Monitoring Salt Remediation with Time-lapse Electrical Resistivity Imaging

EAGE Hydrogeophysics Workshop
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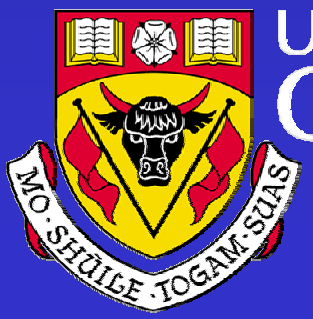

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PROJECT OBJECTIVE

Develop practical methods for assessing the distribution and evolution of salt in soils and groundwater during remediation.

Moving to quantitative interpretations.

Waxman-Smits Equation

$$\sigma_{formation} = \left(\frac{1}{a\phi^{-m} S_W^{-n}} \right) (\sigma_W + BQ_V)$$

a,m,n empirical constants (geology)

S_W water saturation

ϕ porosity (geology)

σ_W EC of pore water

B function of σ_W

Q_V depends on cation exchange (geology)

Our goal

Changes in $\sigma_{formation}$ $\longrightarrow$ changes in salt concentration

SOME ISSUES

Assuming the geology remains constant

$\sigma_{formation}$ changes due to:

soil moisture (S_W)

salt concentration (σ_W)

temperature (σ_W)

Variations in environmental conditions require corrections for

Temperature

Soil moisture

SOME ISSUES (2)

In addition to the ERI surveys:

Cores + lab tests $\longrightarrow$ $\sigma_{formation}(T, S_W)$

Tensiometer and Thermocouple installations to measure soil moisture and temperature.

Study Site

Central Alberta, Canada

Pipeline spill and other upstream oil & gas operations

Hydrocarbons and salts released

Hydrocarbons have been remediated & land surface re-contoured

Drain system installed at ~ 2m bgl - drains to sump for deep well disposal

Phytoremediation experiment in progress

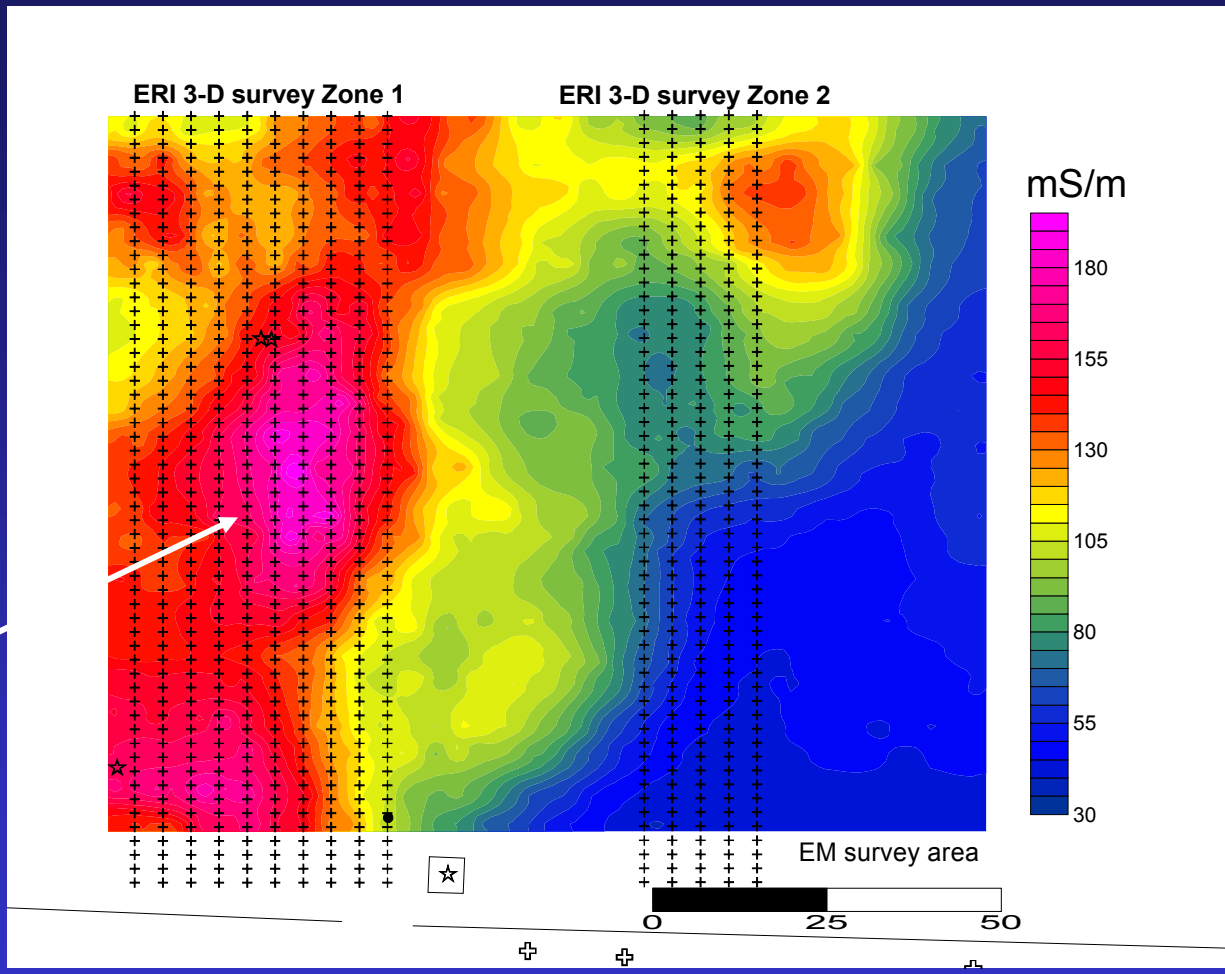
Location map

2 quasi 3-D ERI
urvey zones

EM 31 conductivity

Elevated salt
concentration

Zone 1 Zone 2



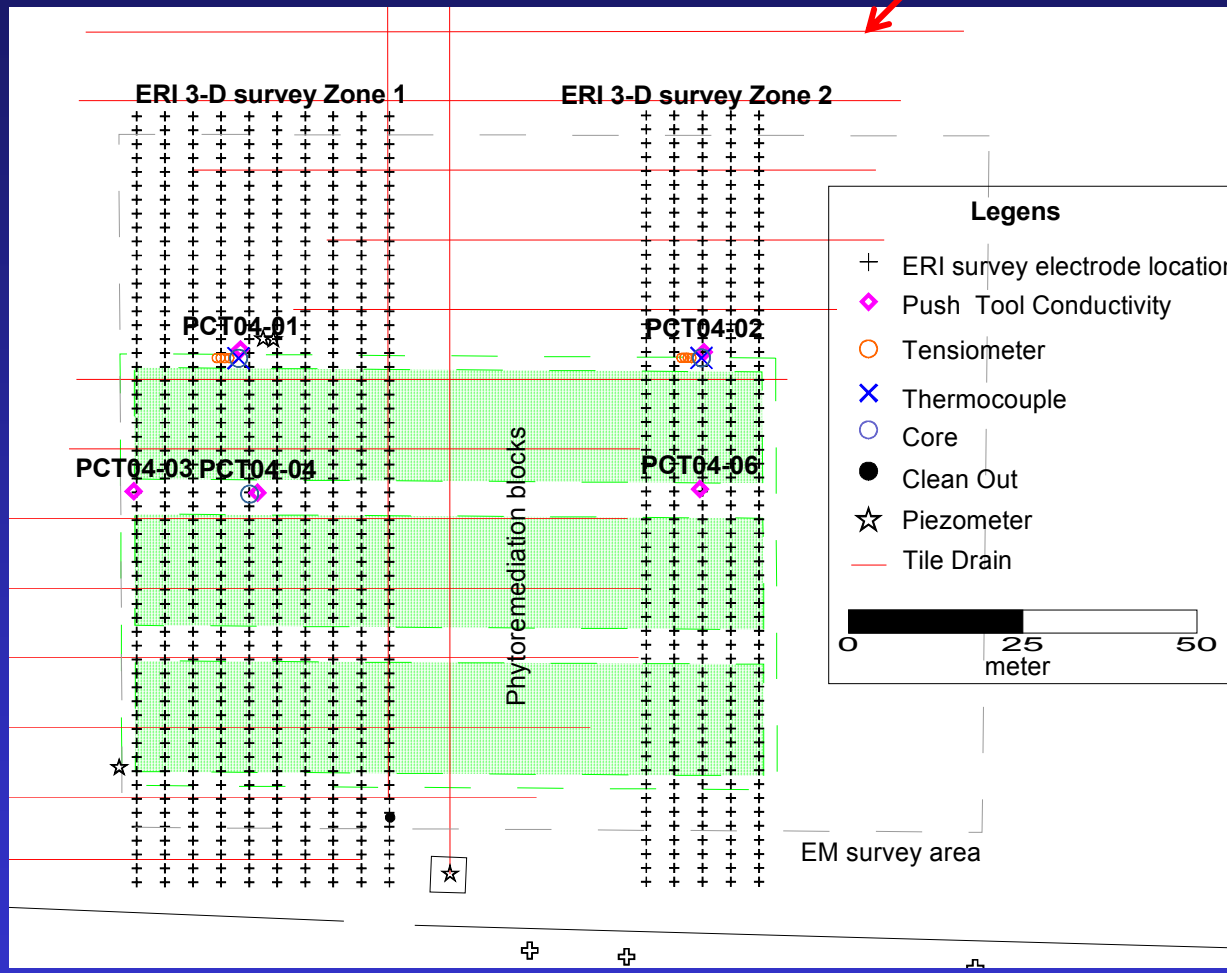
3 ERI surveys (July 04; Nov. 04; May 05)

ERI Surveys

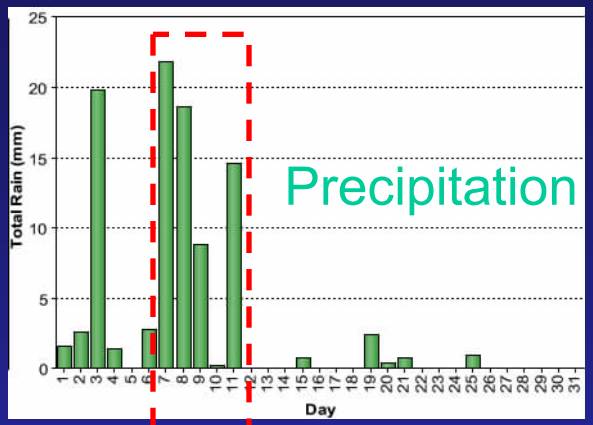
- Dipole-dipole array
- 2 m electrode spacing
- 4 m line spacing
- 56 stations in each line
- 10 lines in zone 1
- 5 lines in zone 2

November Installations

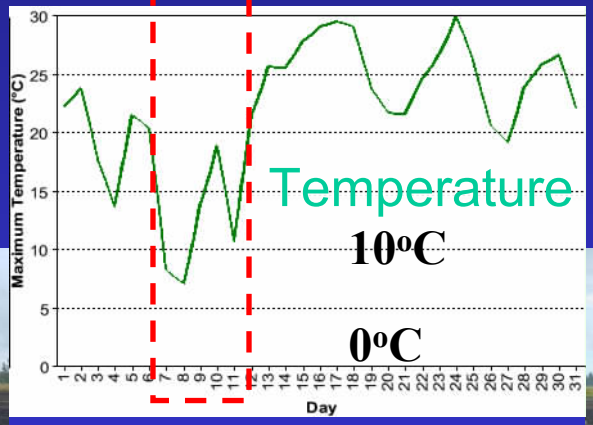
- 2 thermocouple Installations
- 2 tensiometer installations
- 5 PT EC Profiles
- 3 Cores



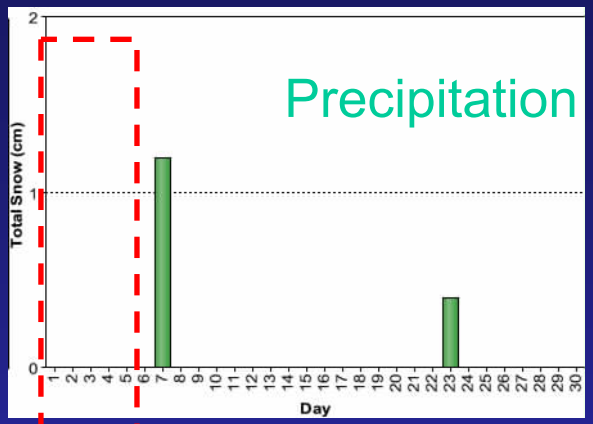
July 2004



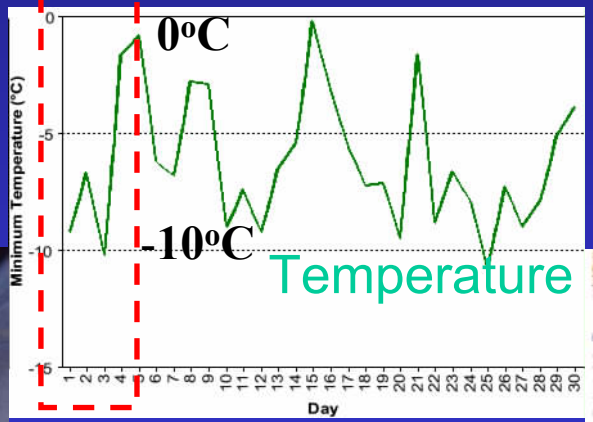
Survey period



November 2004

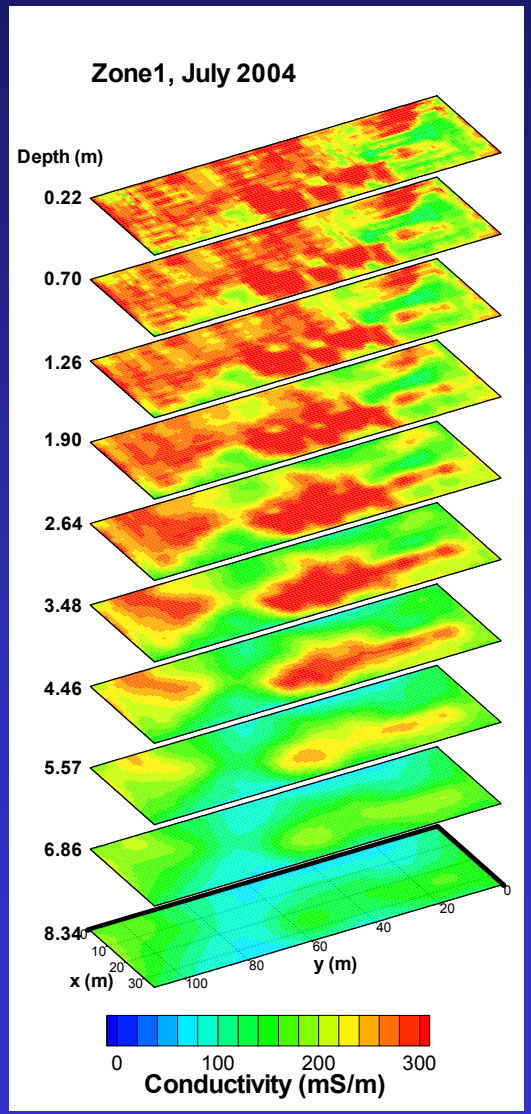


Survey period

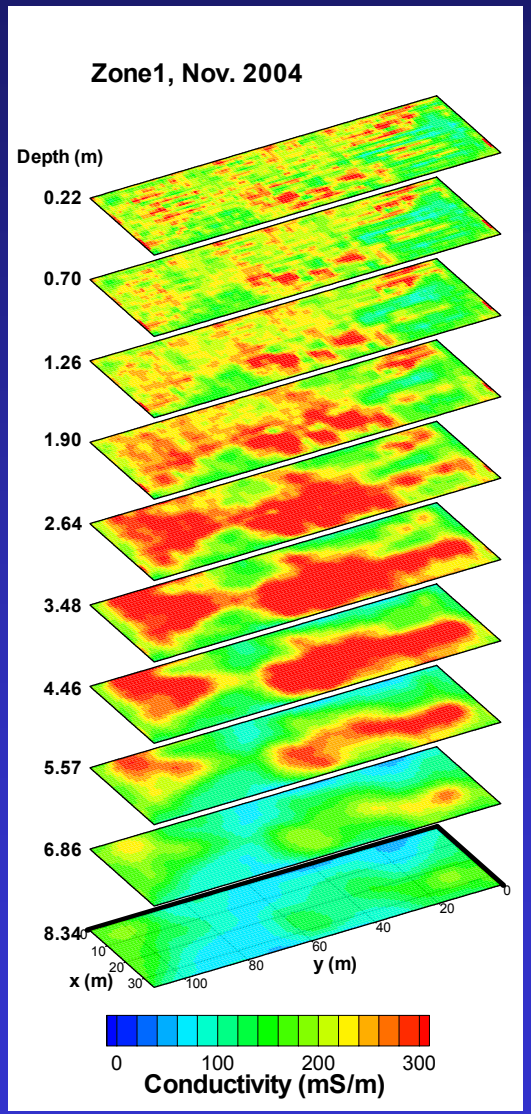


ERI Inversion Zone 1

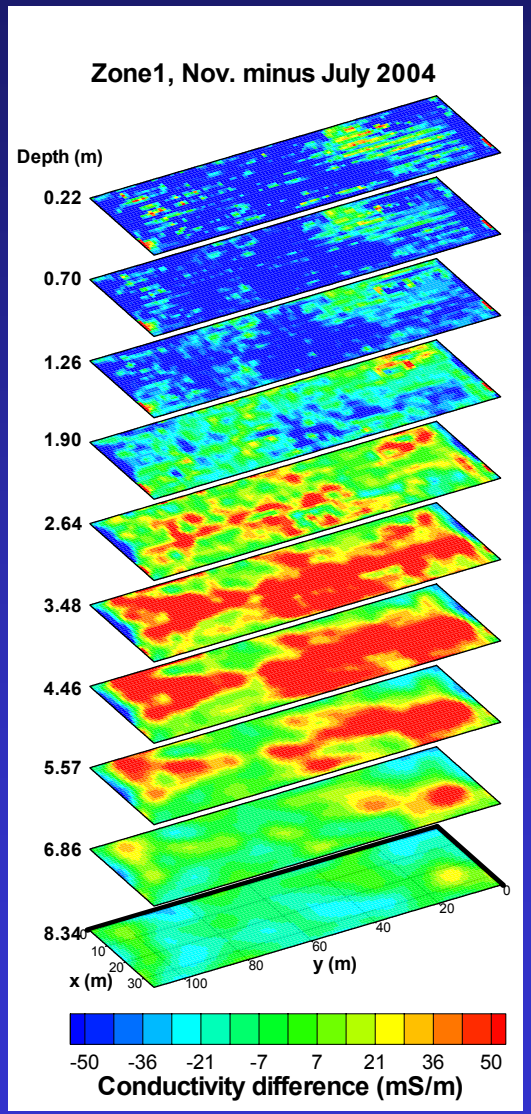
July 2004



November 2004

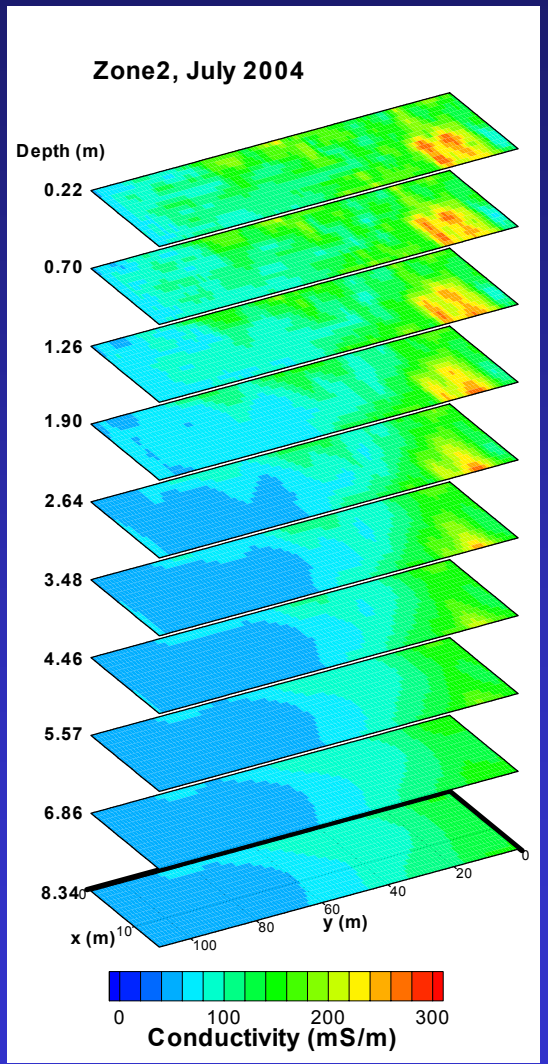


Nov. - July

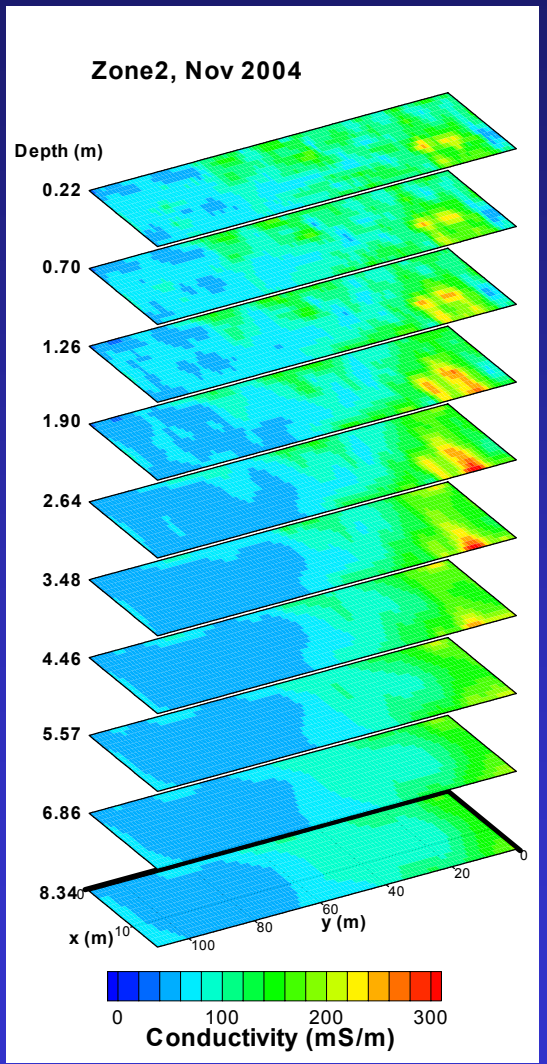


ERI Inversion Zone 2

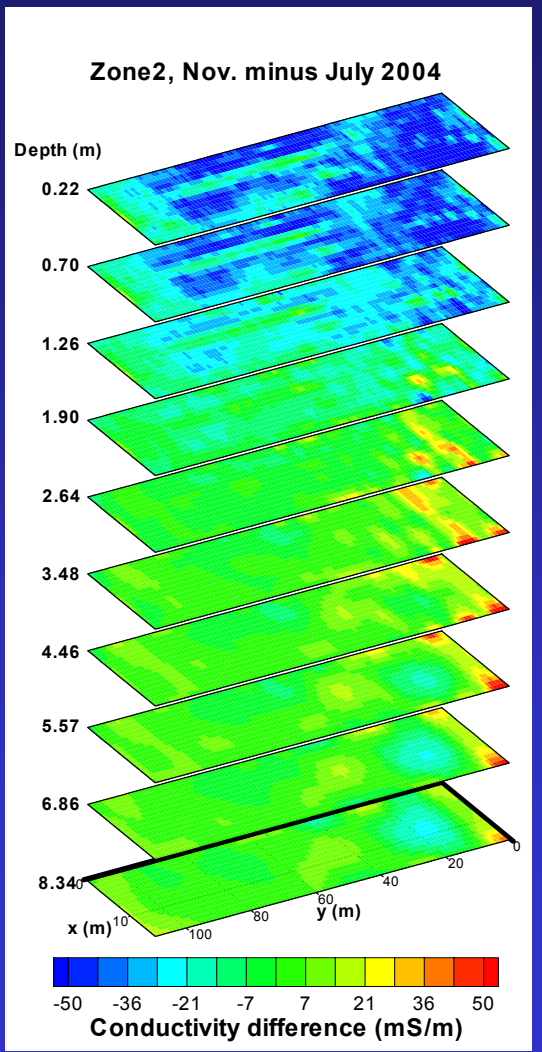
July 2004



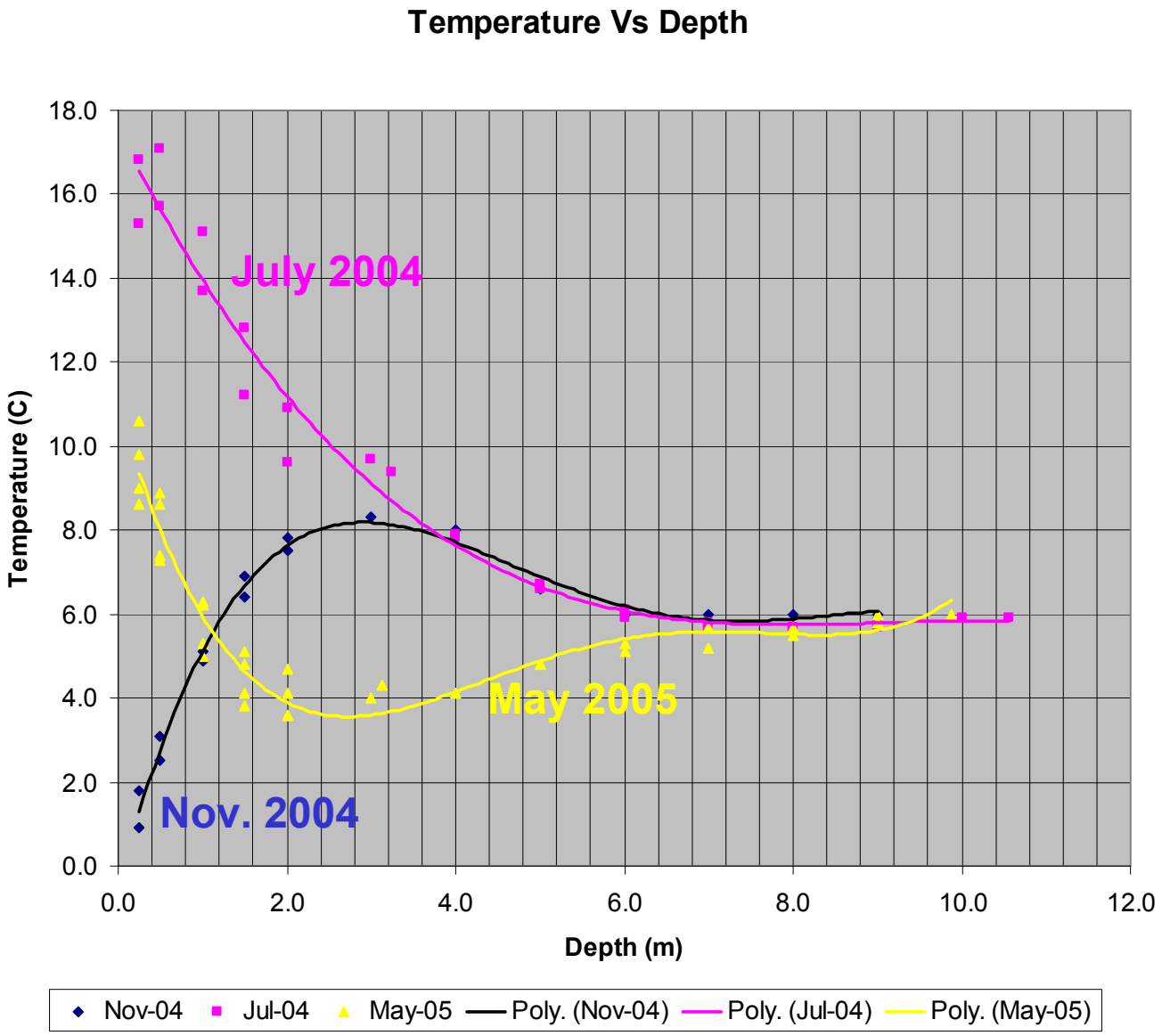
November 2004



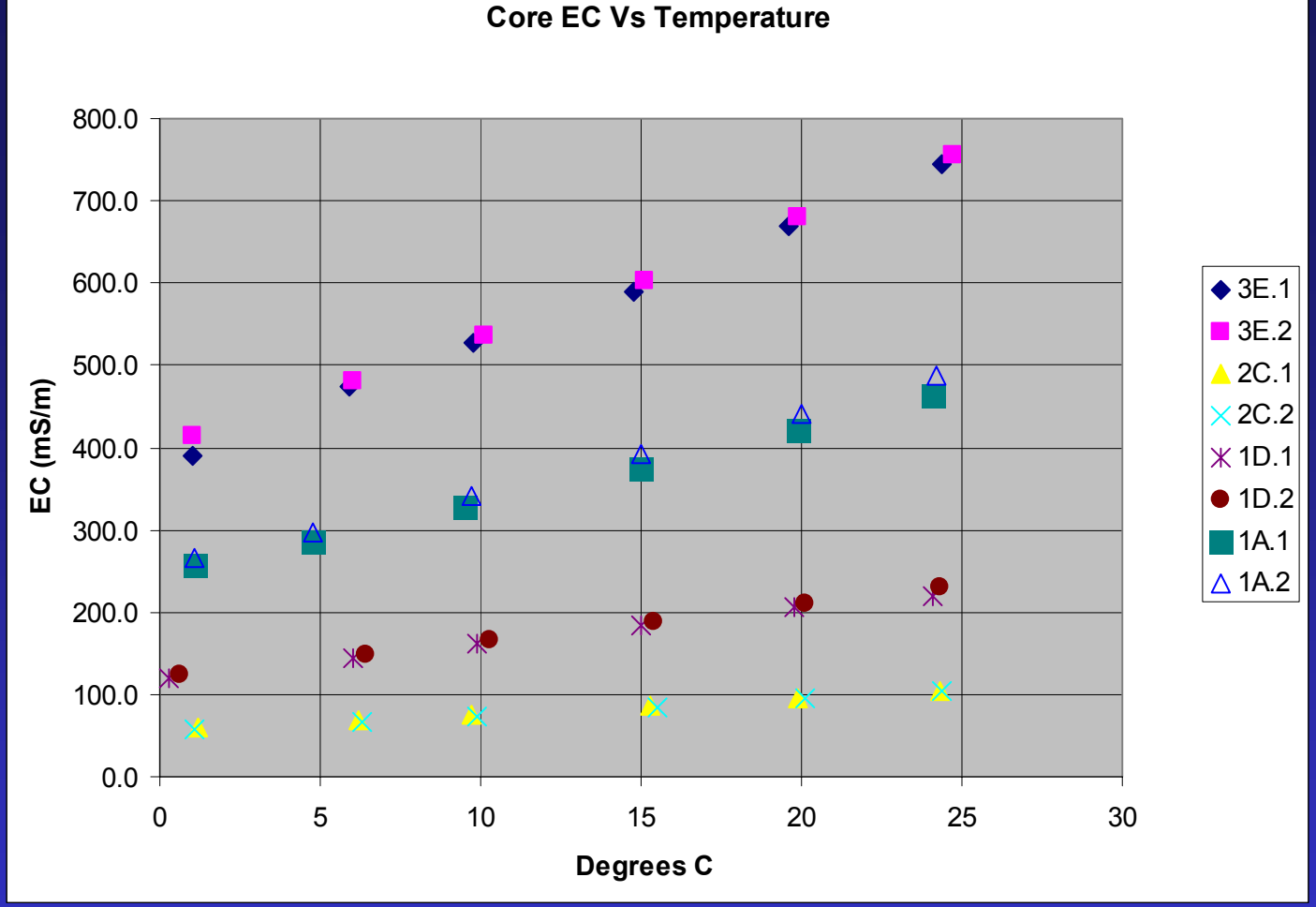
Nov. - July



n situ temperature profiles



July 04 profile approximated by July 05 Measurements.



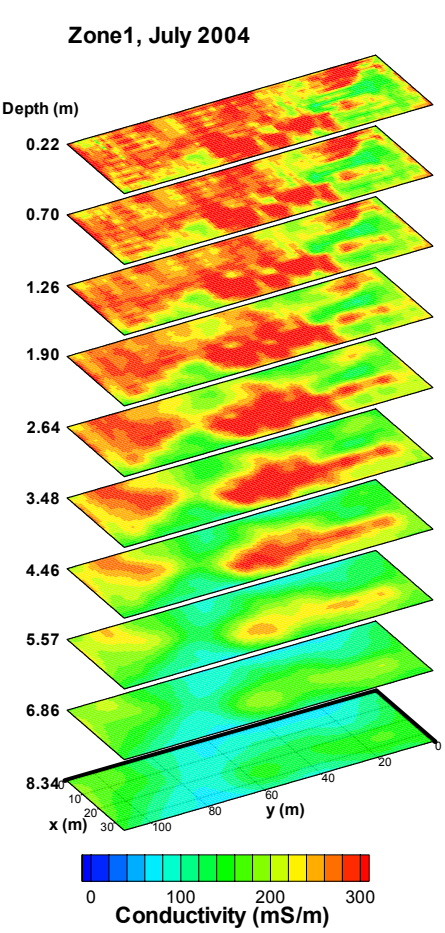
$$EC_{6^o} = EC_T\left(1 + m\left(6^o C - T\right)\right)$$

$$m = 3.0\ \left(\sigma_m = 0.12\right)$$

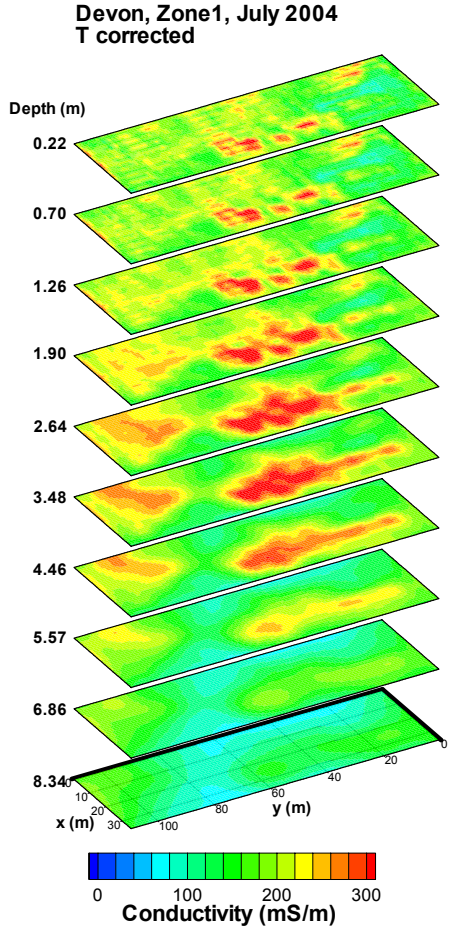
July 2004

Zone 1

Inversion Results

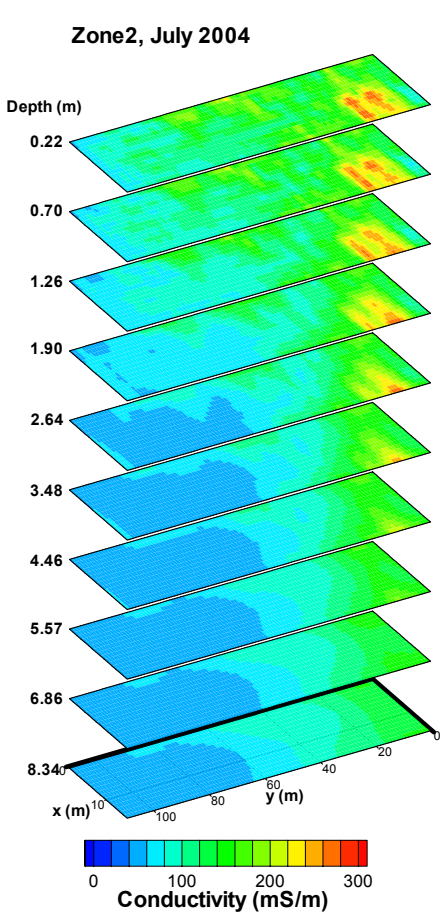


6° C Equivalent

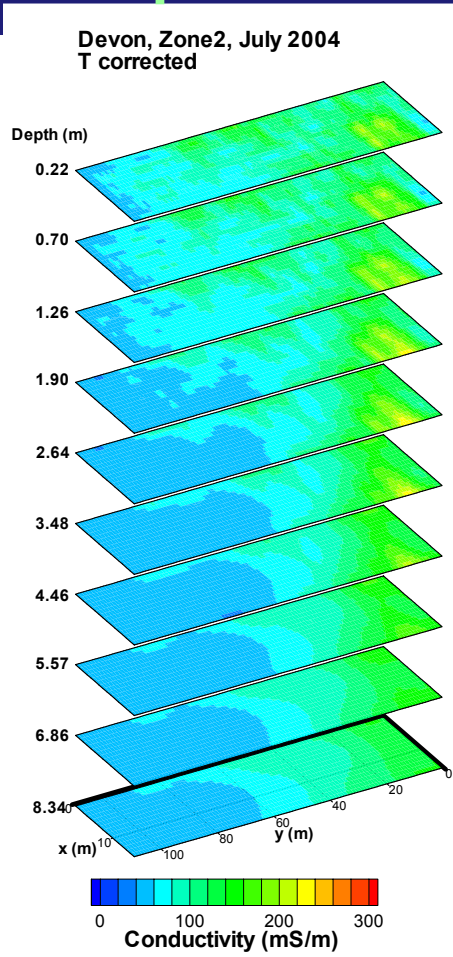


Zone 2

Inversion Results

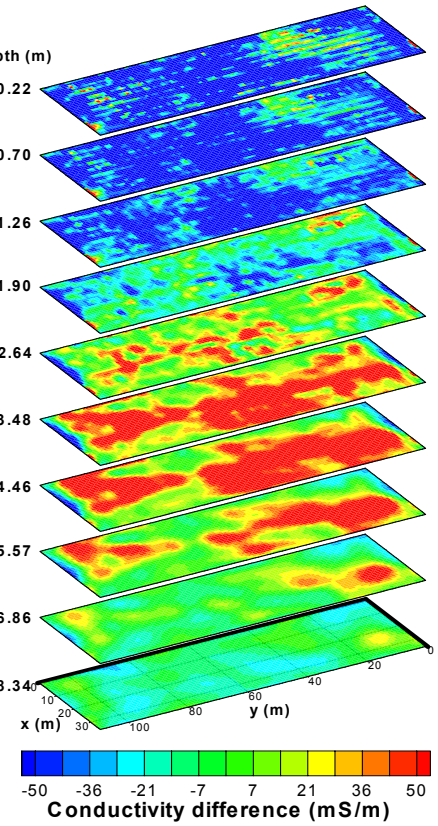


6° C Equivalent

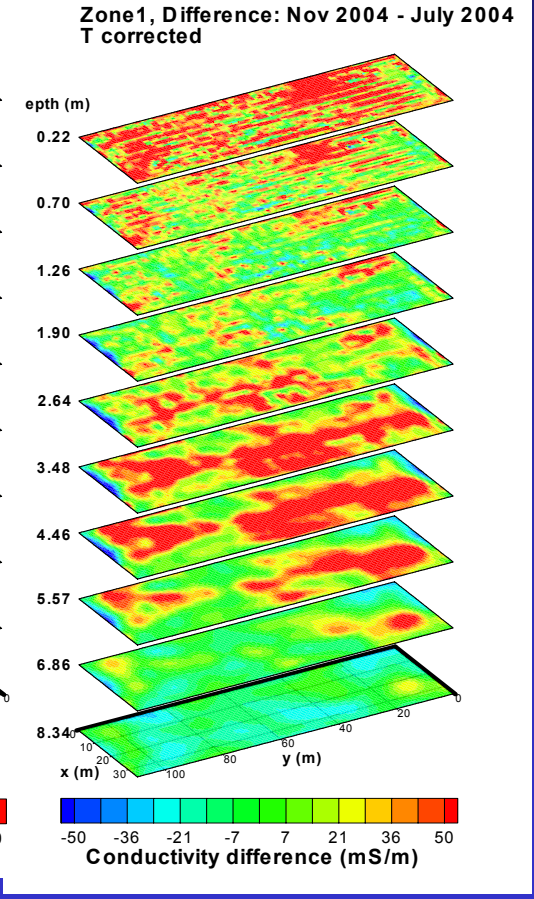


Nov.-July Zone1

Image Difference

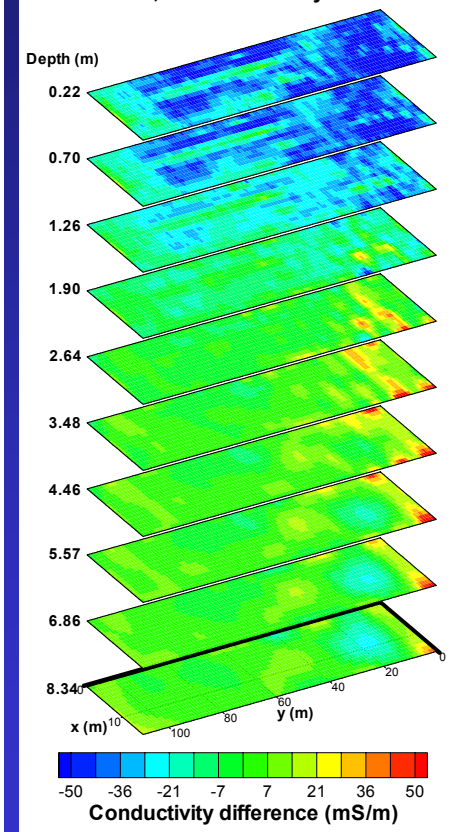


6° C Equivalent Difference

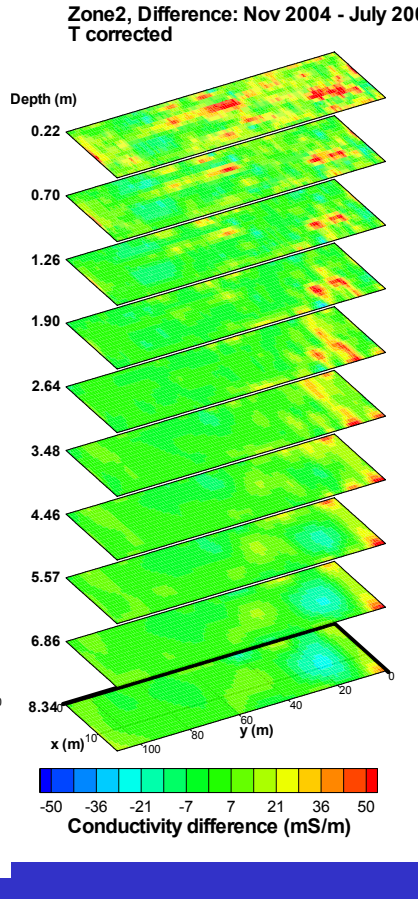


Nov.-July Zone2

Image Difference



6° C Equivalen Difference



CONCLUSIONS

Time-lapse analysis: Need protocols to compensate for changes due to all transient environmental factors.

Quantitative correction relationships
(e.g. EC vs Temperature or S_W)

Appropriate auxiliary field measurements
(e.g. thermocouples, tensiometers)

OR

Incorrect, misleading or ambiguous interpretations

Acknowledgements

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Site and in-kind

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People

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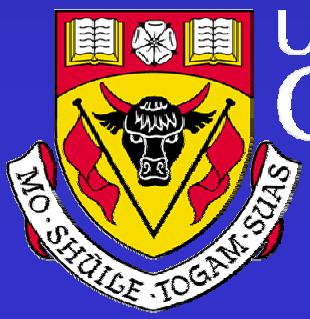

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