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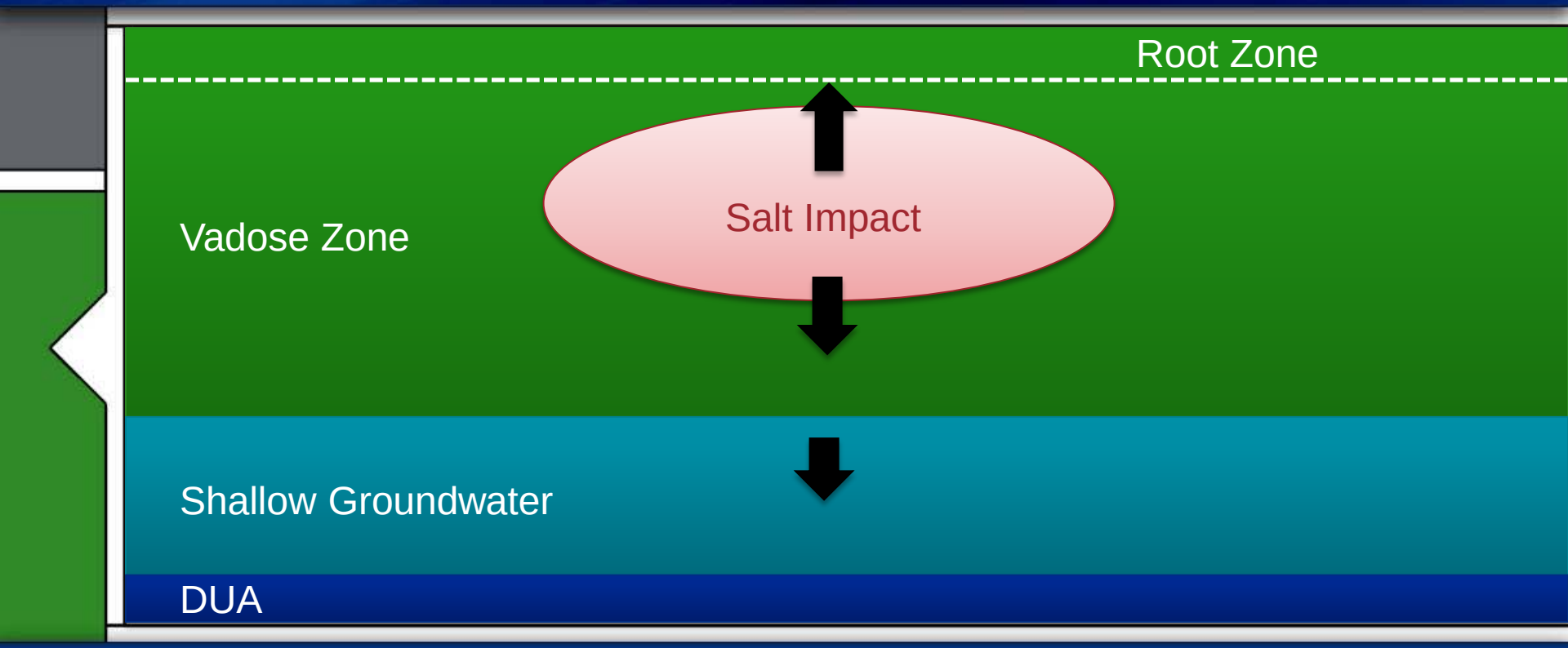
WaterTech 2013

Spatial and Seasonal Variations of Water Movement in the Vadose Zone at Salt-Impacted Sites



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Acknowledgments

- Dr Tai Wong initiated this study
- Some material is based on internal reports by Douglas Haney

Outline

- Introduction
- Methodology
- Case study
- Summary

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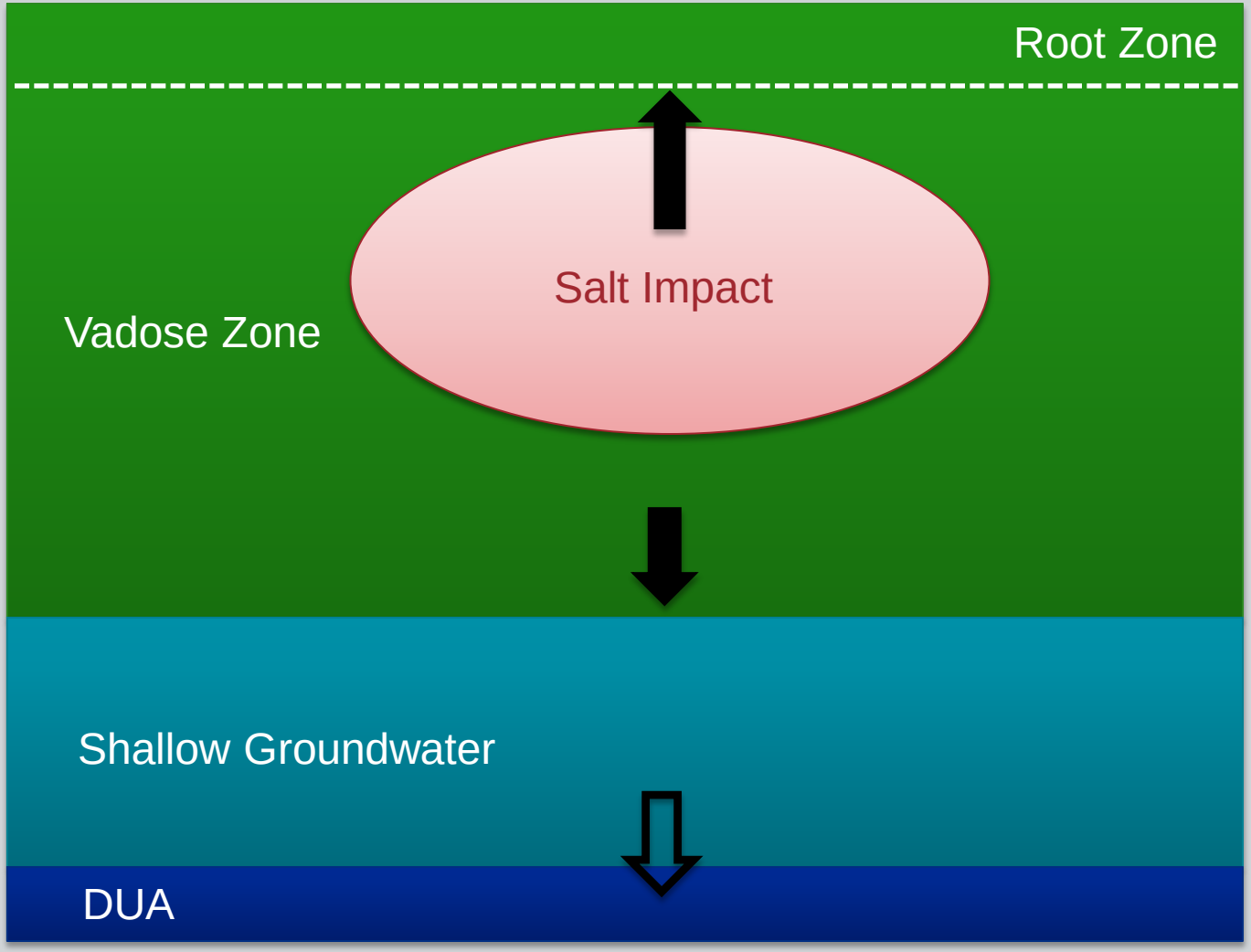
Significance of Vadose Zone



Regulatory Approaches

- Alberta Tier 1 default values
  - Recharge to groundwater: 60 mm/year for coarse-grained soil and 12 mm/year for fine-grained soil
  - No uptake rate is defined
- Alberta Tier 2 approach - Soil Salinity Tool (SST)
  - Estimated recharge (downward) and discharge (upward) rates for different climate sub-regions and different soil (fine or coarse)
  - In Central Parkland sub-region

    discharge = 1 mm/y and recharge = 6 mm/y for fine soil

    discharge = 1 mm/y and recharge = 27 mm/y for coarse soil

Questions Regarding Regulatory Approaches

- Should we use these constant recharge/discharge rates for site-specific assessments (Tier 2C)?
- Can we reasonably estimate site-specific recharge/discharge rates based on the data typically available?
- How significantly do the different rates could affect the assessment of salt contamination at a site?

Hydrus-1D

- A public domain model for analysis of water flow and solute transport in variably saturated porous media (http://www.pc-progress.com/en/Default.aspx?hydrus-1d)
- Features
  - Water flow under unsaturated and unsaturated conditions
  - Soil retention curve (Van Genuchten model)
  - Surface evapotranspiration, surface runoff, and root uptake
  - Contaminant transport, vapour movement, and heat transferring
  - More …

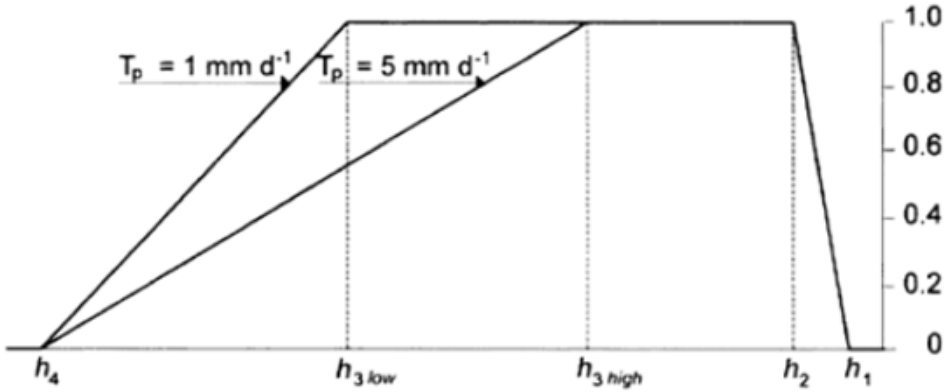
Model for Root Water Uptake

- Roots help transport water back to the surface
  - Evapotranspiration
- Feddes model
  - R. A Feddes, P. J. Kowalik, K. K. Malinka, and H. Zaradny (1978)
  - Actual uptake based on a stress reduction of the potential
- Van Genuchten (VG) Model (1992)
  - An S-shape function for stress reduction of the potential

Model for Root Water Uptake

Feddes Model

$$S(h) = \alpha(h) S_p$$

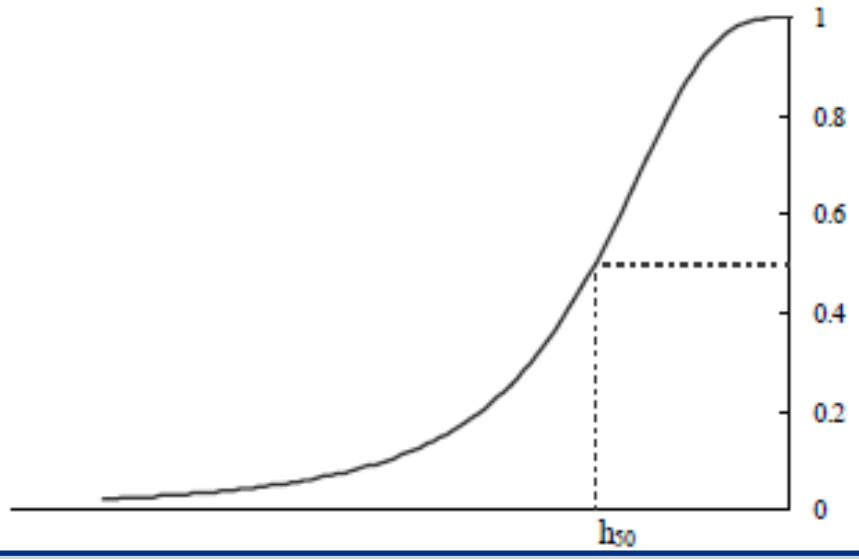


Crop	h_1	h_2	$h_{3,\,high}$	$h_{3,\,low}$	h_4
Potatoes	-10	-25	-320	-600	-16000
Sugar beet	-10	-25	-320	-600	-16000
Wheat	0	-1	-500	-900	-16000
Pasture	-10	-25	-200	-800	-8000
Corn	-15	-30	-325	-600	-15000*)

Model for Root Water Uptake

Van Genuchten (VG) Model

$$\alpha(h) = \frac{1}{\left(1 + \frac{h}{h_{50}}\right)^p}$$



Case Study

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Site Description

- Zoned for agriculture
- Soil mainly composed of silt with sand lenses ($K = 3.1 \times 10^{-7}$ m/s)
- Water table: 5 m below grade

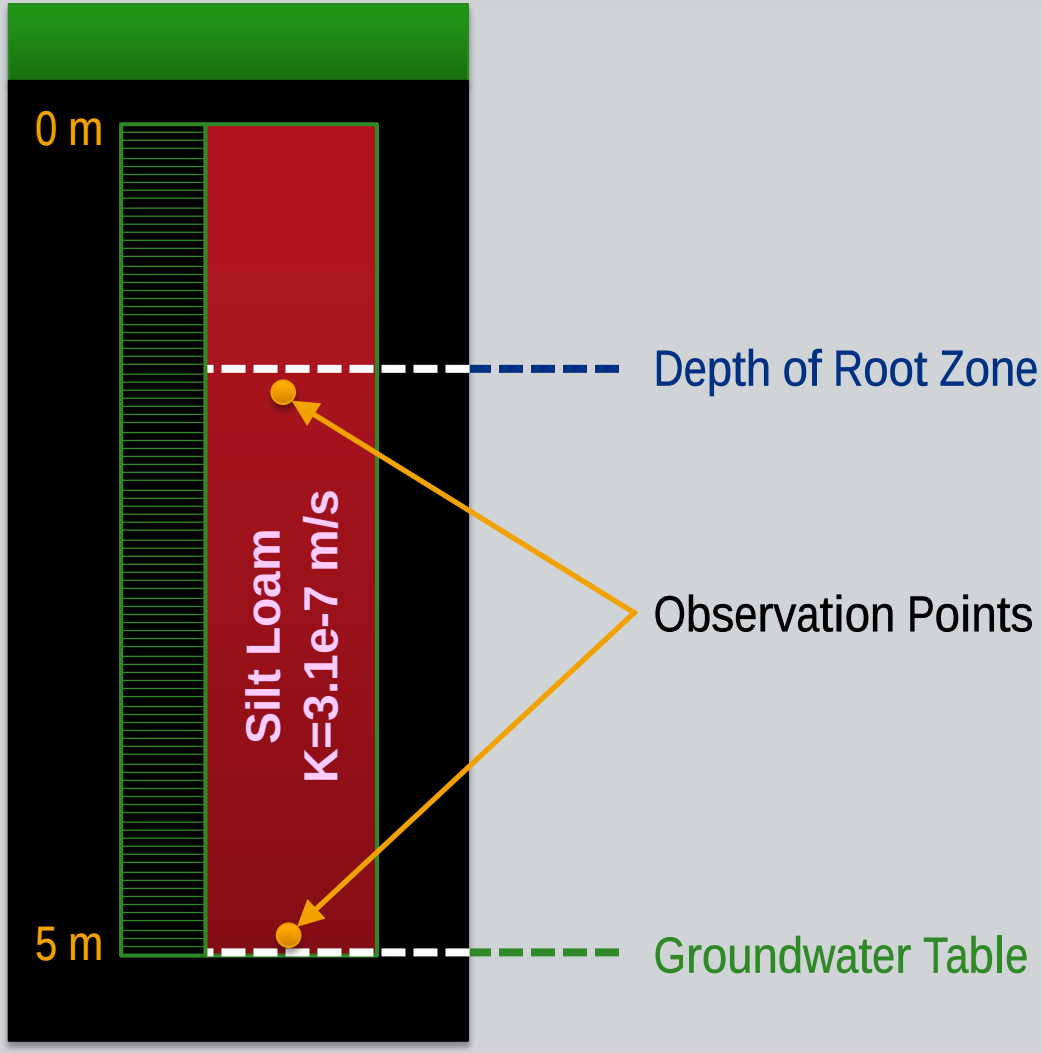
Site Description

- Vegetation: grass onsite with canola cropland in surrounding areas

SST Assessment

- SST Tier 2A conducted to determine the guidelines of chloride
- SST results based on infiltration rate estimated for “Central Parkland” sub-region
  - Discharge (upward) = 1 mm/year
  - Recharge (downward) = 6 mm/year

HYDRUS 1D Model



HYDRUS Scenarios

- Meteorological Datasets:
  - Environment Canada
    - Climate normals (Humidity, Wind)
    - Daily climate data (Precipitation, Temperature)
    - Net Radiation (paid data set)
- Two scenarios:
  - “Average” Dataset
  - Low Radiation, High Precipitation (LRHP)

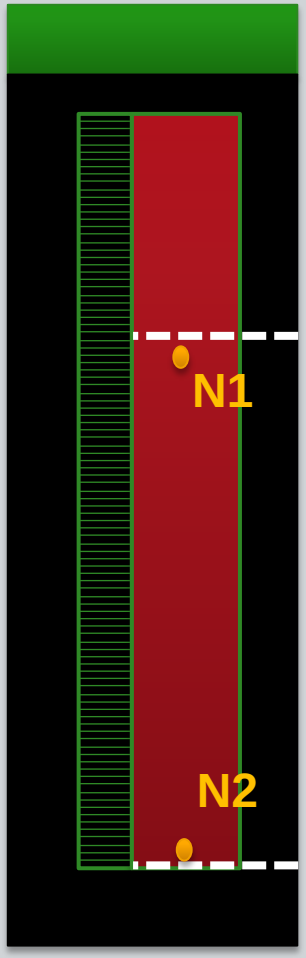
HYDRUS Scenarios

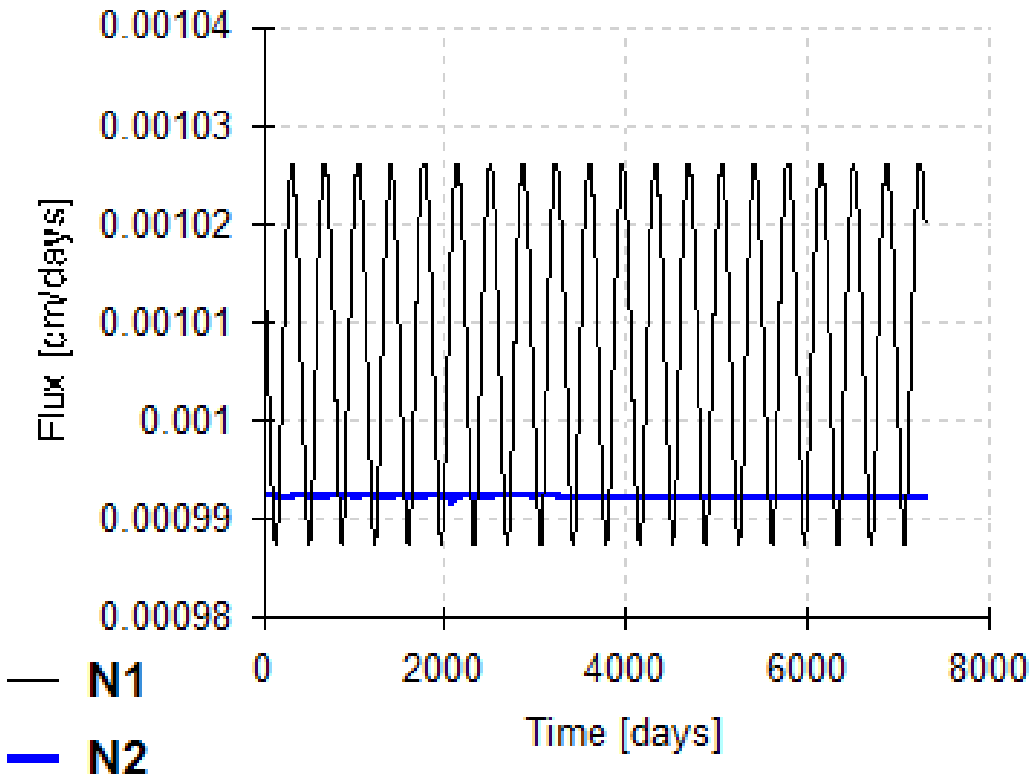
	Average	LRHP (low radiation, high precipitation)
Precipitation (mm yr^{-1})	374.4 (2009)	621.1 (2007)
Radiation ($MJm^{-2}d^{-1}$)	3.83 (1967-2005)	3.38 (1969)
Temperature (°C)	1.72 (2009)	1.16 (1969)
Wind Speed (km/day)	308.1 (2009)	308.1 (2009)
Humidity (%)	79.7 (2009)	79.7 (2009)

HYDRUS Scenarios

- Vegetation
  - Vegetated
    - Root Uptake functions (Feedes Model) based on available values for pasture, corn and potatoes
  - Bare soil (no vegetation)

HYDRUS Results

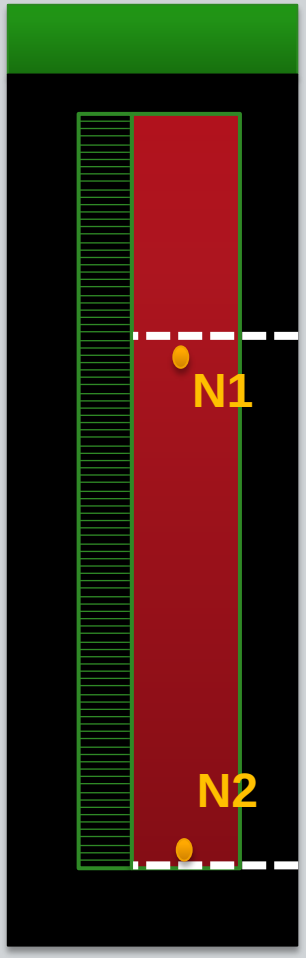


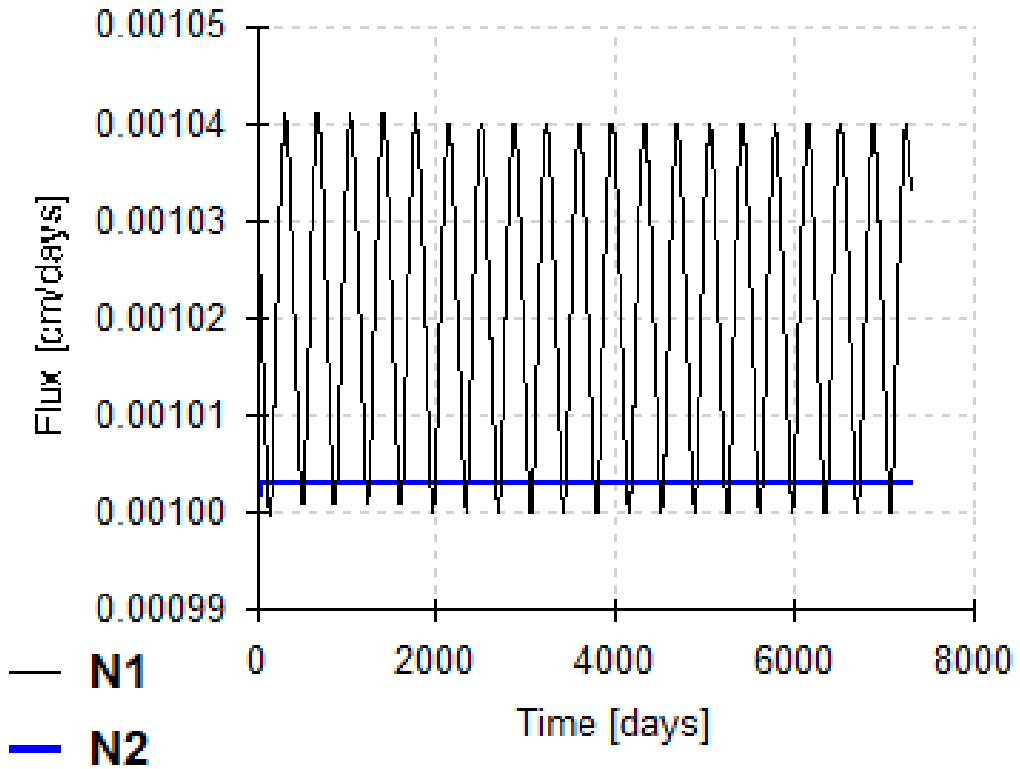


Average climate
Vegetation: default values for pasture

N1 = Immediately below root zone
N2 = Recharge to groundwater
Negative values indicate downward flux

HYDRUS Results

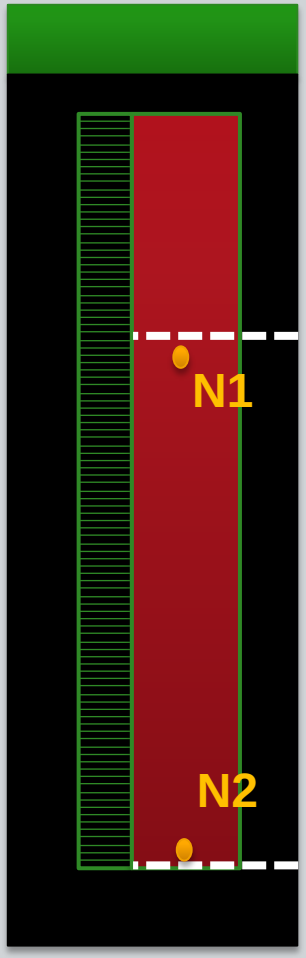


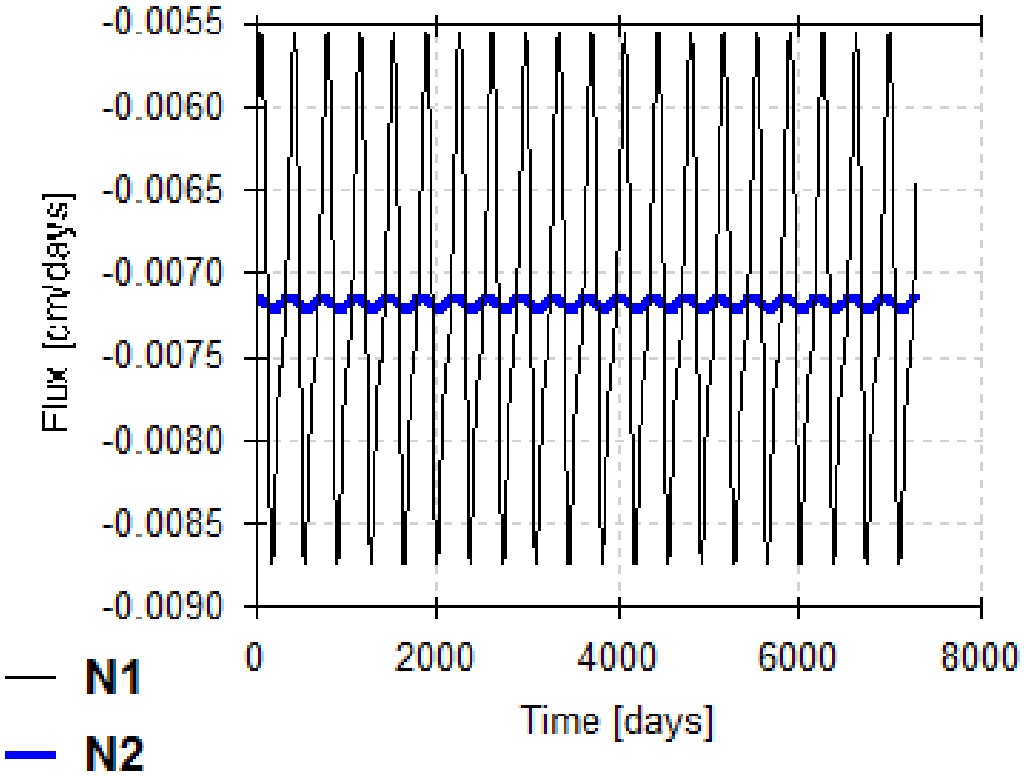


Average climate
Vegetation: default values for corn/potatoes

N1 = Immediately below root zone
N2 = Recharge to groundwater
Negative values indicate downward flux

HYDRUS Results





Average climate
No vegetation

N1 = Immediately below root zone
N2 = Recharge to groundwater
Negative values indicate downward flux

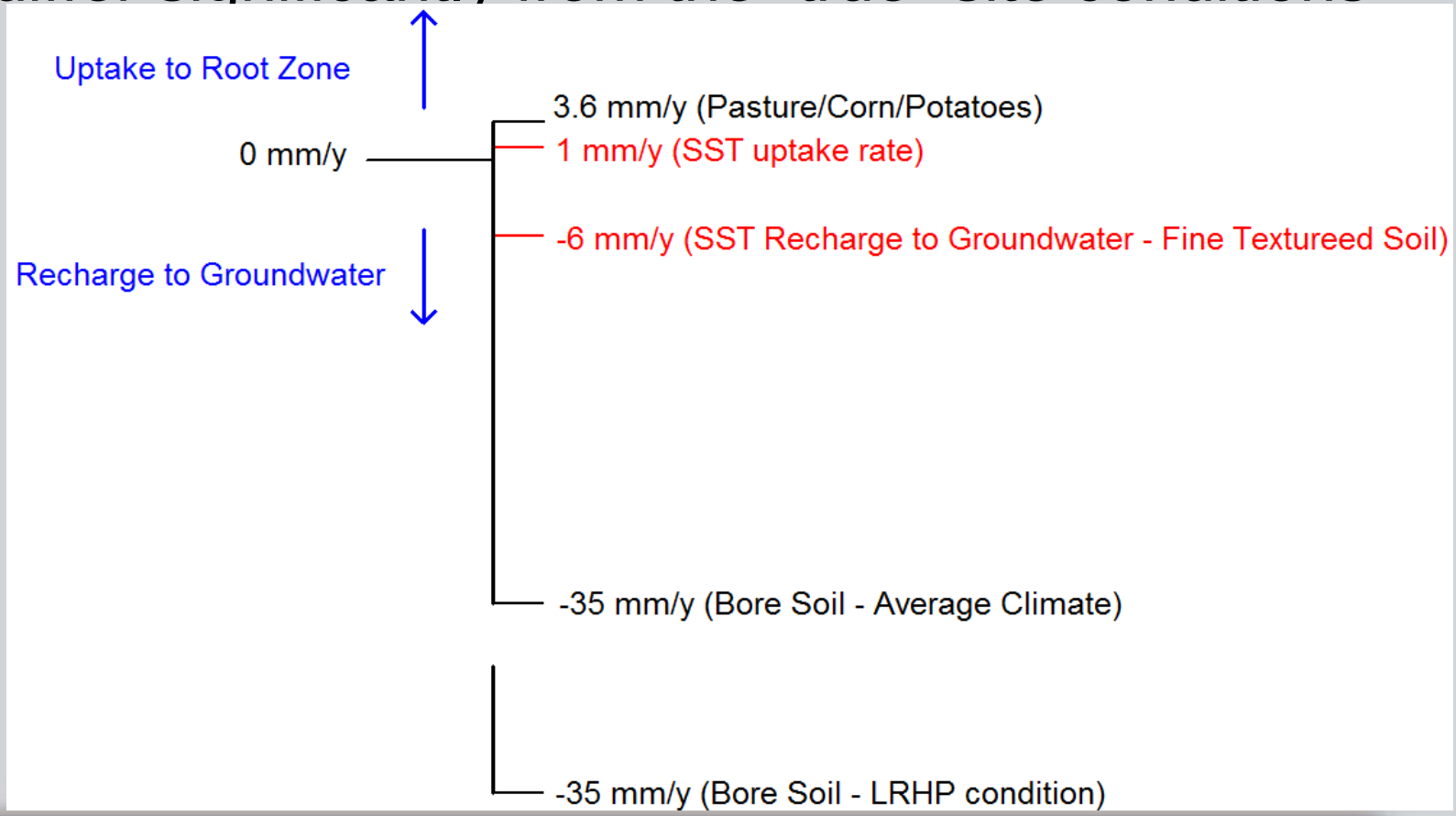
HYDRUS Summary

Root Uptake Type	Discharge to root zone (mm/year)	Recharge to groundwater (mm/year)
Pasture	3.7 / 3.6	3.6 / 3.7
Corn or Potatoes	3.7 / 3.7	3.7 / 3.7
No Root Uptake	-31 / -163	-40 / -163

- Values for average climate / for LRHP
- Negative values indicate downward flux

HYDRUS Summary

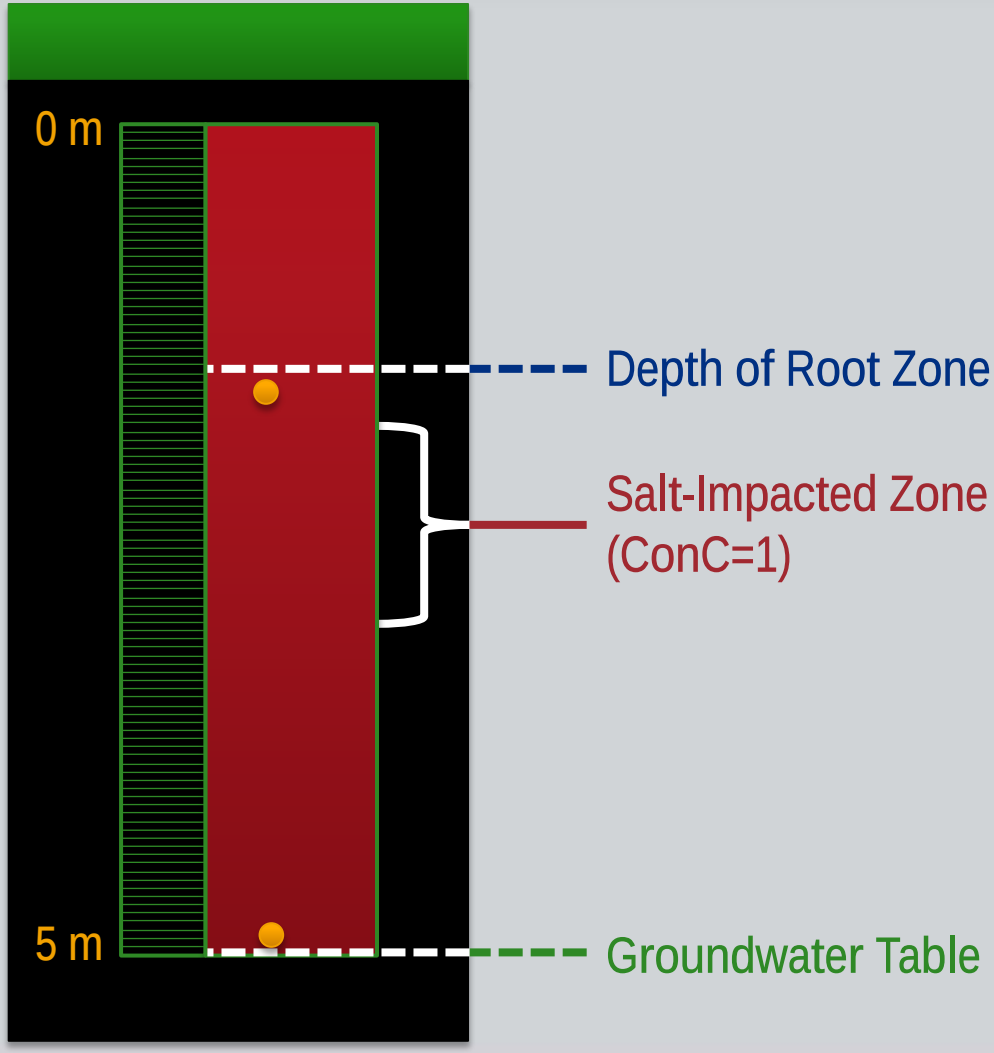
- Alberta Environment default constant values may differ significantly from the “true” site conditions



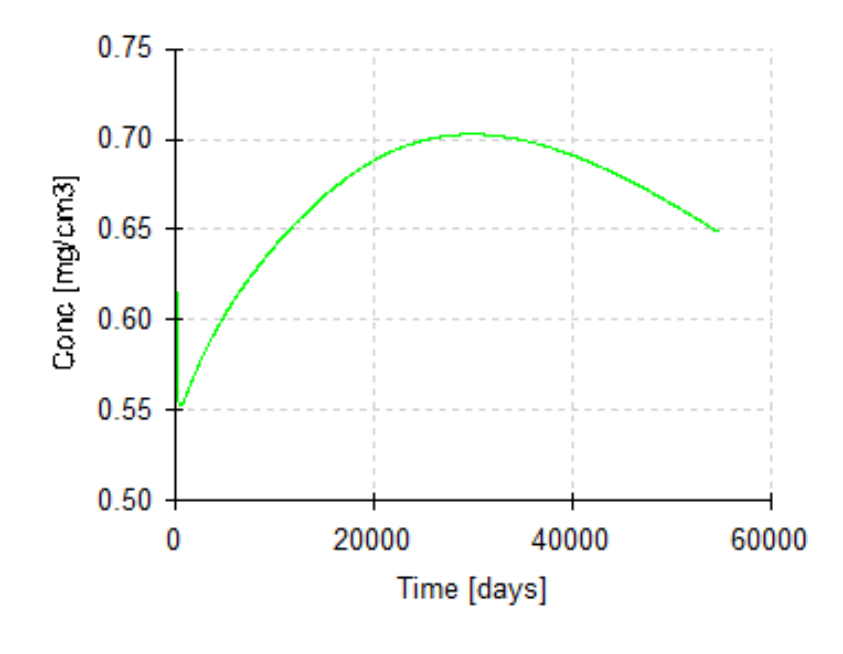
HYDRUS Summary

- Different flux estimations change assessment of salt migration
  - For a site with crop, downward migration of salt could be minimal
  - For a site with -12 mm/y recharge to DUA, the chloride guidelines could be overestimated by 3 times if the default -6 mm/y is used
- Even with the same average flux, salt can migrate different with constant flux than with seasonal varying flux

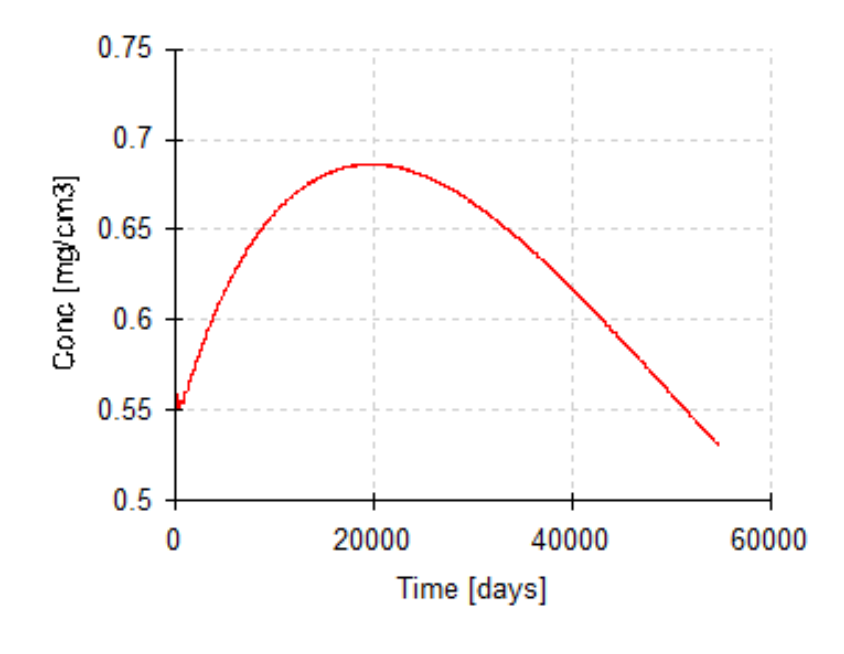
HYDRUS Transport (Example 1)



HYDRUS Transport (Example 1)

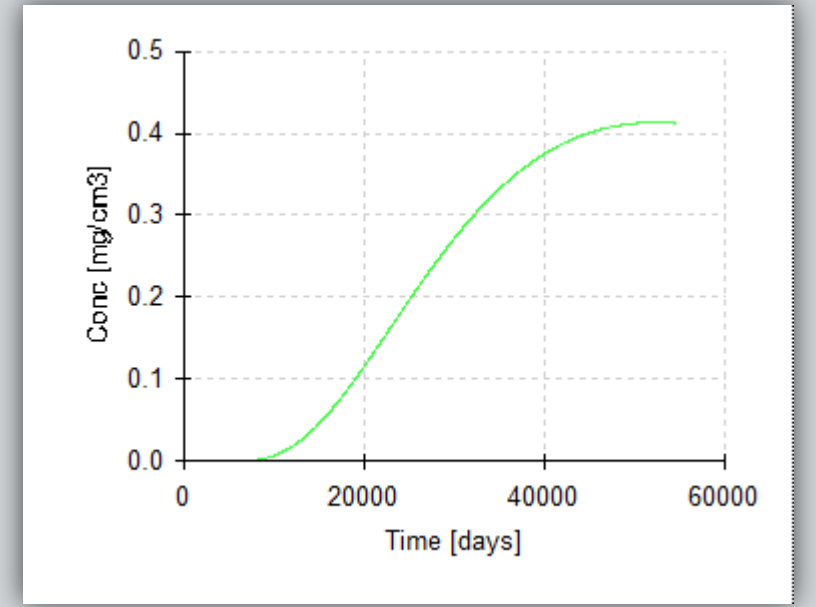


- Relative concentration to root zone
- Constant upward flux = 1 mm/y



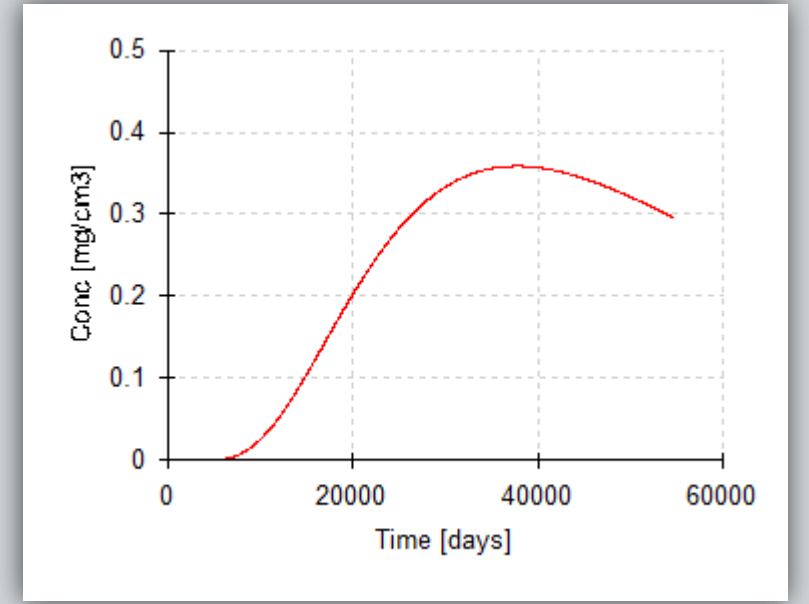
- Relative concentration to root zone
- Seasonally varying upward flux = 1 mm/y on average

HYDRUS Transport (Example 1)



Relative concentration to groundwater

Constant downward flux = 6 mm/y



Relative concentration to groundwater

Seasonally varying downward flux = 6 mm/y on average

Summary

- Water fluxes in vadose could vary significantly from site to site even under the same climate condition
- Different root water uptake rates could be the most important one among a number of other factors
- Using constant recharge/discharge rates does not represent possibly significant difference between sites and may overestimate or underestimate salt migration at the site

Summary

- Challenges remain how to determine site-specific water fluxes
  - Not feasible to conduct field measurements at typical salt contaminated sites
  - A more practical solution could be providing representative climate datasets in different regional and representative parameters values (used in Feddes model or VG model) for typical vegetation/crop types
  - Possibly calibrated against seasonal water level changes