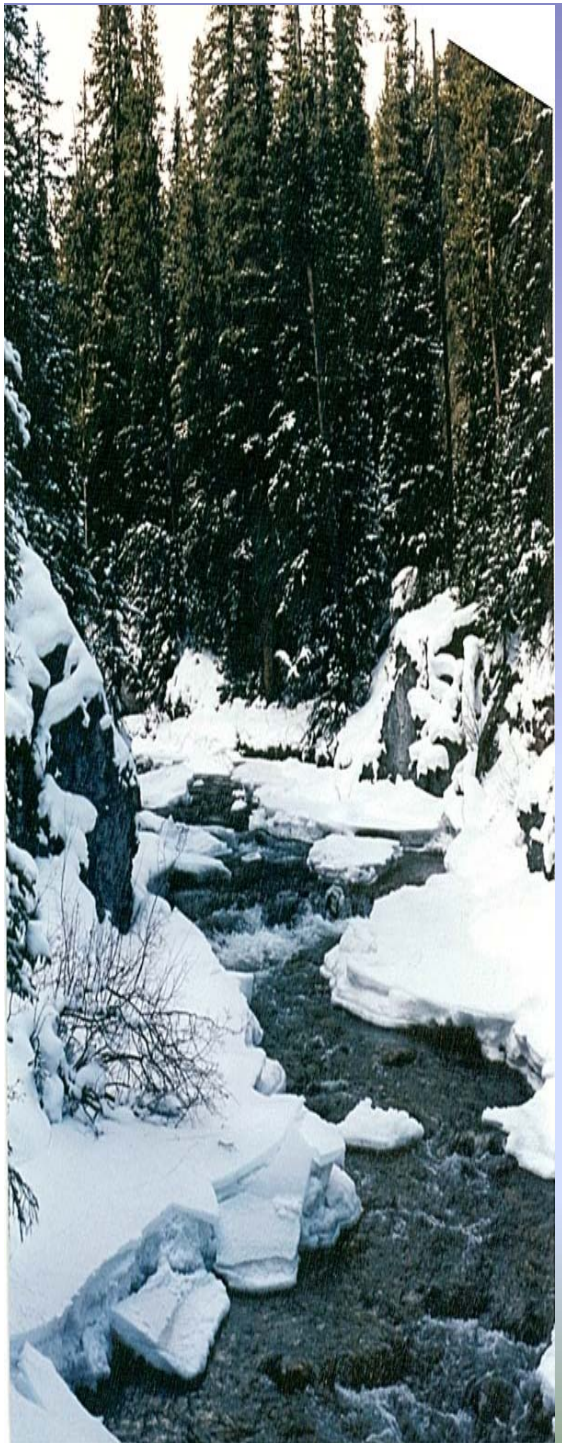

Implementation of Subsoil SAR Guidelines into Subsoil Salinity Tool

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Presentation Overview

- **Subsoil SAR/Sodium Pathways for SST Implementation**
- **SST SAR Implementation and Case Study**
- **SST Sodium Guidelines and Considerations**
- **Summary and Next Steps**

Subsoil SAR/Sodium Pathways for SST Implementation

Subsoil SAR/Sodium Pathways for SST

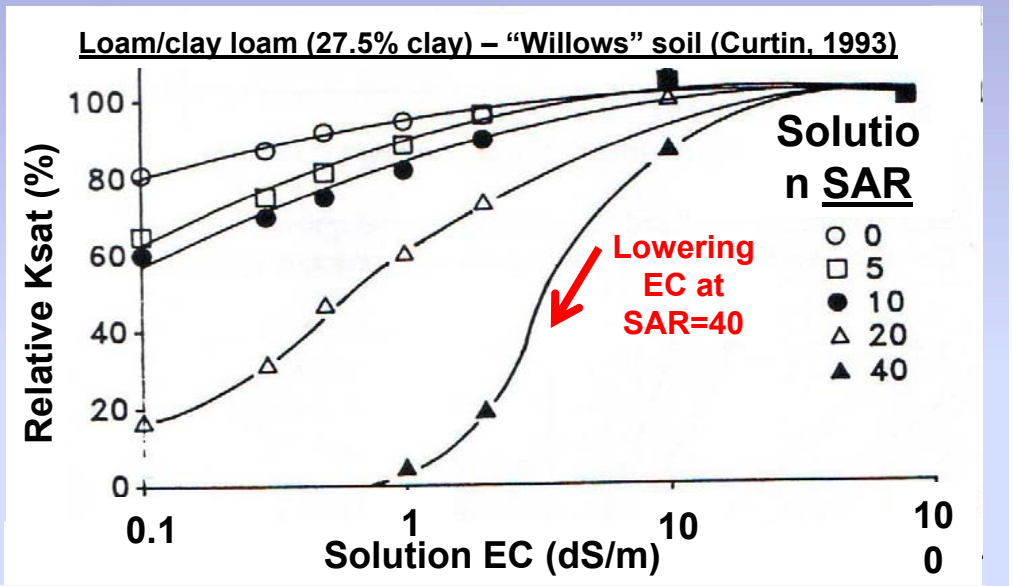
- **Subsoil Salinity Tool (SST) is a software tool which allows generation of Tier 2 salinity guidelines for subsoil using various site-specific data**
- **Tier 1 guidelines generally applied to root-zone soils (1.5m), with the subsoil guidelines intended to prevent future Tier 1 root-zone or groundwater exceedances**
- **Current SST implementation is for chloride, with recent PTAC/PERD- funded research also aimed toward implementing:**
  - **Subsoil SAR guidelines (this presentation)**
  - **Subsoil sulfate guidelines (see poster)**
- **Standard SST pathways for chloride protect:**
  - **Root-zone (upward migration)**
  - **Livestock watering (from dugout)**
  - **Human drinking water (from DUA)**
  - **- Aquatic life (lateral transport)**
  - **- Irrigation water (from dugout)**
- **Consultations with Alberta Environment and PTAC Salinity Working Group have identified three key risk pathways for subsoil SAR:**
  - **Soil structure**
  - **Root-zone (upward migration)**
  - **Irrigation water (from dugout)**

  Two pathways similar to chloride, one pathway new
- **Various technical/policy aspects of each pathway discussed…**

Soil structure pathway

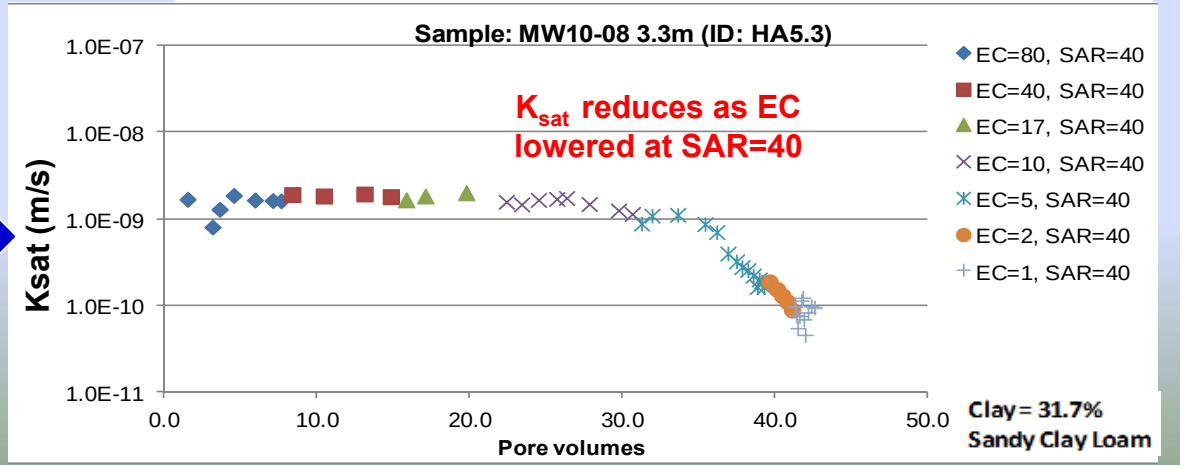
- Elevated SAR can cause dispersion of clay particles, disruption of soil structure, and loss of hydraulic conductivity (K_{sat})
  - Particularly problematic in root-zone (e.g., infiltration problems)
  - Poses less risk in subsoil, but could potentially result in water-logged root-zone or perched water table

- Literature threshold curves (e.g., Curtin and Steppuhn) show EC to have a protective effect on soil structure using repacked soil cores



- Confirmed and expanded with PTAC/PERD-funded leaching column experiments on undisturbed Alberta soil cores

- Allows estimation of K_{sat} losses as function of texture



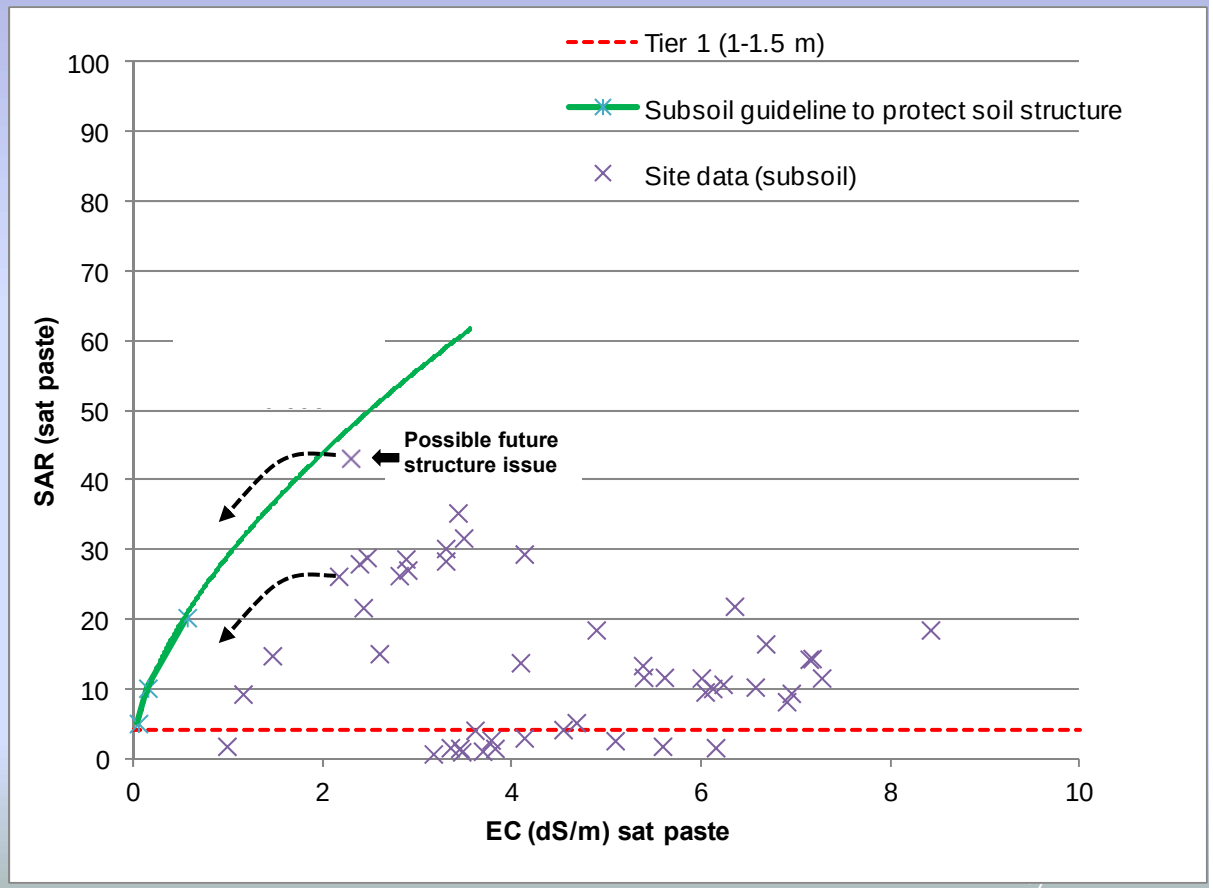
Soil Structure cont'd: K_{sat} thresholds

- **K_{sat} threshold will be chosen by SST based on soil texture and other factors such as water table depth, impact depth and dimensions**
  - **A typical threshold will be 10-fold, a typical level which is distinguishable from natural variability and may cause a water-logged root-zone in some cases**

- **10-fold K_{sat} reduction threshold for high-clay soil shown based on literature and Alberta leaching column experiments→**

- **Site subsoil SAR data should be below/right of threshold for less than 10-fold K_{sat} loss**
  - **All data OK at present→**

- **Also need to consider that future EC reductions toward background will occur faster than SAR reductions**
  - **Could conservatively address by assuming EC reverts to background at constant SAR**

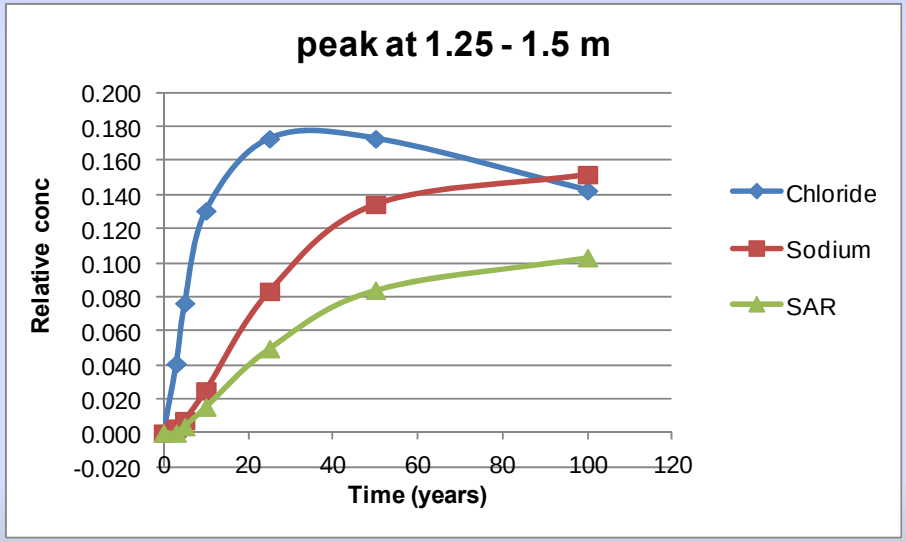


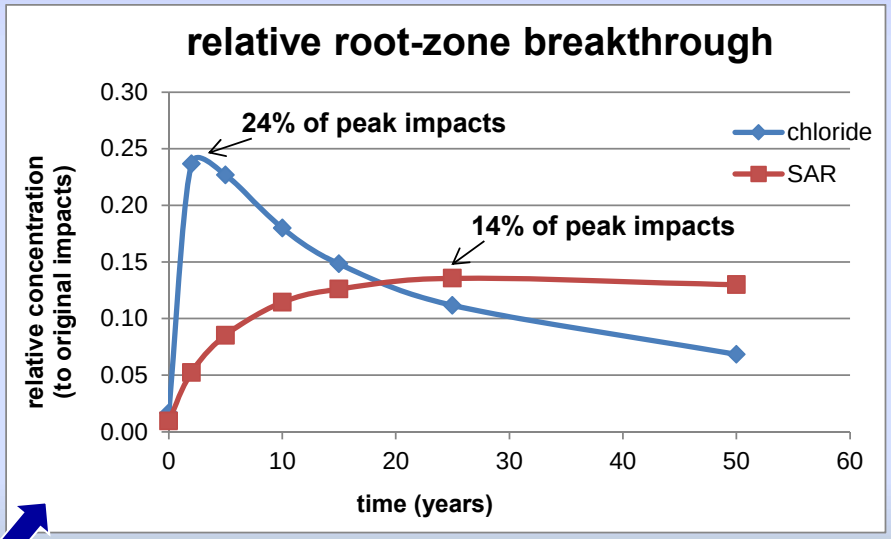
Upward migration of SAR into root-zone

- Elevated SAR/sodium in subsoil may migrate upward into root-zone and cause potential future root-zone Tier 1 SAR exceedances
- Also an important pathway for chloride in the SST
- Amount of upward transport affected by SST input parameters such as:
  - Climate
  - Soil texture
  - Drainage rate
  - Top of impacts
  - Bottom of impacts
- Acceptable amount of upward transport dependent on root-zone salinity and how close they are to Tier 1 guidelines ('buffers')
- SST protocol currently estimates this upward transport for chloride
  - can be modified for SAR/sodium transport…

Upward migration (cont'd)

- SAR/sodium tends to transport more slowly than chloride due to the buffering effect of cation exchange reactions
  - predicted by theory and observed in Alberta leaching column experiments
- Leaching of SAR/sodium into root-zone was modeled to be slower and have a lesser relative peak than chloride
  - Modeled with 'LEACHC' program
  - complex function of water transport, background salinity, cation exchange, and impact characteristics





- Here, SAR peak is approx 55-60% of chloride peak (fairly typical)
  - In this case 1 mm/year drainage and CEC of 240 mg/kg

Irrigation from dugout pathway

- As per SST protocol for chloride, water may be sourced from a dugout and potentially used for irrigation
  - applies to agricultural land-use
- Dugouts are modeled to largely collect surface water, but also could have a contribution from contaminated groundwater
  - Depends on factors such as soil texture and water table depth
- SAR/sodium concentrations in dugout water can be modeled with modified SST techniques, but what target to use?

- Alberta SCARG document shows irrigation SAR thresholds of:

  <4: 'safe' 4-9: 'possibly safe' >9: 'unusable'

- These guidelines anot explicit about whether SAR guidelines should be a function of EC, but imply the possibility since EC is protective of SAR effects

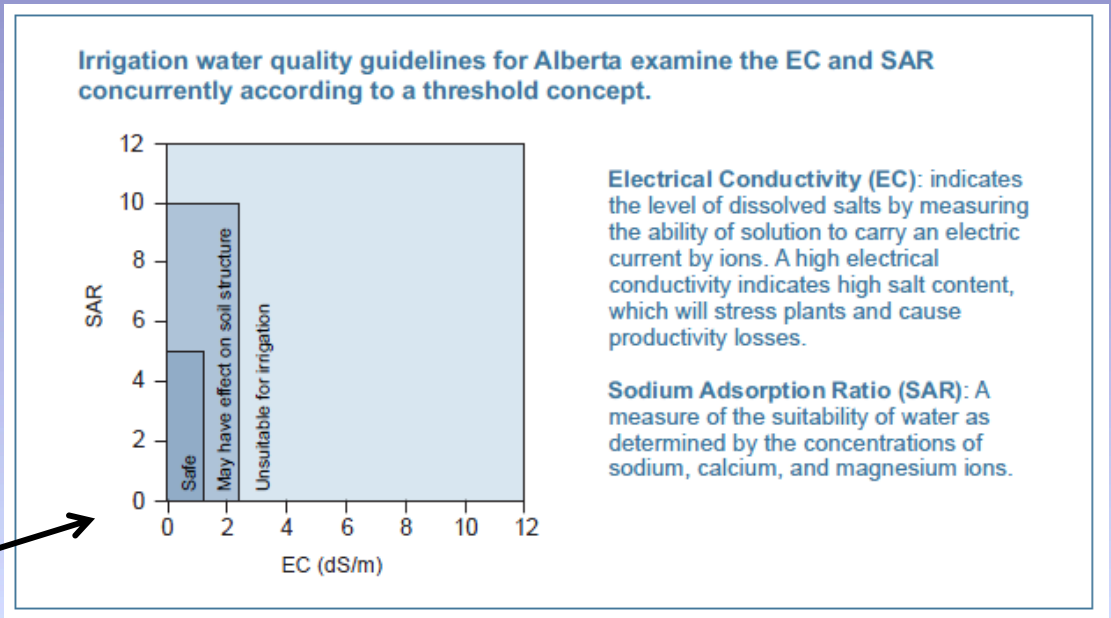
Table 3.6 Irrigation Water Quality Guidelines (Alberta Agriculture 1983)

Irrigation Water Parameter	Safe (all conditions)	Possibly Safe	Hazardous
EC dS/m	<1	1 – 2.5	>2.5
SAR	<4	4 – 9	>9

- These are based on older Alberta Agriculture guidelines from 1983. Anything newer?

Irrigation from dugout pathway (cont'd)

- It appears newer Alberta irrigation guidelines exist and are based on SAR/EC combinations rather than SAR by itself
- From "Assessment of Water Quality in Alberta's Irrigation Districts" (Alberta Agriculture and Rural Development, 2010)



- These guidelines based on Alberta research (Buckland 2002) which describes EC/SAR relationships, and defines some 'safe', 'unsuitable', and 'potentially suitable' ranges as a function of SAR and EC
  - The 'potentially suitable' range possibly influenced by soil texture, etc
- This Buckland research is fairly consistent with Steppuhn and Curtin work which it cites and compares to
  - also identifies soil texture as a factor
  - Steppuhn/Curtin defined the more sensitive 'fine/heavy' textured soils as >36% clay content

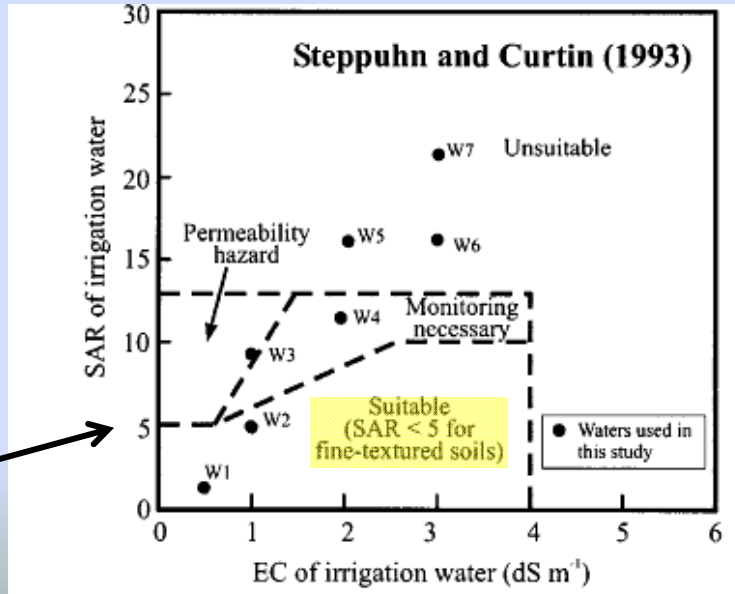


Fig. 2. Irrigation waters used in relation to various irrigation water quality guidelines.

Other potential SAR/sodium pathways

- Three other pathways considered in chloride-SST currently considered less relevant for SAR:

Livestock water

- Livestock risk currently evaluated via TDS, with the chloride guidelines providing sufficient protection since contribution of cations already considered

DUA

- Human drinking water guideline protected by chloride version of SST (250 mg/L chloride)
- Drinking water sodium guideline (200 mg/L) less constraining on an equimolar basis when comparing concentrations above background

Aquatic life

- Currently protected by aquatic life guideline for chloride by SST
- Currently no AENV or CCME aquatic life guideline for sodium, though transport would be expected to be substantially slower than chloride

SST SAR Implementation and Case Study

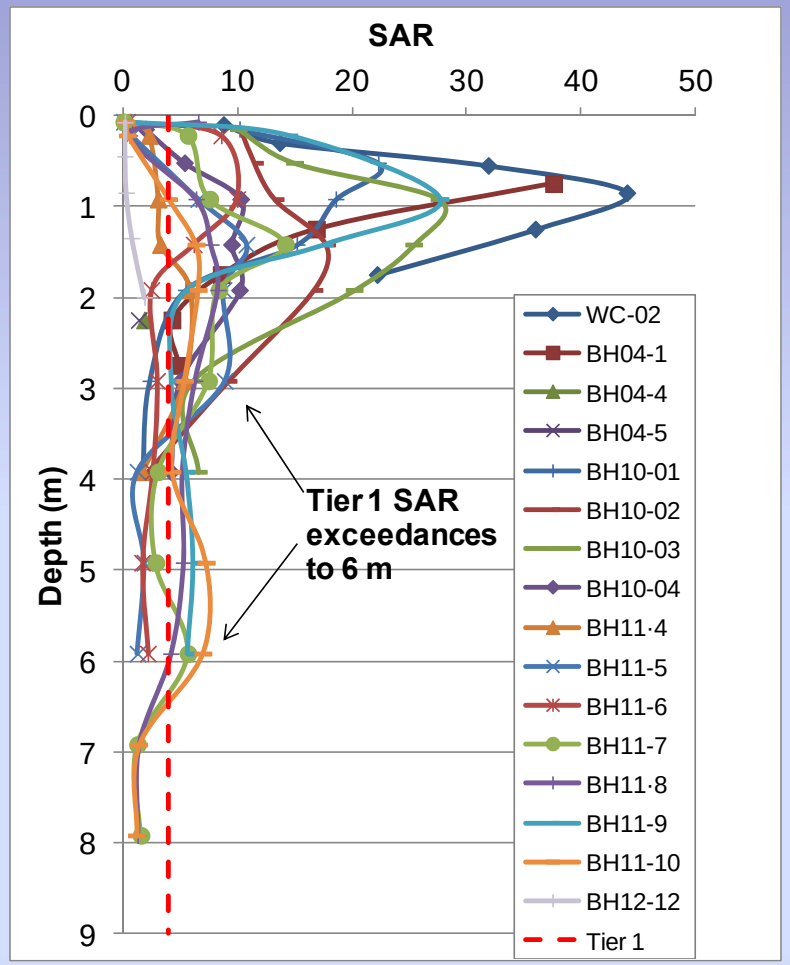
Subsoil SAR SST Input Parameters

- **Calculating subsoil SAR guidelines require many inputs common to the standard SST for chloride:**
  - **Soil texture** **(influences thresholds, drainage, dugout dilution)**
  - **Natural subregion** **(influences climate and drainage rate)**
  - **Vertical gradient** **(influences drainage rate)**
  - **Top/bottom of impacts** **(influences soil structure root-zone, dugout risks)**
  - **Source length** **(influences soil structure risk)**
  - **Water table** **(influences soil structure and dugout risk)**
  - **Land use** **(influences if irrigation is active)**
  - **Background root-zone EC** **(influences upward migration)**
  - **Backfill EC** **(influences upward migration)**
- **Shallow and deep GW parameters less relevant to SAR since they mainly influence transport to DUA and aquatic life receptors**
- **Subsoil SAR implementation also requires additional parameters**
  - **Background root-zone SAR** **(influences root-zone SAR guideline and buffer)**
  - **Backfill SAR** **(influences SAR buffer)**
  - **Clay content** **(influences soil structure stability)**
  - **Subsoil background SAR/EC** **(influences several transport calculations)**

(subsoil background likely needed to just ~4.5 m, as subsoil SAR less relevant >6m)

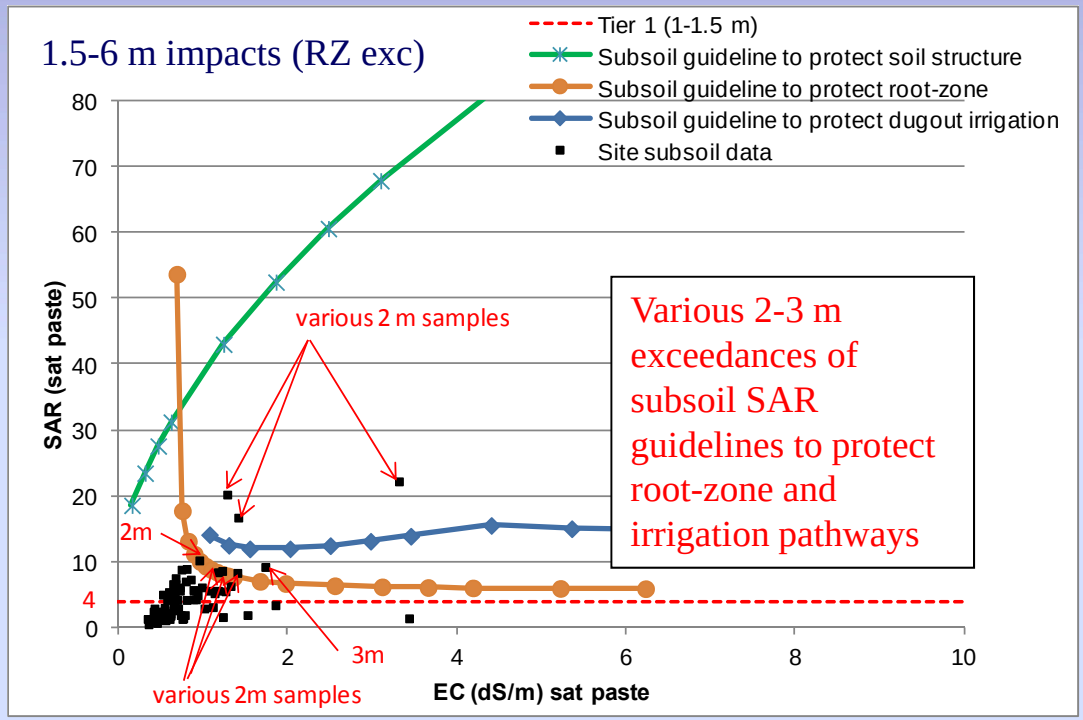
Subsoil SAR SST Case Study

- **Well-site on agricultural land**
  - Good background salinity
  - Low background EC and SAR
- **Widespread Tier 1 SAR exceedances in root-zone near WC**
  - RZ excavation will be needed
- **Tier 1 SAR exceedances to 6 m nearest well-center**
- **No Tier 1 EC exceedances in subsoil (fairly low chloride)**
- **What is an appropriate excavation depth for subsoil SAR here?**
  - 6 m is impractical and would likely imply land-filling of low-risk soils



Subsoil SAR SST Case Study (cont'd)

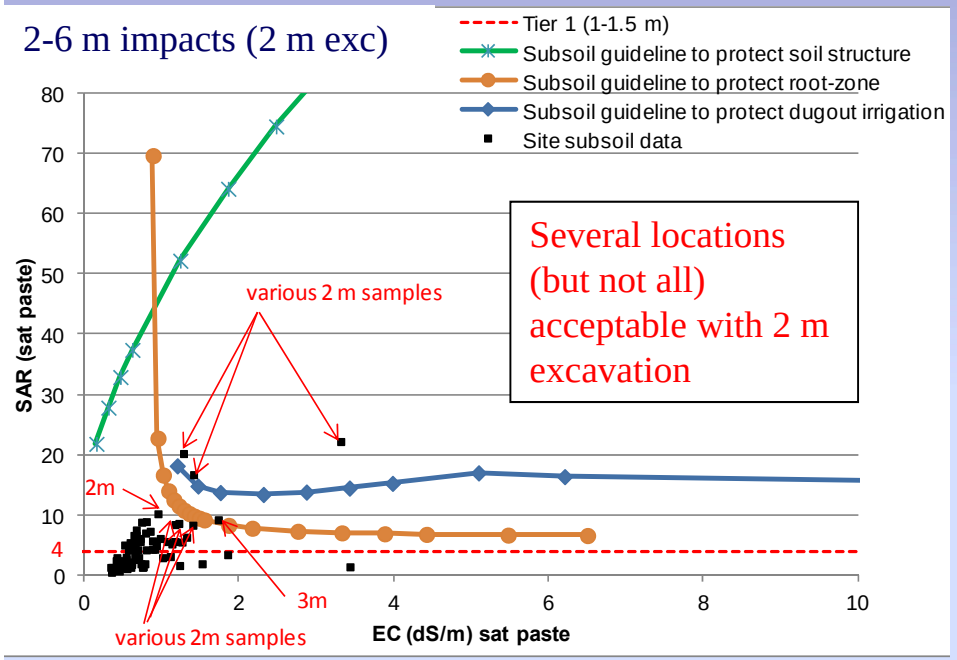
- **Initial thresholds from SAR software for 1.5-6 m impacts shown below**
  - **Assumes excavation and backfill of Tier 1 root-zone exceedances with background soils**
- **Shows trend of soil structure most constraining at low impact-EC, with irrigation and root-zone pathways being most constraining at high-impact EC**
  - **High SAR and high EC implies high sodium and thus high transport risk**

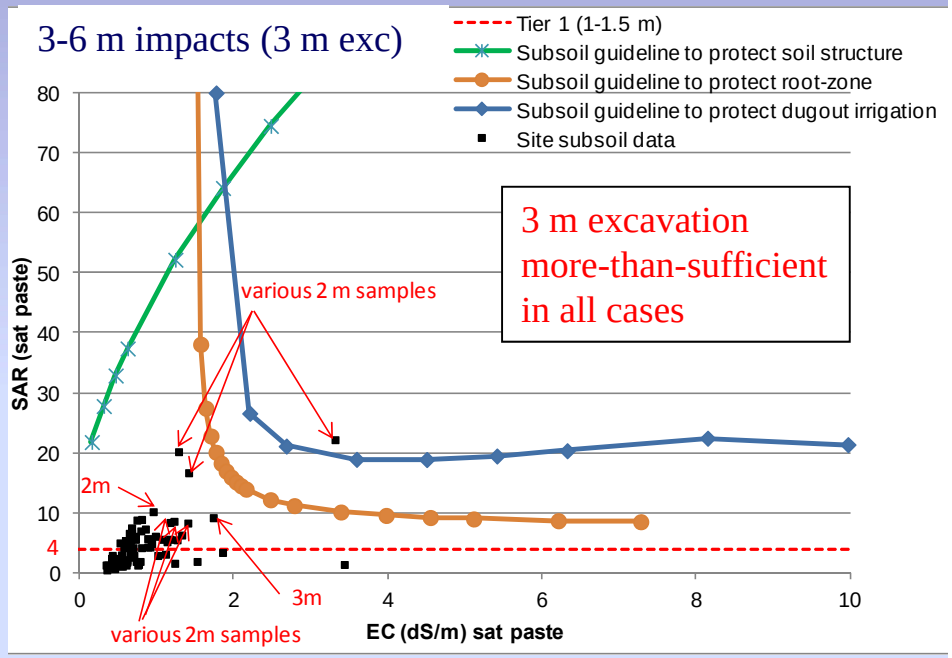


- **Large number of samples do not exceed subsoil guidelines – no remediation**
- **Some exceedances of root-zone and irrigation subsoil SAR guidelines noted**
  - **All at 2-3 m depth, identified by red arrows**
- **Thus, some targeted subsoil excavations required…**

Subsoil SAR SST Case Study (cont'd)

- **Effects of targeted excavations evaluated by adjusting 'top of impact' input parameter to 2 m and then to 3 m**



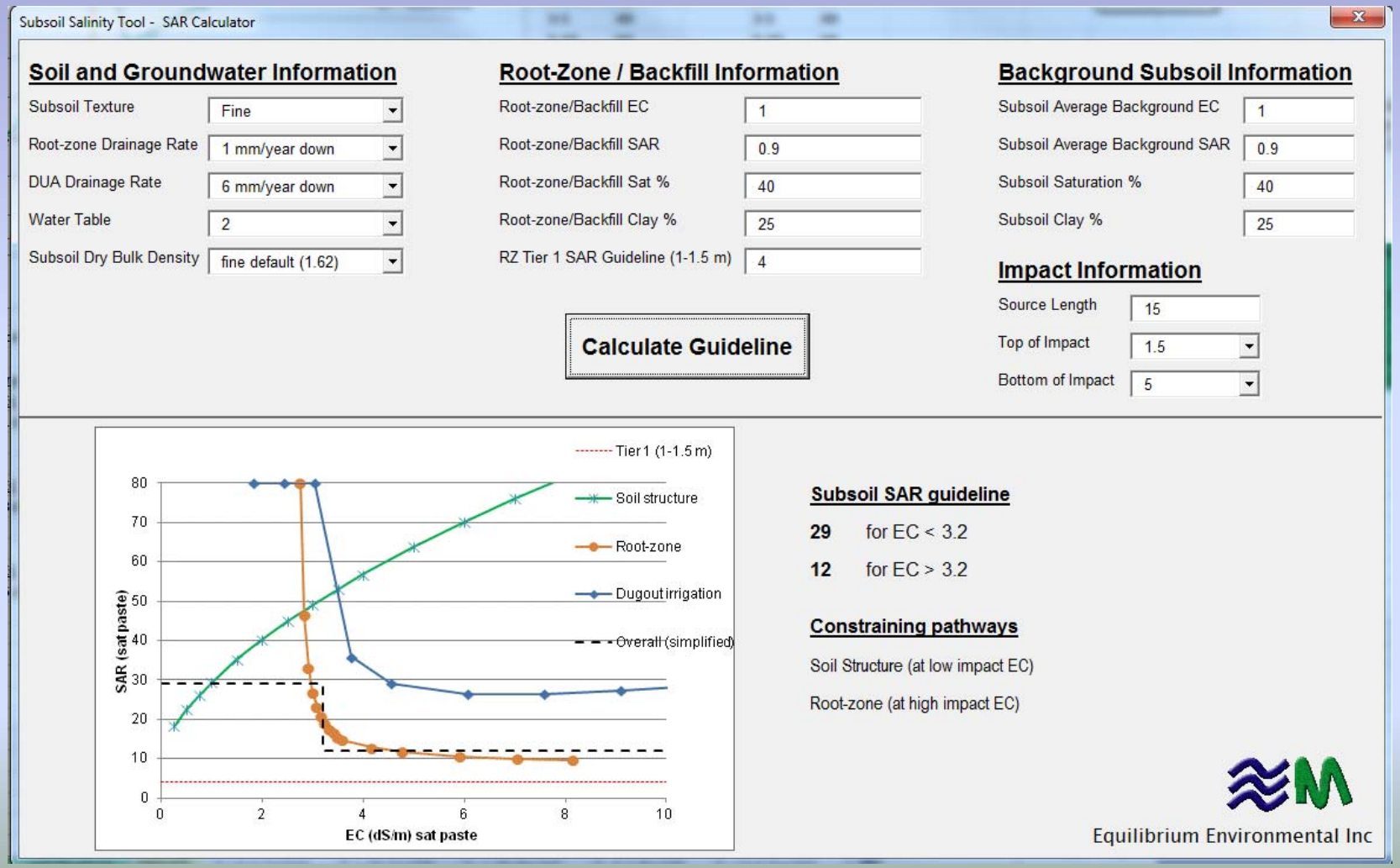


- **Shows 2 m excavation to be sufficient in most locations**
- **Shows 3 m excavation to be more-than-sufficient in worst area**
  - **Thus, 2-2.5 m excavations recommended in some areas**
  - **No subsoil excavation required in others**

Sodium Guideline Considerations

Sodium Guideline Considerations

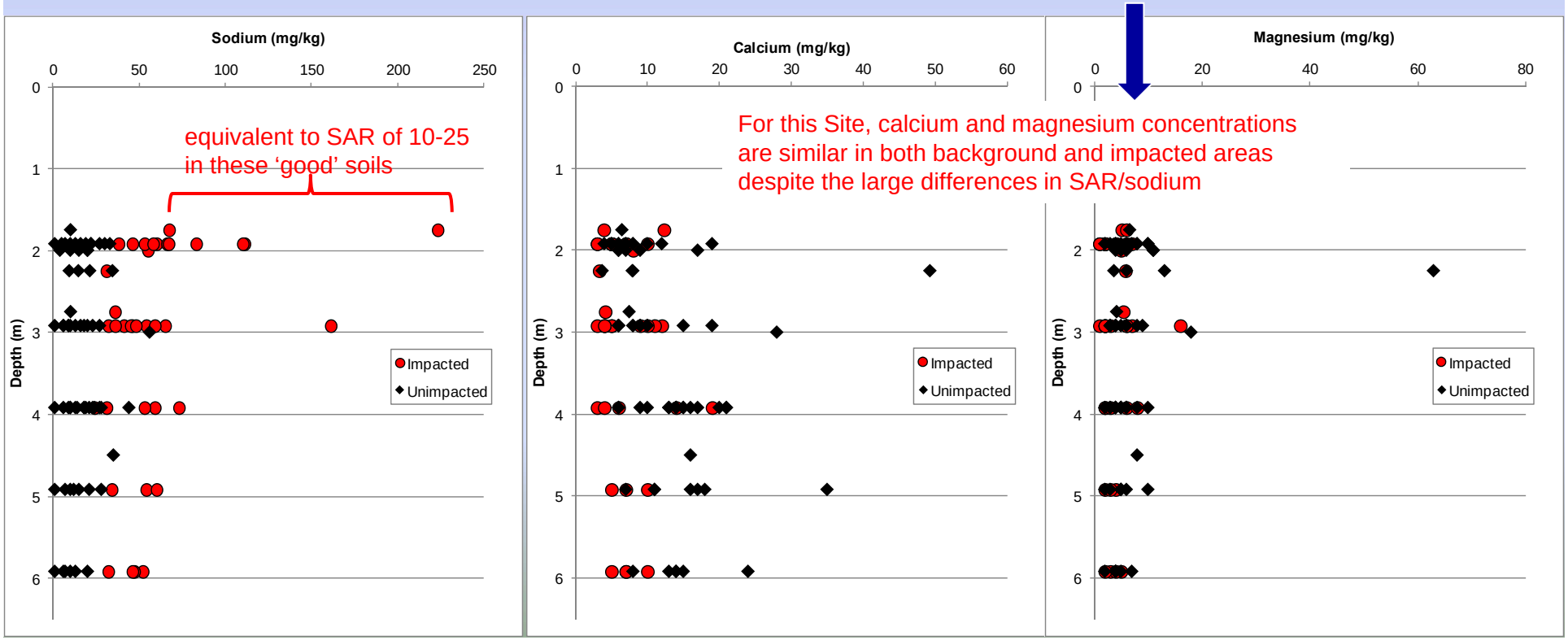
- **These SAR guidelines are quite versatile (eg, Tier 2C) but may be difficult to implement in practice in a reliable/consistent manner**
  - **Even with guideline simplifications, software would need to display complex graph that may be difficult to interpret under many circumstances. eg:**



- **What about sodium guidelines as an alternative?**

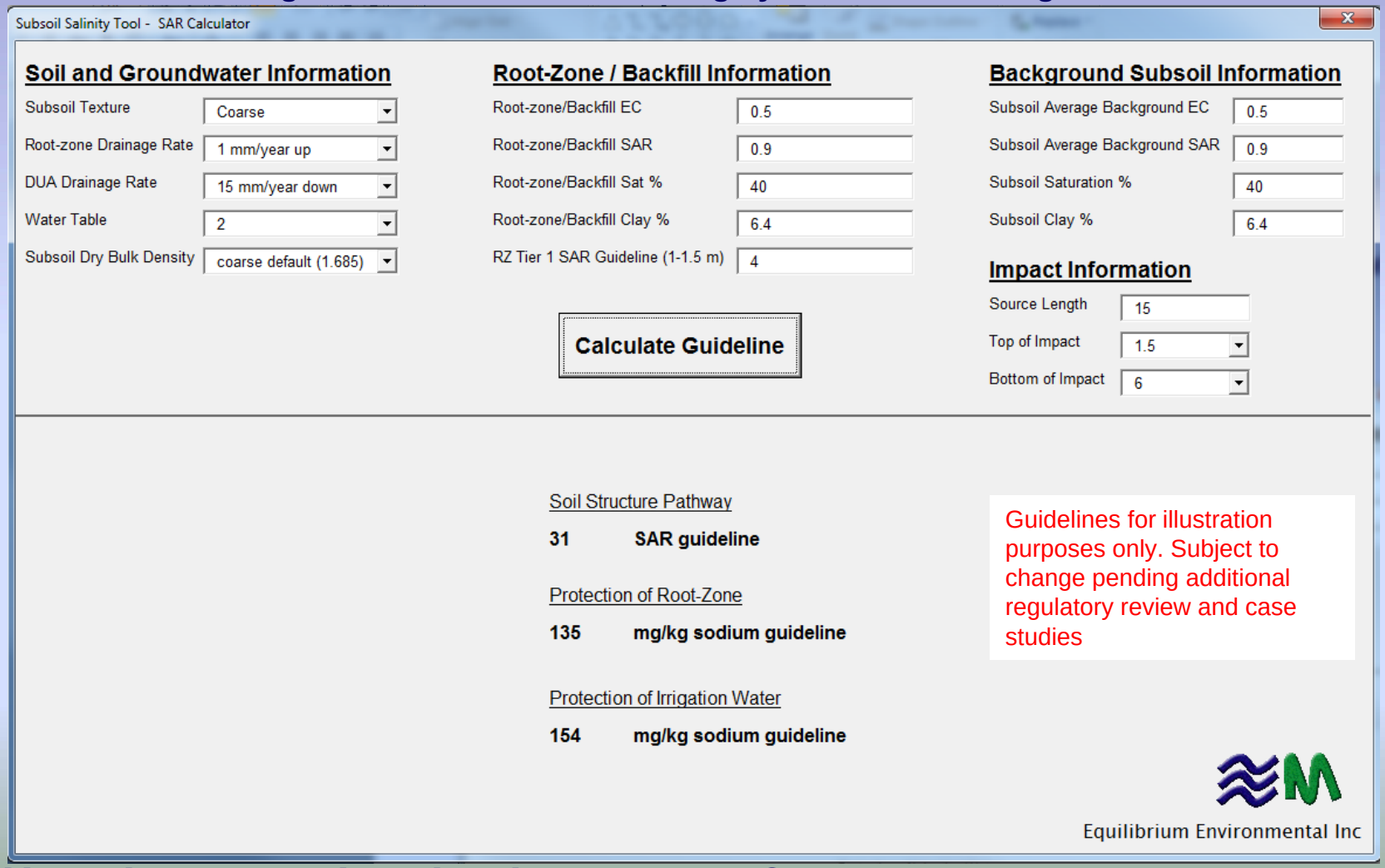
Sodium Guideline Considerations (cont'd)

- **Sodium guidelines are an alternative, and could reduce some complexity and the need to simultaneously evaluate SAR and EC**
  - **"Root-zone SAR→subsoil sodium" aligns nicely with the "root-zone EC→subsoil chloride" paradigm currently used in the SST**
- **Sodium guidelines likely to be particularly useful for the transport-related pathways of upward migration into root-zone and irrigation from dugout**
- **Requires an assumption about the concentrations of other subsoil cations (calcium and magnesium) in the impact area**
  - **assume to be similar to background concentrations (appears reasonable)**



Sodium Guideline Example #1

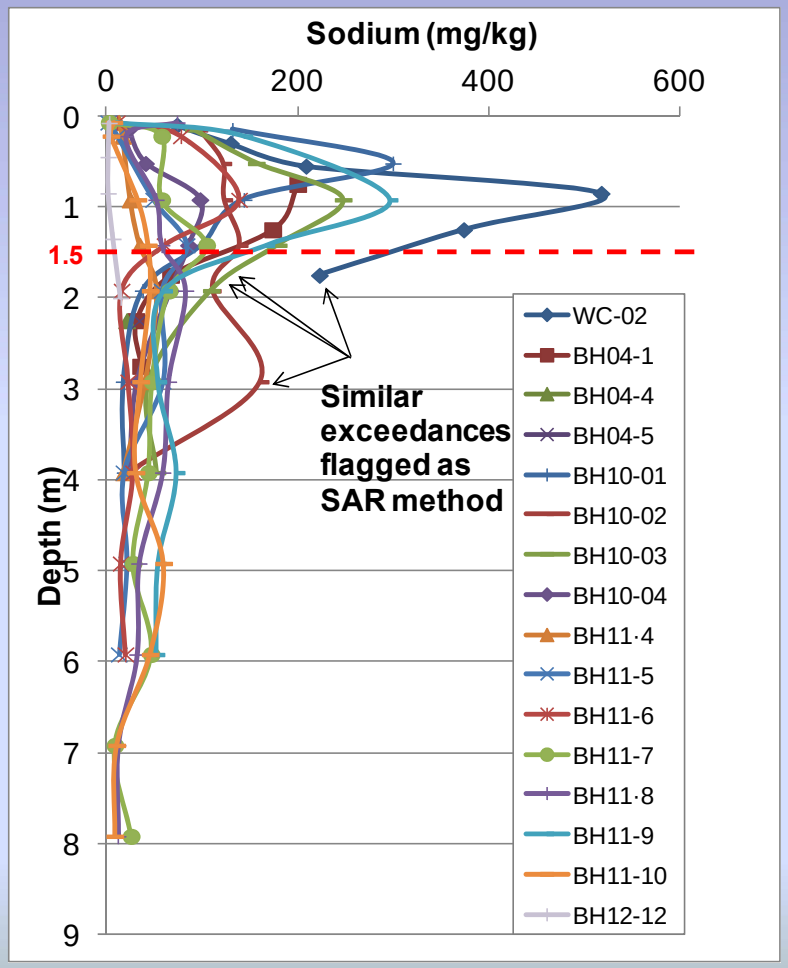
- **Same input parameters as 'SAR Case Study' results in following example sodium guidelines**
  - **Root-zone and irrigation guidelines shown on a sodium basis**
  - **Soil structure guideline left as SAR since highly sensitive to Ca/Mg concentrations**



- **How do excavation depths compare?**

Sodium Guideline Example #1

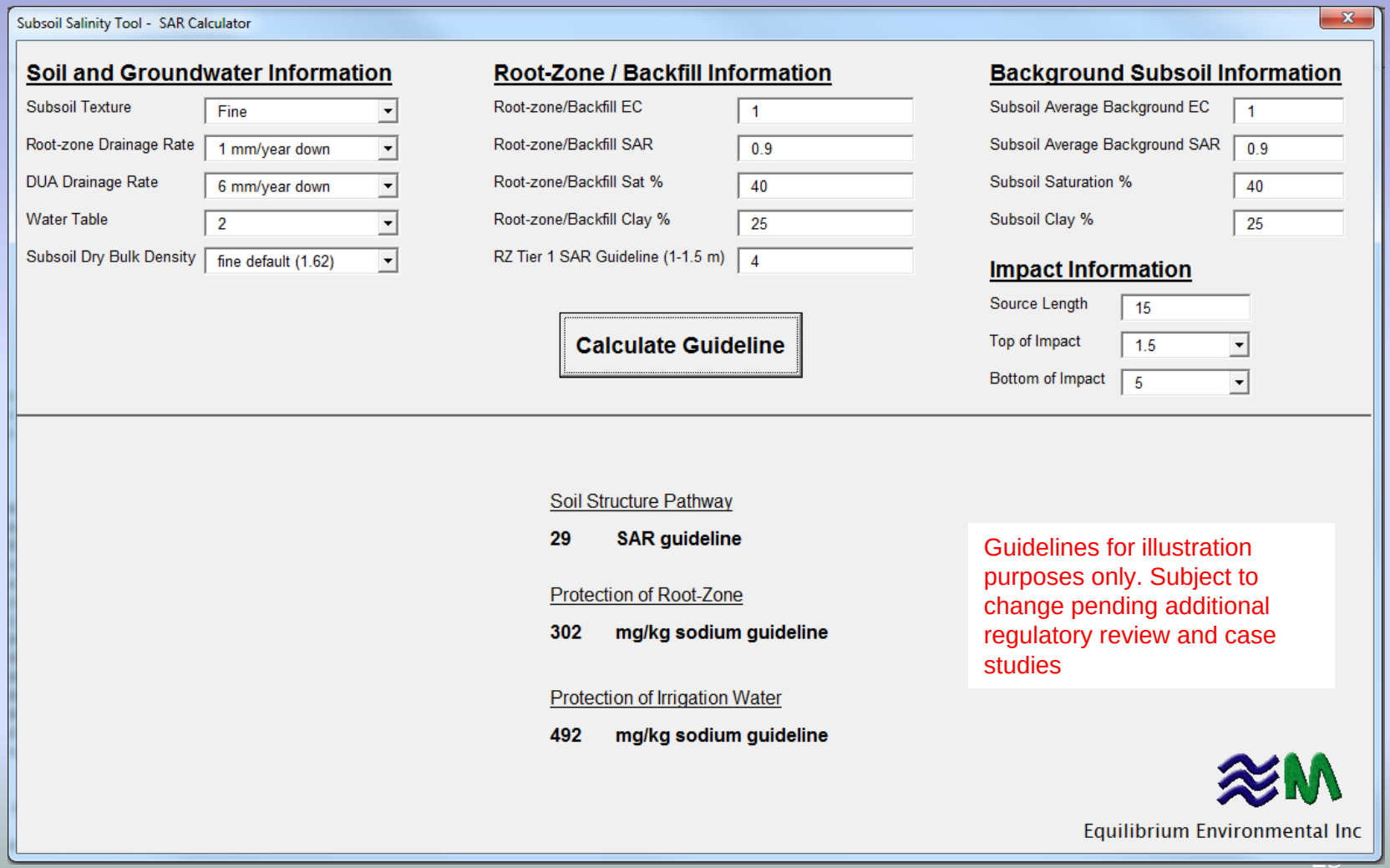
- This sodium method flagged similar exceedances in 2-3 m depth interval as for previous SAR method
- Results in very similar excavation depths of up to 2-2.5 m



- Try other input parameters for illustration…

Sodium Guideline Example #2

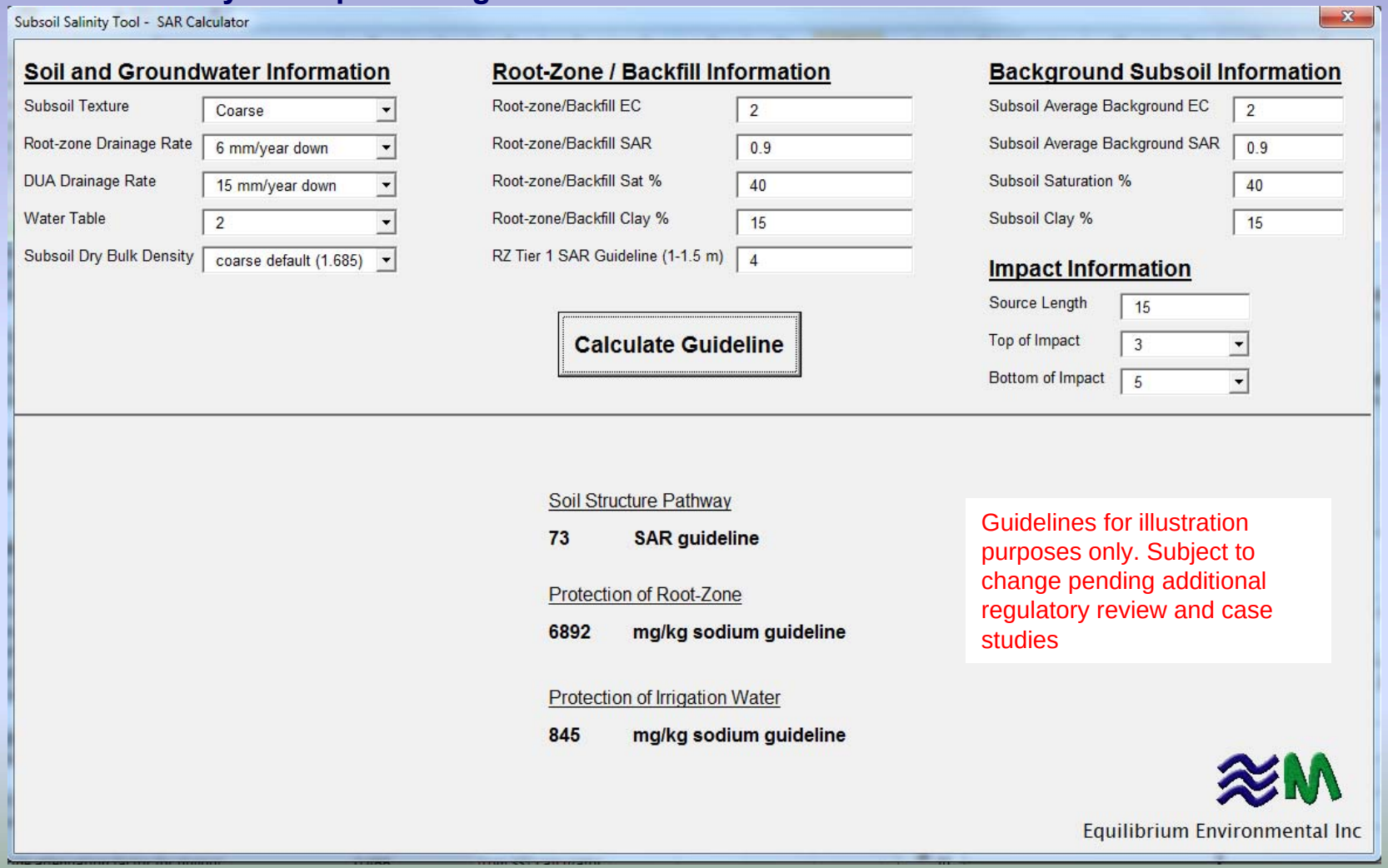
- **Fine soil, higher background EC**
  - **Results in higher Ca/Mg in background**
  - **Higher RZ and irrigation guidelines**



- **Try other input parameters for illustration…**

Sodium Guideline Example #3

- **Input changed back to 'coarse' soil, higher background EC, and thinner impacts**
  - **Coarse soil results in higher drainage rate**
  - **Substantially less upward migration of sodium into root-zone in this case**



- **Thus, wide range of sodium guidelines possible based on inputs**

Summary and Next Steps

Summary and Next steps

Summary

- Subsoil SAR/sodium guidelines have been implemented into an SST-software module considering three key pathways
  - Standard input parameters needed, as well as some additional SAR-related inputs
- SAR/EC interactions introduce additional complexity in calculating and implementing guidelines compared to chloride
  - SAR/EC thresholds for each pathway can be calculated using modified SST techniques
  - SAR/EC thresholds may be most suitable on a Tier 2C basis since complex
- For upward migration and irrigation pathways, sodium guidelines provide a potentially simpler alternative to SAR guidelines by considering background salinity data
  - Allows for simpler guideline display and interpretation
- For soil structure pathway, a guideline on a SAR basis may be most robust/practical based on SAR impacts attenuating to background EC

Next Steps

- Continued evaluation of sodium guidelines via case studies
- Updating SAR/sodium user-interface to most current SST version
- Write-up SAR/sodium portion of SST manual
- Similar status for subsoil sulfate SST implementation…

Subsoil Sulfate SST Implementation

- **Subsoil sulfate currently similar status as subsoil SAR**

  --See EQM poster for details of subsoil sulfate SST implementation--

- **Example subsoil sulfate software screenshot shown below**
  - **Comparable chloride guidelines shown in red for context**
  - **Preliminary guidelines shown for illustration purposes only, and subject to revision following further regulatory review and evaluation of additional case studies**