

Notes:

¹ The chloride criterion for potable water in a DUA and for protection of aquatic life in the creek was calculated for the impact area using detailed excavation simulation.

SAR = sodium adsorption ratio; NA = not applicable.

NR = negligible risk, current impacts are below rooting zone and upward migration is not predicted.

 The lowest site-specific Cl⁻ guideline of 700 mg/kg is equivalent to 4,200 mg/L in groundwater.



Excavation Approach

- Cl⁻ concentration of 700 mg/kg was used as remediation guideline for wall samples within Area 2 (depths >1.5 mbg).
- SST Tier 2C modeling indicated that for an equivalent depth of excavation the FAL receptor was the limiting pathway.
 - ... Base of excavation was evaluated for protection of FAL in nearby creek in an iterative manner.
- As excavation progressed, detailed base and test pit sampling was used to develop a model of Cl⁻ distribution below base.
- Due to heterogeneity in the Cl⁻ distribution below the base of the excavation, four sub-areas were defined for modeling purposes.
- The recommended depth of excavation was determined using the modeling results that were protective of FAL in creek.





Modeling Results for FAL



Summary of Modeling Results for FAL

Sub-Area Number	Calculated GW Concentration at Peak at Creek (mg/L)	
1	166	
2	0	
3	34	
4	9	
Dilution Factor	None	
Background Chloride Concentration	17	
Combined Result	226	

- Modeled peak Cl⁻ concentration at creek (226 mg/L) is below the target value of 230 mg/L – AENV Tier 1 value for FAL.
- Thus, depth of excavation of 7.0 mbg is recommended for each of the sub-areas defined in Area 2.

5. Compare SST and SRA

- Re-ran SST using residual chloride concentrations (at 7 mbg).
- Recall: initial SST Tier 2B Cl⁻ guideline was 60 mg/kg for soil and 260 mg/L for GW.

SST Calculated Chloride Guidelines

Pathway	Chloride Guideline (mg/kg)	Breakthrough Time (years)
Root Zone:	850	992
Livestock Watering:	3100	1000
Irrigation Watering:	600	1000
Aquatic Life:	80	1000 Shallow Groundwater Table
		6.9 Aquatic Life Receptor Location
DUA:	560	384
Minimum Chloride Gu	ideline (mg/kg): 80	
Shallow Groundwater	Guideline (mg/L): 340	

Compare SST and SRA

 Area-specific Cl⁻ guidelines are much higher (less stringent) than the remediation guideline calculated with SST Tier 2B.

D 1 1 4

Sub-Area Number	Depth Interval (m)	Chloride Concentration (mg/kg)
1 (TP205)	7 to 8	1000
	8 to 9	1050
	9 to 10	920
	10 to 11	540
	11 to 12 ¹	400
	12 to 13	300
	13 to 14	200
2 (TP202)	7 to 8	360
3 (TP201)	7 to 8	670
	8 to 9	230
4 (TP228)	7.5 to 8.5	220

SST Calculated Chloride Guidelines

Pathway	Chloride Guideline (mg/kg)
Root Zone:	850
Livestock Watering:	3100
Irrigation Watering:	600
Aquatic Life:	80

DUA:	560		
Minimum Chloride Guide	line (mg/kg):	80	
Shallow Groundwater Gu	ideline (mg/L):	340	

Compare SST and SRA

- Why do remediation guidelines developed through SST Tier 2B appear overly conservative as compared to SRA?
 - Large source length
 - SST assumes a fixed source width (50 m)
 - > SST assumes a distance to the creek of 50 m



DRA7

DRA7 On this slide we should be trying to show the SST calc shown below and Exhibit B-4 in the SRA report. David Alberti, 10/17/2011

Compare SST and SRA

	SST	SRA
Excavation Area (m ²)	2,900	2,100
Excavation Depth (m)	10.0	7.0
Volume (m ³)	24,650	11,550
Cost (million \$)	2.5	1.2

- Areas of impact have been estimated based on soil data for the site.
- Assuming surface soil (0.0 to 1.5 mbg) is salvaged/reused.
- At complex sites, SST Tier 2B good screening tool for preliminary cost estimate?



6. Conclusions

- SRA approach was appropriate for the site based on the available site-specific information and conditions.
- SRA allowed for minimization of the removal of marginally impacted soils to the landfill thereby:
 - I. contributing to conservation of an important resource soil; and,
 - II. providing cost-savings.
 - At complex sites, SST may be useful as a screening tool but is limited wrt to the quantity of site-specific data that can be incorporated.







QUESTIONS

