Equilibrium Environmental Inc

Subsoil Salinity Tool (SST)

Technical Manual and FAQ

Greg Huber, M.Sc., P.Eng., PMP
Anthony Knafla, M.Sc., P.Biol, DABT

RemTech 2025 –

PTAC Remediation Reclamation Session

October 15, 2025

Presentation Overview

- **Version 3.0 Technical Manual**
  - **Purpose and Contents**
  - **Examples from different sections**
    - **General Modeling**
    - **Chloride**
    - **SAR/sodium**

- **SST FAQ (Frequently Asked Questions)**

- **SST Courses**

SST Technical Manual: Contents

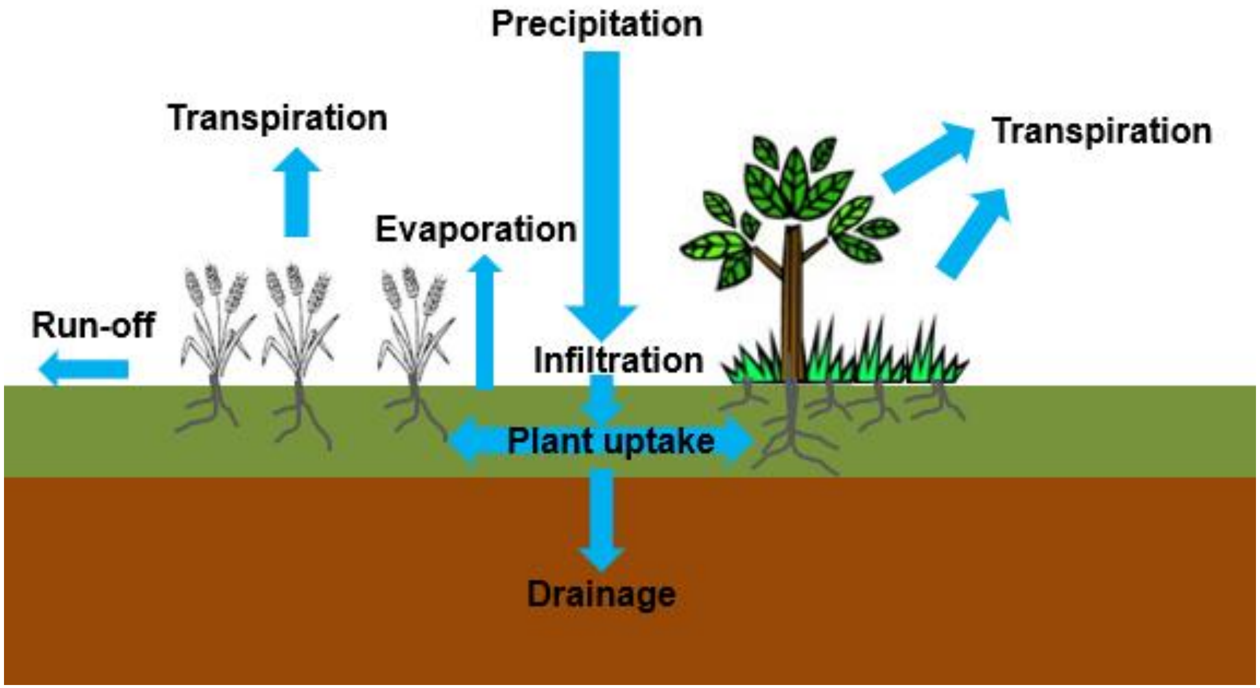
- Existing ‘User Manual’ focuses on use of tool
- ‘Technical Manual’ provides additional supporting detail for the algorithms and modeling approach used in the SST
- Divided into four main sections
  - General Modeling Info
  - Chloride Modeling
  - SAR/Sodium Modeling
  - SAR Effects on Soil

TABLE OF CONTENTS

General Modeling Information

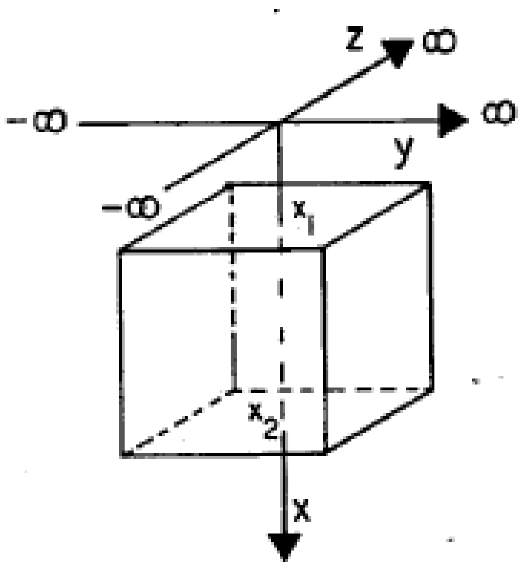
Vertical Transport Modeling

- **Discusses details of main vertical transport model (LEACHM) and assumptions**
- **Complex 1-dimensional model incorporating many aspects of climate, soil, water, and solute transport**



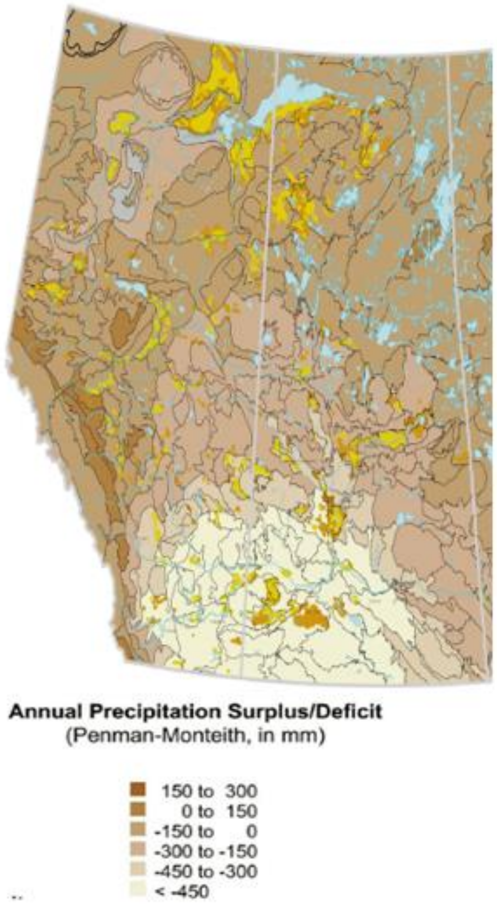
Horizontal Transport Modeling

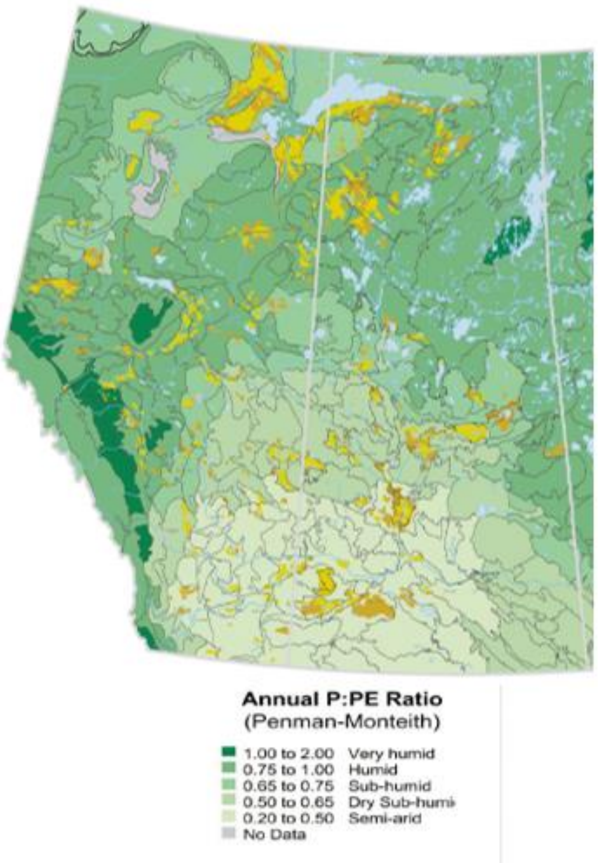
- Discusses details of main horizontal transport model (3DADE) and assumptions
- Simpler model, but considers diffusion, advection, and dispersion in three-dimensions.
- Used for both lateral transport modeling (eg, to aquatic receptors), and for lateral smearing during vertical transport (eg, to Domestic Use Aquifer)



Climate

- **Additional detail provided for the climate information used for transport modeling**
  - **Factors such as Precipitation (P) and Potential Evapotranspiration (PE)**
- **Affects water balance, drainage rates, and risk to various receptors such as root-zone and DUA**

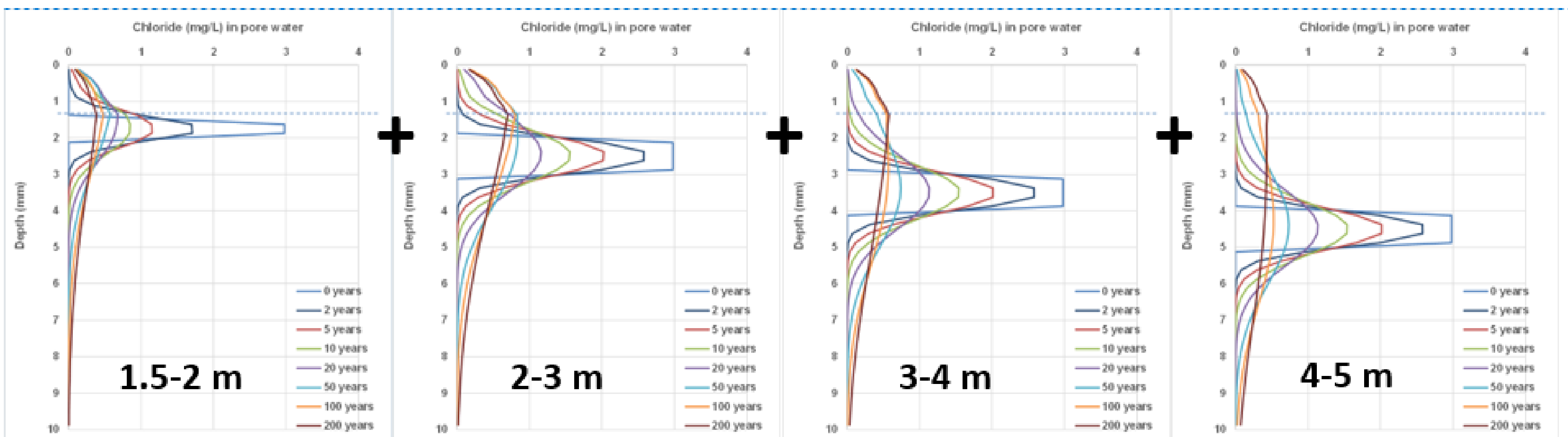


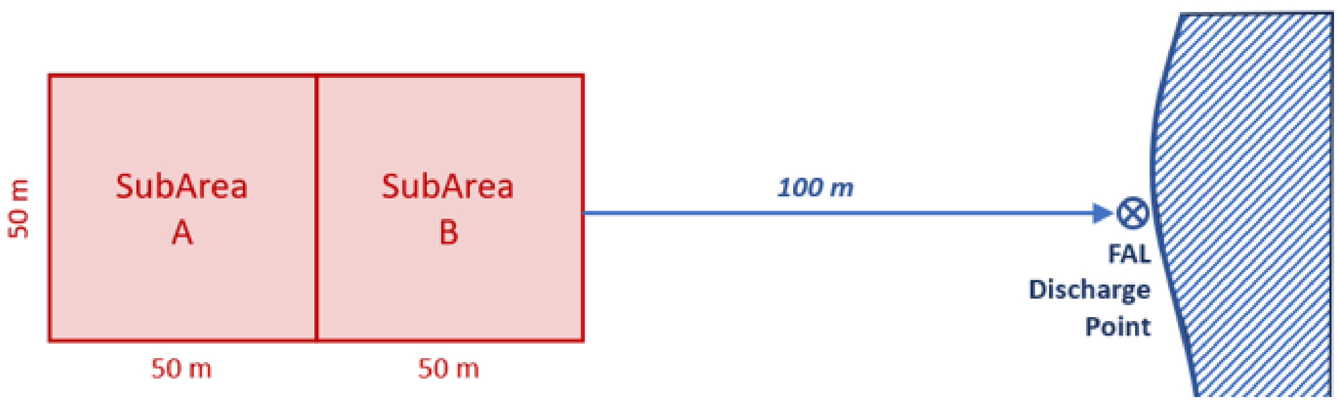


Chloride Transport Modeling

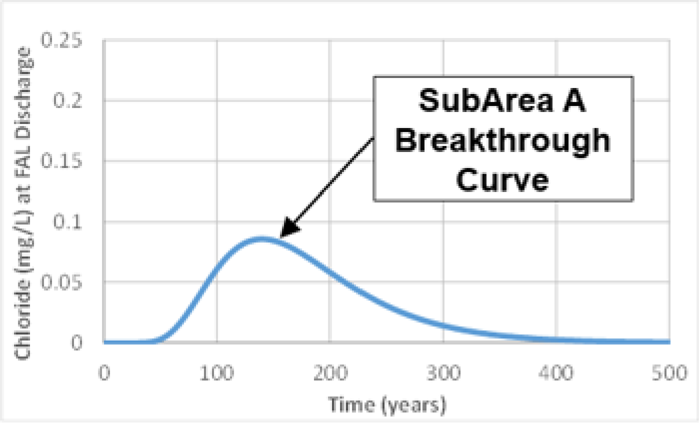
Principle of Superposition

- **Key concept to allow wide range of scenarios to be modeled by breaking them into small pieces, modeling each piece, and then recombining**
  - **Broad application both vertically (top) and laterally (bottom)**

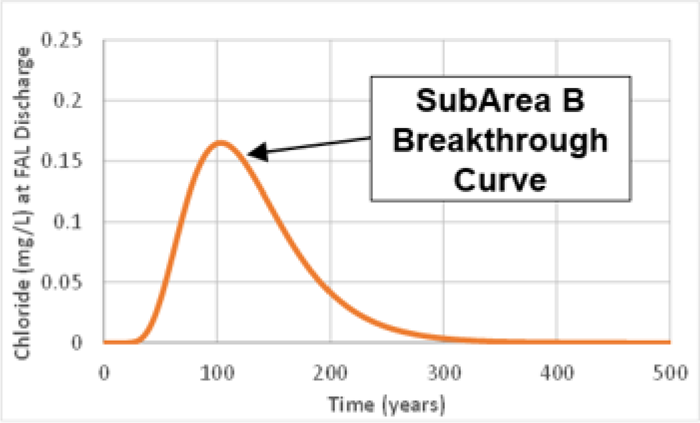




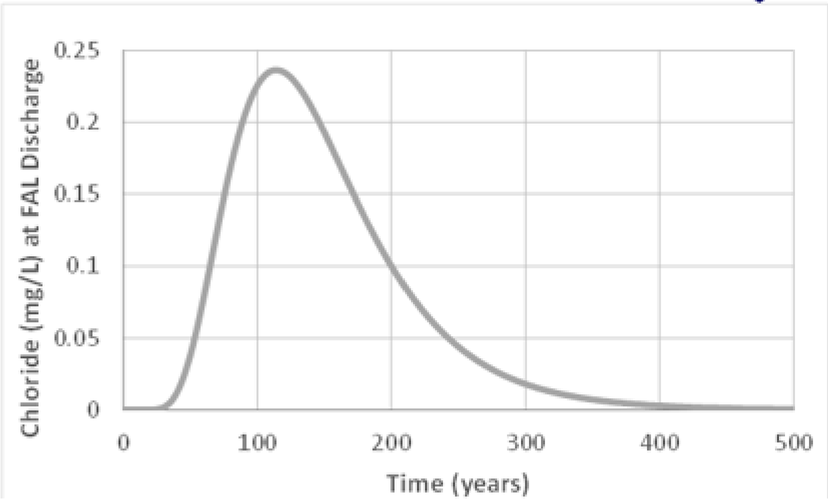
Principle of Superposition: Horizontal



+



Summated A + B Breakthrough Curve

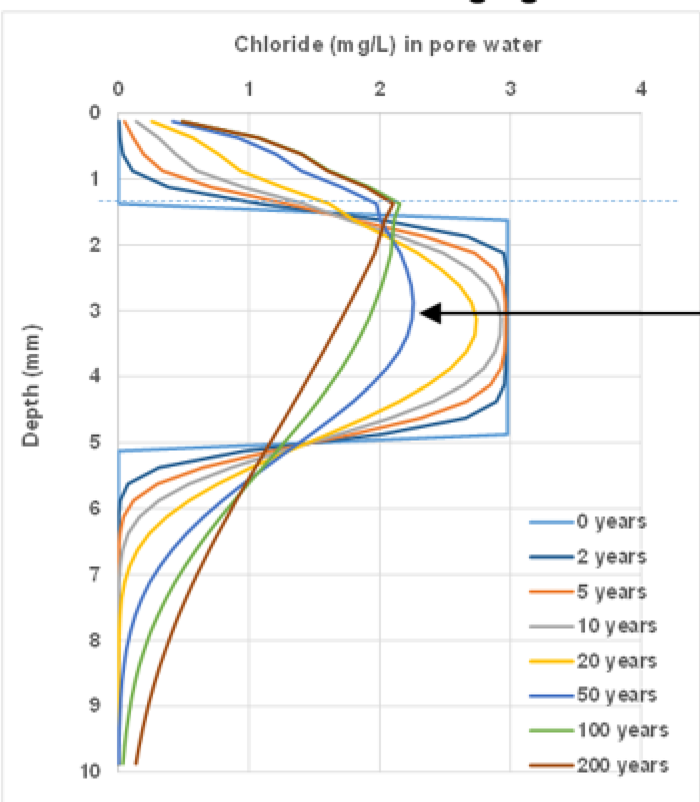


- **Tool would not be possible to implement in any practical way without this concept (except for very simple scenarios)**

Linear Scaling

- **Another key modeling concept allowing runs at standardized concentrations to be performed and concentrations then ‘scaled’ to actual site conditions**
  - **Like superposition, the SST would not be possible to implement without this technique**

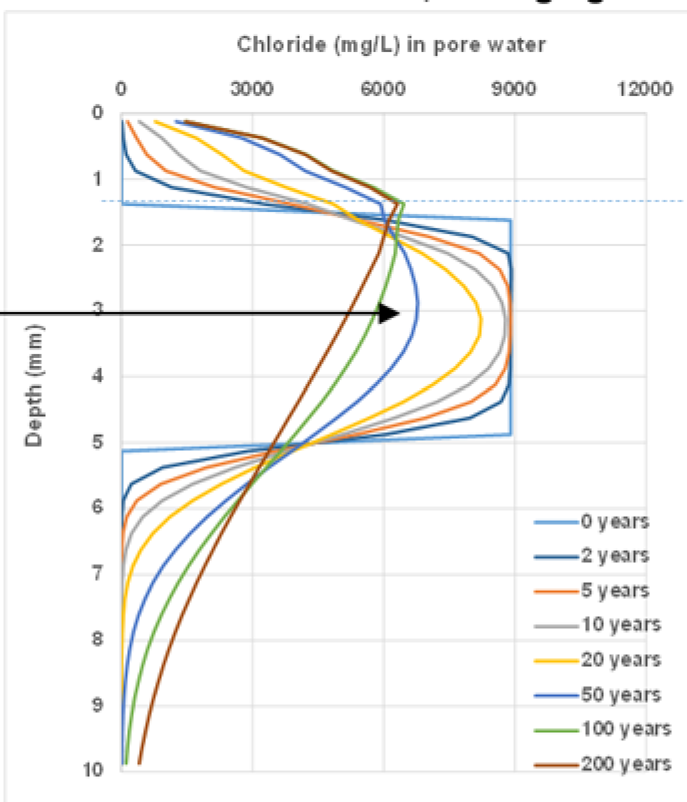
Initial Concentration of 1 mg/kg



Vertical profiles scale linearly for initial concentrations (in this case, two LEACHP runs differ by 3,000-fold but retain same relative behavior)

e.g. at 50 yrs the peak concentration is at 3 m and 76% of initial concentration (regardless of the absolute magnitude of the initial concentration)

Initial Concentration of 3,000 mg/kg



LEACHM Details

- **LEACHM is based on solving complex differential equations to model vertical flow of both water and solute**
  - **LEACHP sub-module most suitable for SST and chloride aspects**
- **'Richards Equation' for water flow**
  - **Super-messy (glad the LEACHP program does it…)**
  - **Uses parameters such as water capacity, pressure head, vertical distance**

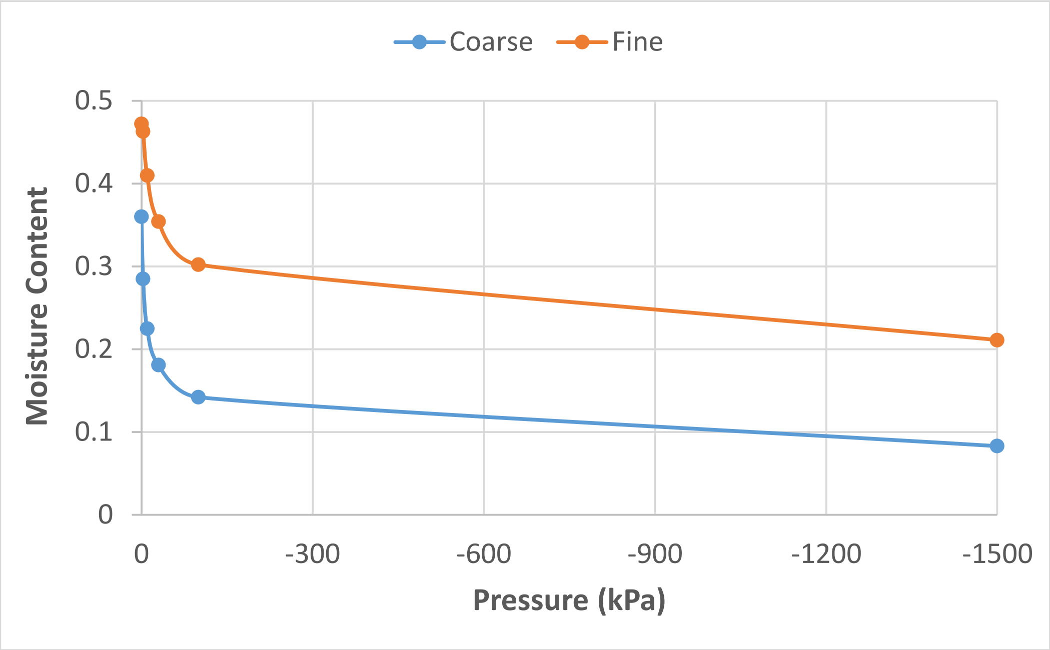
$$\frac{\partial h}{\partial t}C(\theta) = \frac{\partial}{\partial z}\left[K(\theta)\frac{\partial H}{\partial z}\right] - U(z,t)$$

- **'Convection-Dispersion Equation' for solute flow**
  - **Also super-messy**
  - **Uses parameters such as concentrations, diffusion coefficients**

$$\frac{\partial(\theta c)}{\partial t} = \frac{\partial}{\partial z}\left[\theta D(\theta,q)\frac{\partial c}{\partial z} - qc\right]$$

LEACHP Details (cont'd)

- **Other parameters used in LEACHP modeling also discussed**
  - **bulk density, porosity**
  - **hydraulic conductivity**
  - **moisture retention**

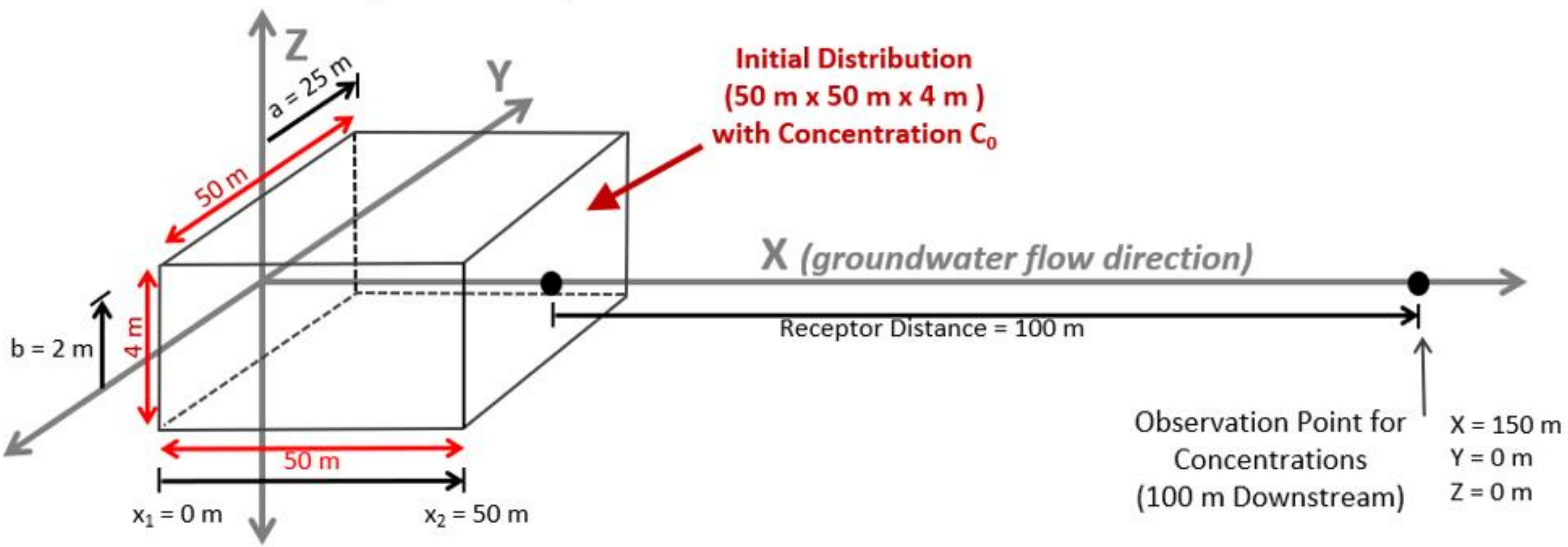


Parameters	**Fine Texture (median < 75 µm)**	**Coarse Texture (median > 75 µm)**
Bulk Density (g/cm³)	1.4	1.7
Total Porosity	0.47	0.36
Hydraulic Conductivity at Saturation (mm/d)	0.88	8.8
Hydraulic Conductivity at Saturation (m/s)	1.0×10^{-8}	1.0×10^{-7}
Campbell's Parameter 'a'	-3.47	-0.938
Campbell's Parameter 'b'	7.54	5.058
Moisture Content at -3 kPa	0.463	0.285
Moisture Content at -10 kPa	0.410	0.225
Moisture Content at -30 kPa	0.354	0.181
Moisture Content at -100 kPa	0.302	0.142
Moisture Content at -1500 kPa	0.211	0.083

3DADE Details

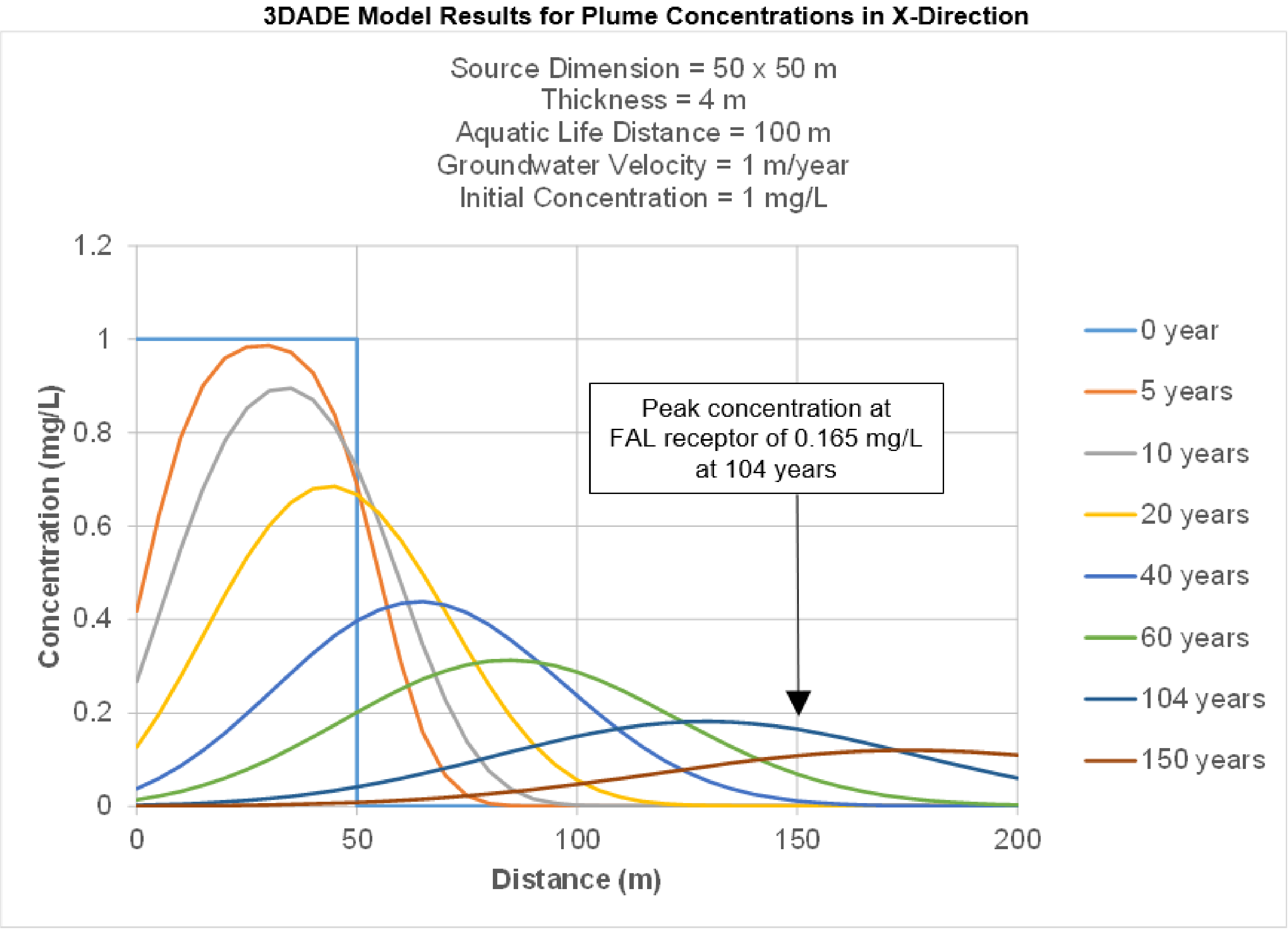
- **3DADE used to model lateral transport of water and solute over three dimensions**
- **Primary use in SST is for lateral transport to aquatic life receptors (FAL)**
- **Based on defining parameters for different subareas such as:**
  - **Source dimensions** **- distances to receptors**
  - **groundwater velocity** **- impact thicknesses**

3DADE Model Inputs for an Impact Source Dimension of 50 x 50 m and FAL distance of 100 m



3DADE Results Interpretation

- **3DADE output processed to provide "Breakthrough Curves" which are used throughout the SST for guideline calculation**
- **Peak breakthrough concentrations and times are key outputs**

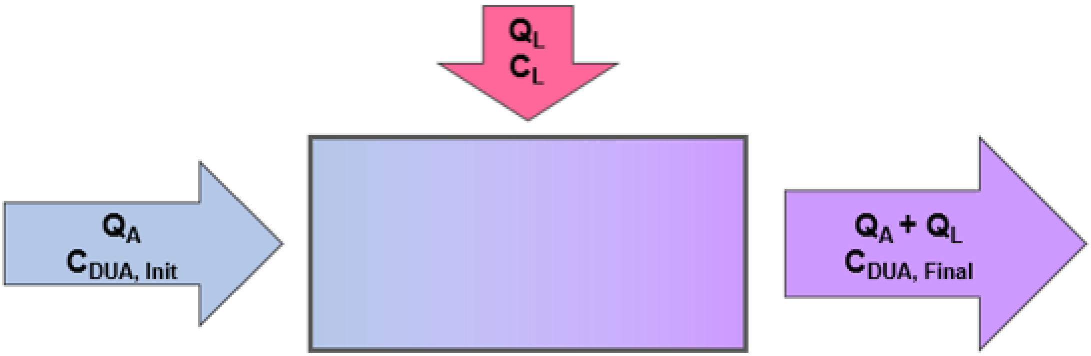


DUA Guideline Calculations

- DUA pathway is a complex pathway where both LEACHP and 3DADE components are used for transport (3-D)
- Combined with additional 'dilution' calculations into DUA
  - Dilution calculations used in SST are a more generalized implementation of "DF3" used in Tier 1 / Tier 2 model

- Single Subarea implementation:

Summers Mixing Model (Mass Balance) Approach for DUA Dilution

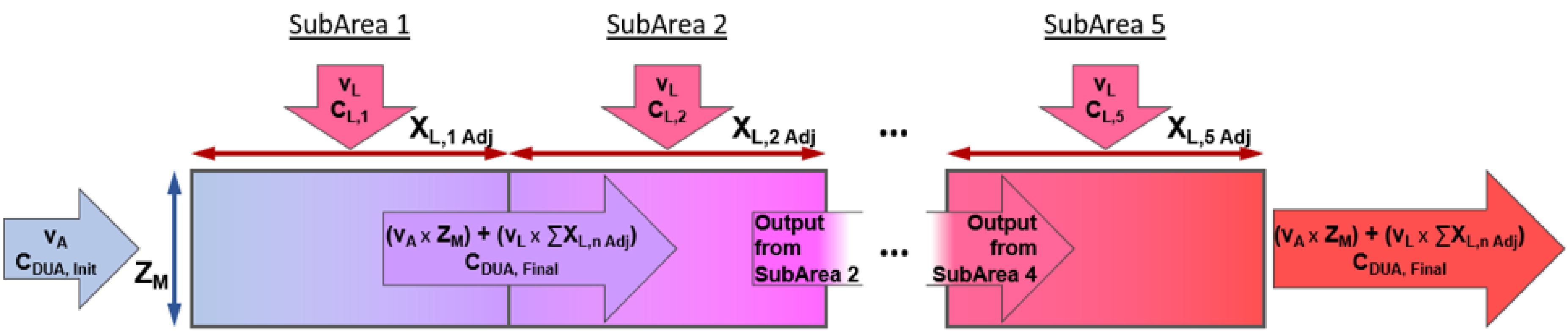


$$C_{DUA,Final} = \frac{Q_L \times C_L + Q_A \times C_{DUA,Init}}{Q_L + Q_A}$$

DUA Guideline Calculations (cont'd)

- **Also implemented for multiple subareas**
- **More complex calculations, but necessary for most sites**
- **Algorithm ensures that DUA is protected not only below each subarea, but for the combined loading of all subareas**

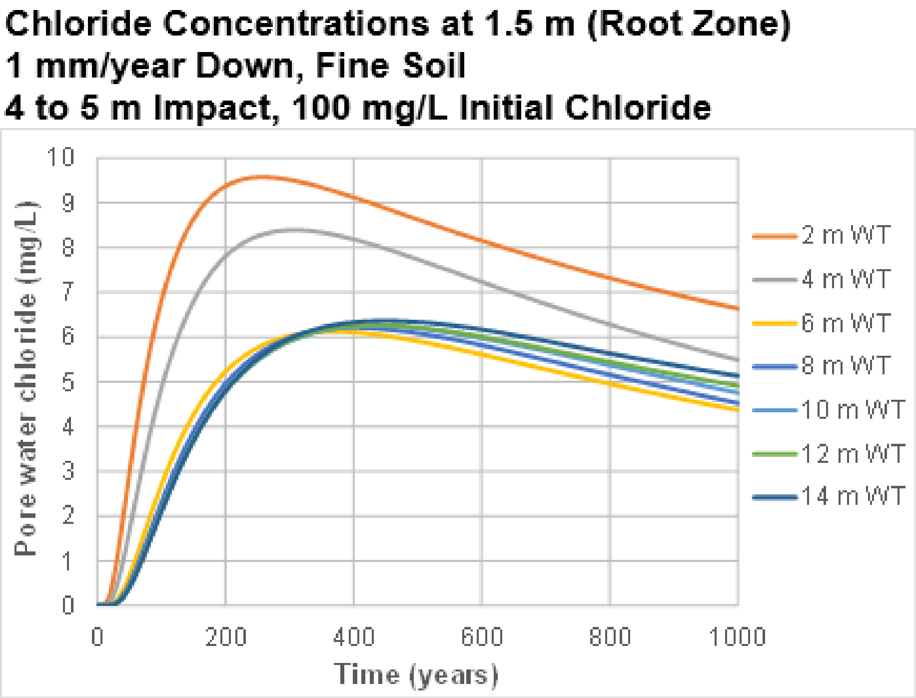
Stepwise Summers Mixing Model for DUA Dilution of Multiple SubAreas

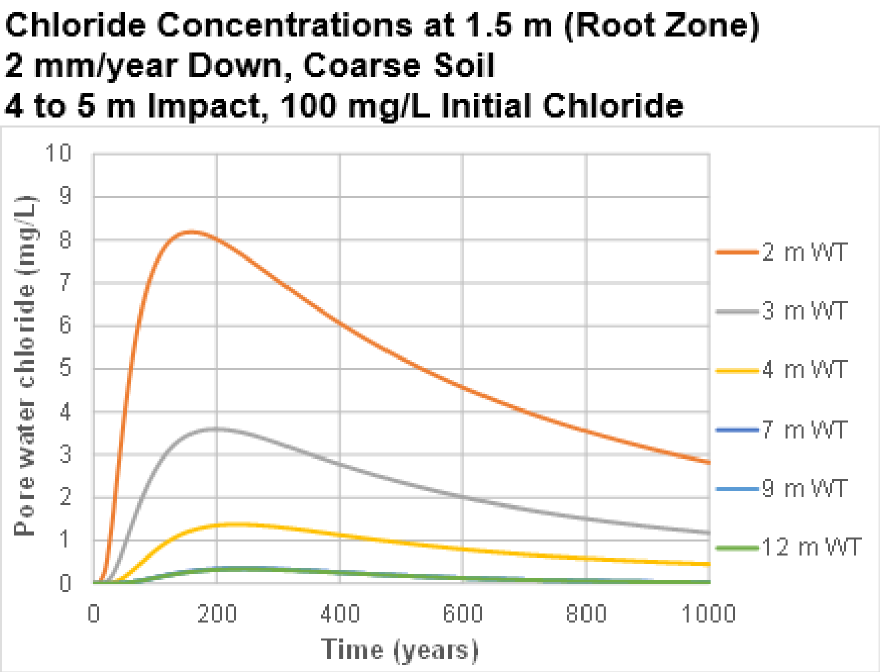


$$C_{DUA,Final} = \frac{(v_A \times Z_m) \times C_{DUA,Init} + v_L \times \sum_1^n (C_{L,n} \times X_{L,n\,Adj})}{(v_A \times Z_m) + v_L \times \sum_1^n (X_{L,n\,Adj})}$$

Water Table Effects

- **Version 3.0 of SST incorporated much more complex set of algorithms for upward chloride transport into root-zone taking water-table depth into account more directly**
- **Deeper water table → drier soils → slower upward diffusion**
  - **More pronounced effect for coarse soils**

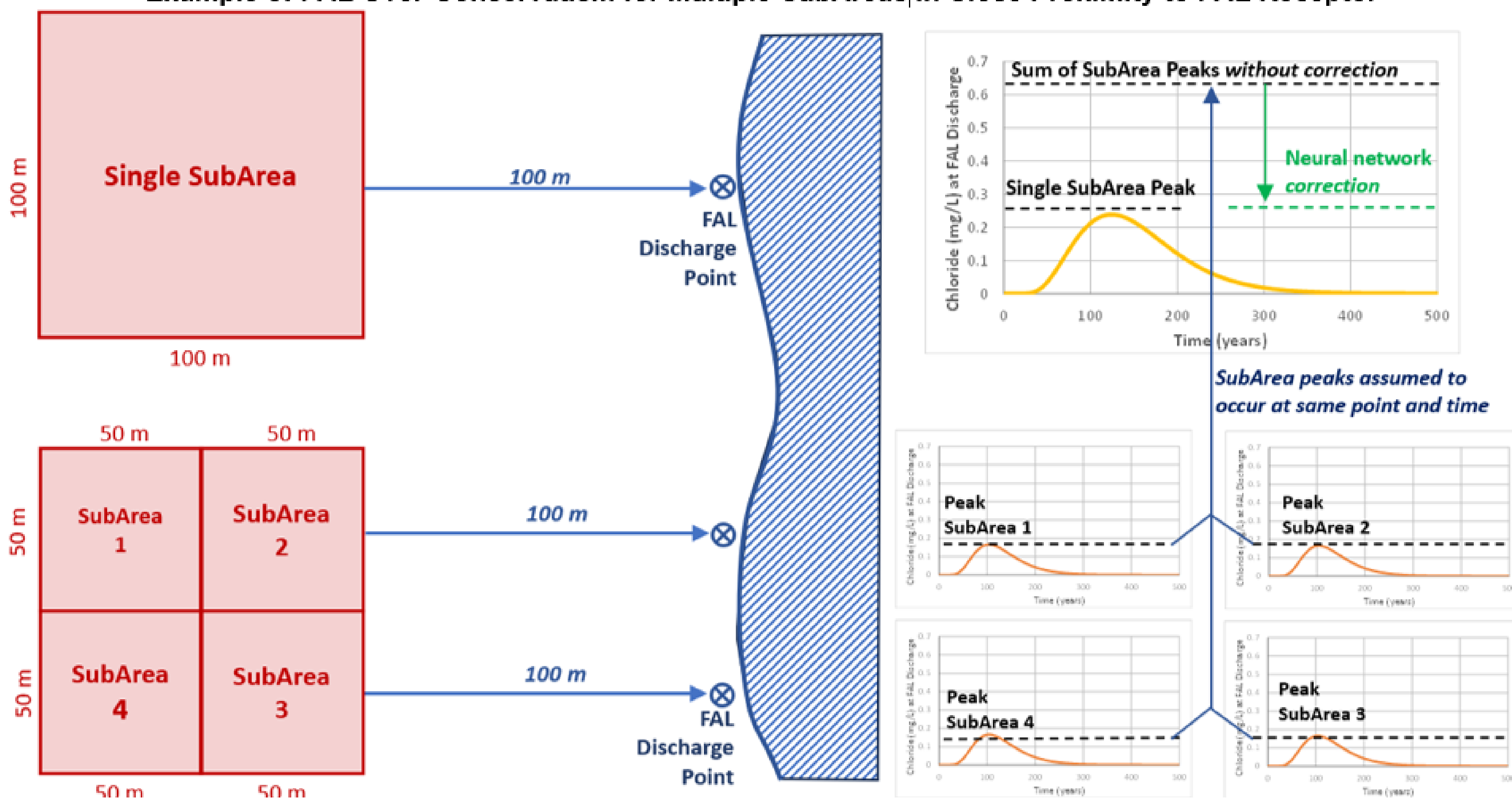




Aquatic Life Transport

- **Complex approach used for multiple subareas for FAL**
- **Includes a neural network to remove over-conservatism**

Example of FAL Over-Conservatism for Multiple SubAreas in Close Proximity to FAL Receptor

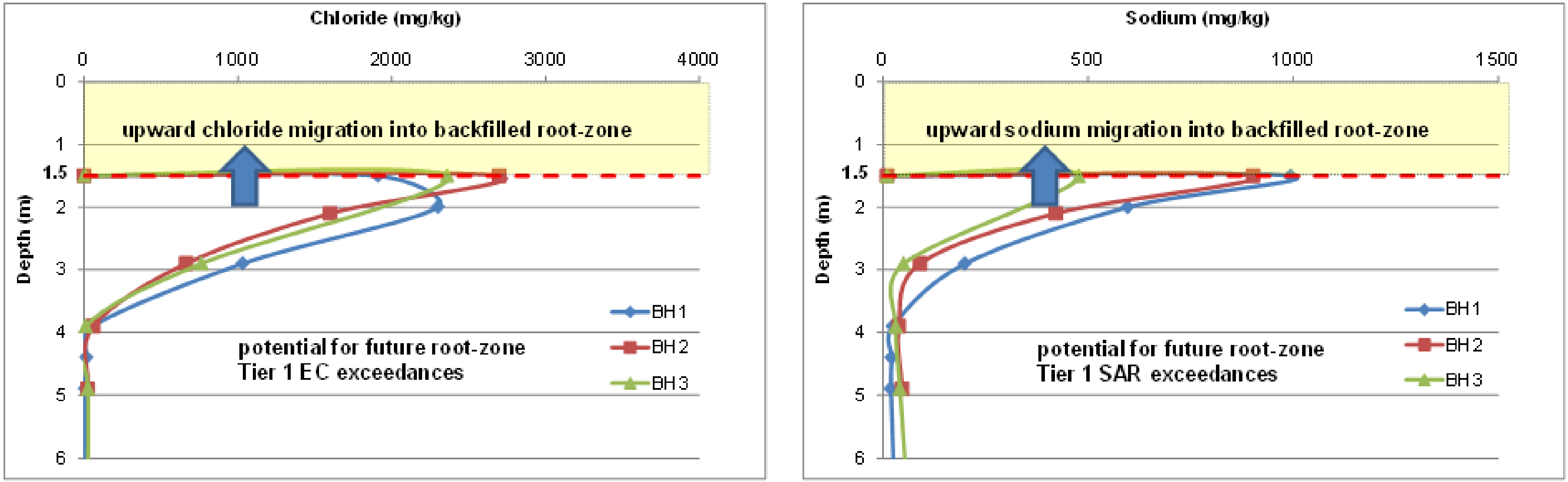


SAR and Sodium Transport Modeling

Sodium Transport

- **Sodium transport modelled in SST Version 3.0**
  - **Primarily modelled upward into root-zone as key pathway**
  - **Relevant to potential future root-zone SAR exceedances**

Example Chloride and Sodium Depth Profiles After 1.5 m Root-Zone Excavation



- **Sodium modeled similar to chloride, but with adjustments due to cation exchange effects**
  - **Substantial more complexity, handled in LEACHC sub-module**

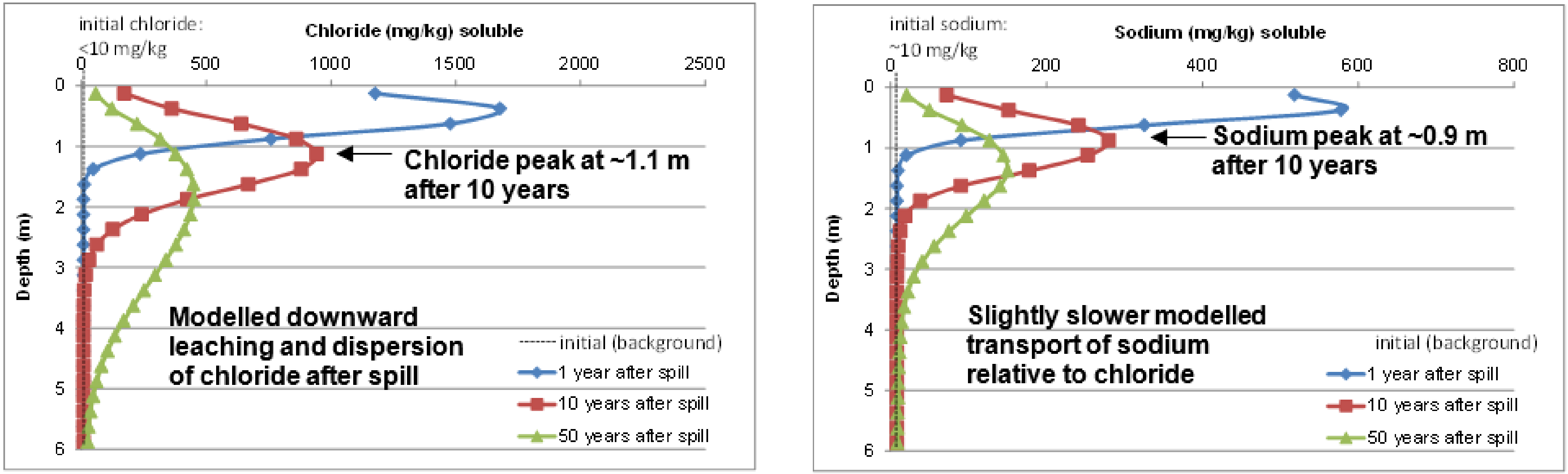
Sodium Transport (cont'd)

- **Cation exchange reactions result in slowing of sodium transport relative to chloride**
  - **Sodium and calcium exchange on cation exchange complex**

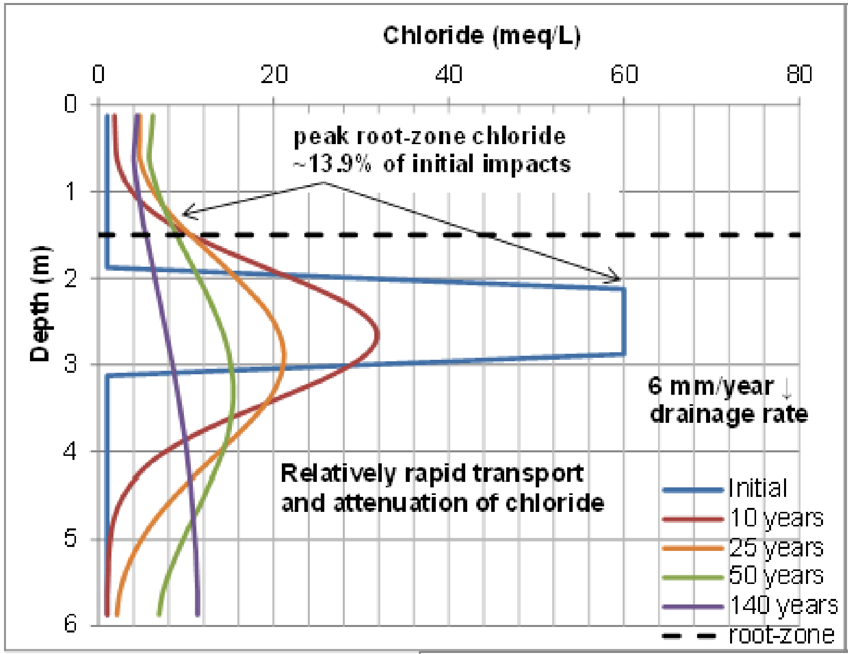
$$\text{adsorbed calcium} + NaCl \leftrightarrow \text{adsorbed sodium} + CaCl_2$$

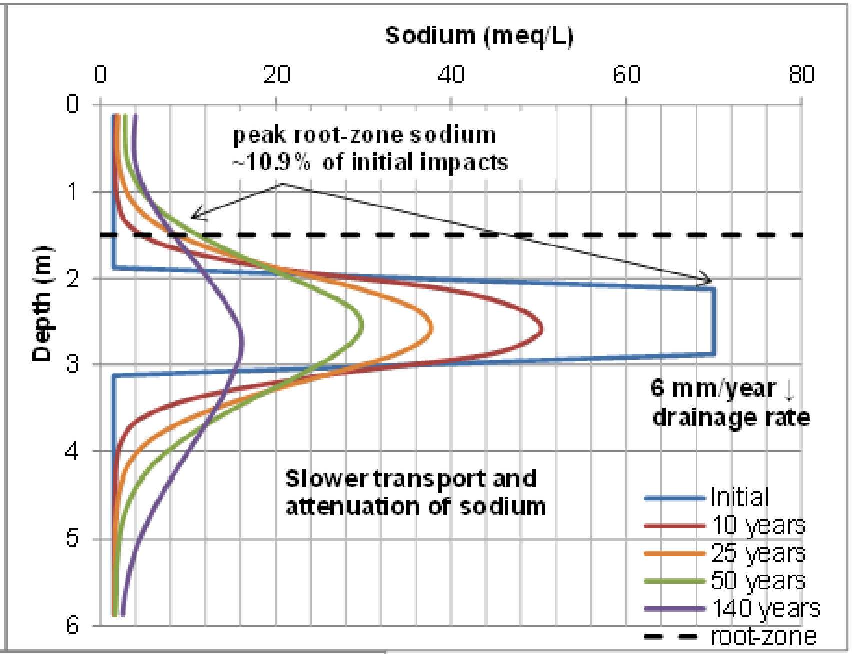
- **Net effect: chloride gets further, faster**
  - **Sodium has more tendency to linger closer to initial source area**
  - **Elevated SAR can persist longer than elevated chloride or sodium**

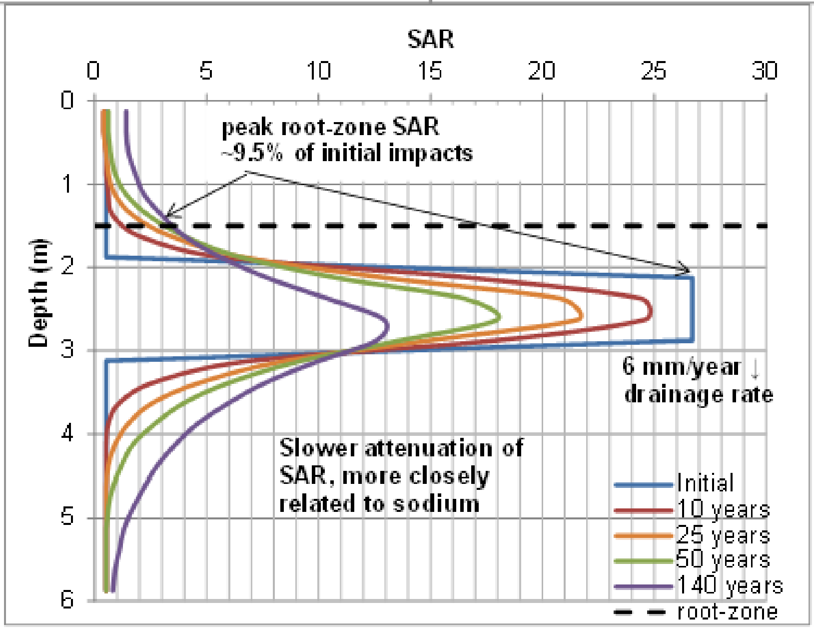
Example of Modeled Soluble Ion Concentrations After Produced Water Spill



Example of Modeled Sodium, Chloride, and SAR transport
(initial impacts 2-3 m with CEC=240 meq/kg)







- **Chloride, sodium, and SAR all modeled / estimated in SST for guideline calculations**

Sodium Guideline Calcs

- **Examples provided of the process used to calculate subsoil sodium guidelines to protect root-zone from upward migration**
  - **Complex, multi-step calculation process (example of first steps below)**

Parameter	Value	Source
User-entered parameters		
Soil texture	Fine	User entered (>18% clay as per SST protocol). Assumed consistent for both root-zone and subsoil.
Root-zone scenario	Excavate+backfill	User-entered
Backfill average EC	1 dS/m	User-entered
Backfill average SAR	1	User-entered
Calculated parameters: Tier 1 SAR guideline and SAR buffer		
Root-zone Tier 1 SAR guideline	4	Previously calculated
SAR buffer	4	Previously calculated
Calculated parameters: Initial root-zone		
Initial backfill EC	1 dS/m	Previously calculated
Initial backfill SAR	1	Previously calculated
Initial backfill total cations	12 meq/L	Previously calculated
Initial backfill sodium	2.21 meq/L	Previously calculated
Initial backfill Ca+Mg	9.79 meq/L	Previously calculated
Calculated parameters: Future root-zone		
Initial $(Ca+Mg)^{1/2}/Na$ in root-zone	13.84	Calculated from initial Ca+Mg concentrations (meq/L)
Exponent for relative SAR vs Na increase	0.750	Calculated from fine regression ($y=0.5338x^{0.1292}$)
Relative SAR increase (x-fold)	4	Equivalent to SAR buffer
Relative sodium increase (x-fold)	6.36	Calculated from exponent and relative SAR increase ($=4^{1/0.75}$)
Future root-zone sodium	14.06 meq/L	Based on initial sodium and relative sodium increase
Future root-zone Ca+Mg	24.71 meq/L	Based on future SAR and sodium
Future root-zone EC	3.23 dS/m	Calculated from future total cations
Future root-zone SAR	4	Back-calculated as a check

-all EC, SAR, and cation concentrations above on a saturated paste basis

SAR Effects on Soil Structure

- **Section 4 provides a comprehensive summary of the SAR research conducted over the last 10+ years to support subsoil SAR guideline derivation in SST Version 3.0**
  - **Wide range of topics including literature results, Alberta-specific soil core experiments, water table modeling, and guideline derivation process**

SST Frequently Asked Questions (FAQ)

- **A way for the SST user community to engage and get feedback on important topics / questions**
- **Process:**
  - **Send questions to SSTInfo@eqm.ca**
  - **Questions are announced on EEI LinkedIn page once complete**
  - **Question and Answer provided on FAQ page:**
    https://www.eqm.ca/faq

- **Answers to key questions will also involve regulatory vetting**

SST Frequently Asked Questions (FAQ)

Six technical questions with vetted answers to be posted shortly:

- **Is there a Tier 1 chloride guideline for soil?**
- **What is the chloride delineation objective for soil?**
- **When should I use the SST?**
- **How do I decide between a Tier 2A and Tier 2B SST assessment?**
- **Is 100 mg/kg chloride ever used as a site-specific remedial objective?**
- **How are SST guidelines used to evaluate confirmatory samples when performing an excavation?**

SST Courses

Full Certification Course (3.5-day)

April 2026 – dates TBD

SST Overview Course (1-day) *NEW*

April 2026 – dates TBD

Advanced SST Techniques Course (1-day) *NEW*

April 2026 – dates TBD

For further information:

Visit our webpage at www.eqm.ca

Or contact SSTinfo@eqm.ca

Or visit our LinkedIn page

Acknowledgements

- Alberta Environment and Protected Areas
- Alberta Energy Regulator
- Petroleum Technology Alliance of Canada (PTAC)

Thank you!

SSTinfo@eqm.ca