Determining Frost Depth in Pavement Systems Using a Multi-Segment Time Domain Reflectometry Probe

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Applications in Pavement Research and Engineering

- **Seasonal Load Limit**
  - Optimize timing of:
    - Winter load increase
    - Spring load decrease
- **Mechanistic Empirical Design**
  - Seasonal Changes in Strength Properties
    - Material properties database

Objectives

- Evaluate Mult-Segment TDR probe for improved frost depth measurements within pavement structures.
- Implement field testing at designated Road and Weather Information (R/WIS) System sites.

Summary of Methods

	Frost Tube	Resistivity Probe	Moisture Block	TDR Probe
Data Collection	Manual	Primarily Manual	Automated	Automated
Data Interpretation	Subjective	Subjective, requiring temperature data.	Subjective, requiring temperature data.	Potential for developing algorithm for automated analysis.
Installation	Labor intensive. Extensive soil disturbance.	Labor intensive. Extensive soil disturbance.	Labor intensive. Extensive soil disturbance.	Minimal Labor. Minimal soil disturbance.

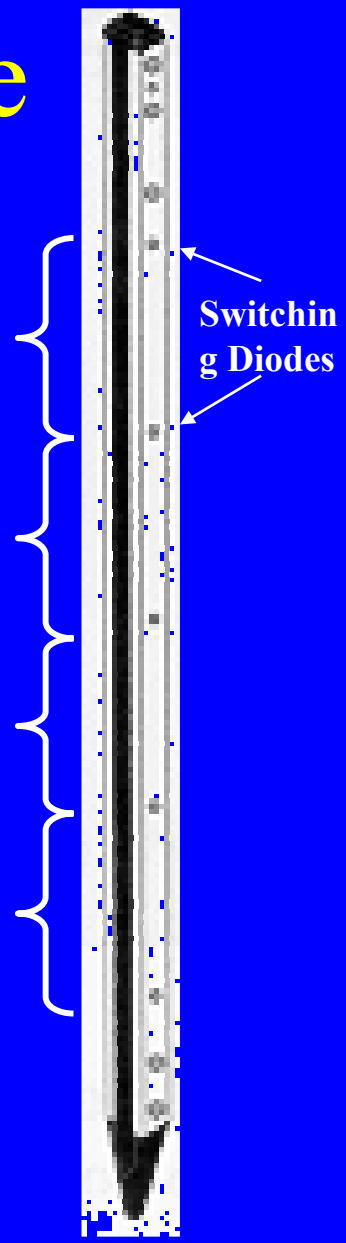
Using TDR to Estimate Frost Depth

- Significant decrease in dielectric constant (Ka) when water freezes.
- Result is abrupt decrease in the propagation time(Δt) measured by the TDR probe.

Multi-Segment TDR Probe

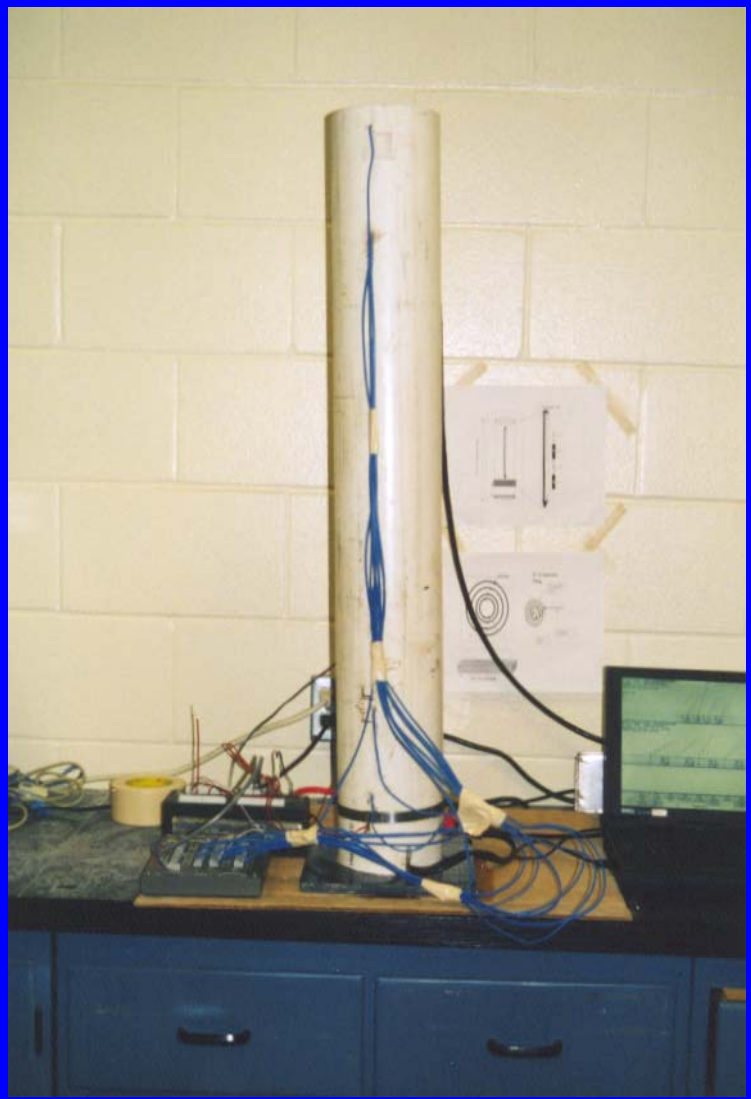
Type K Probe:

- Four segment Probe
- Each segment 15 cm
- Two stainless steel rails separated by an epoxy and high density plastic.
- Segment boundaries defined by switching diodes.

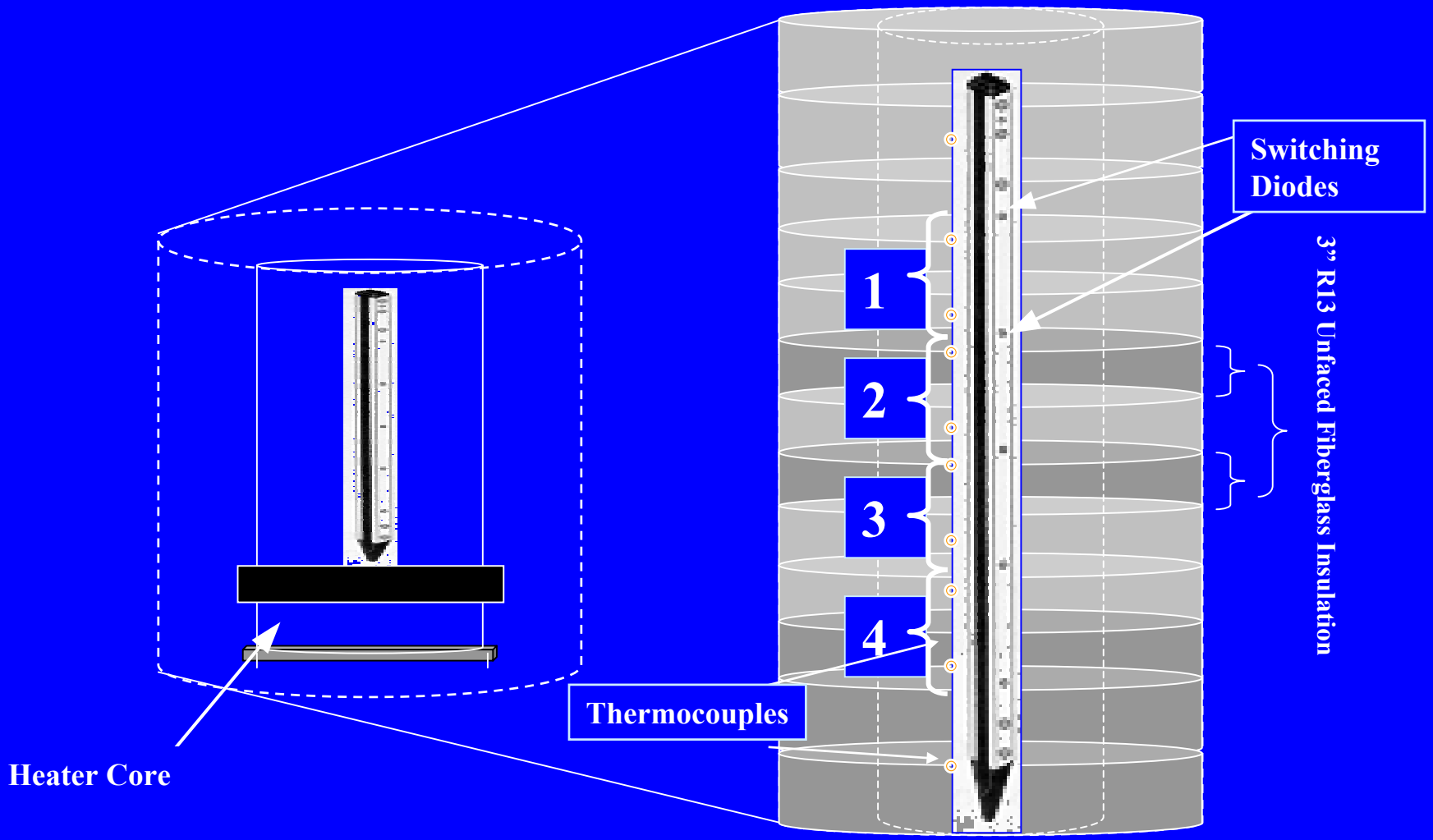


Laboratory Experiment

- Frozen Soil Core
  - PVC column packed with Class 5 Special resting on heater core base.
  - Instrumentation
    - MP Probe
    - Thermocouples
  - Automated Data collection
    - MP917
    - Campbell Scientific CR10X and AM416
    - Dell PC (Procomm script file)

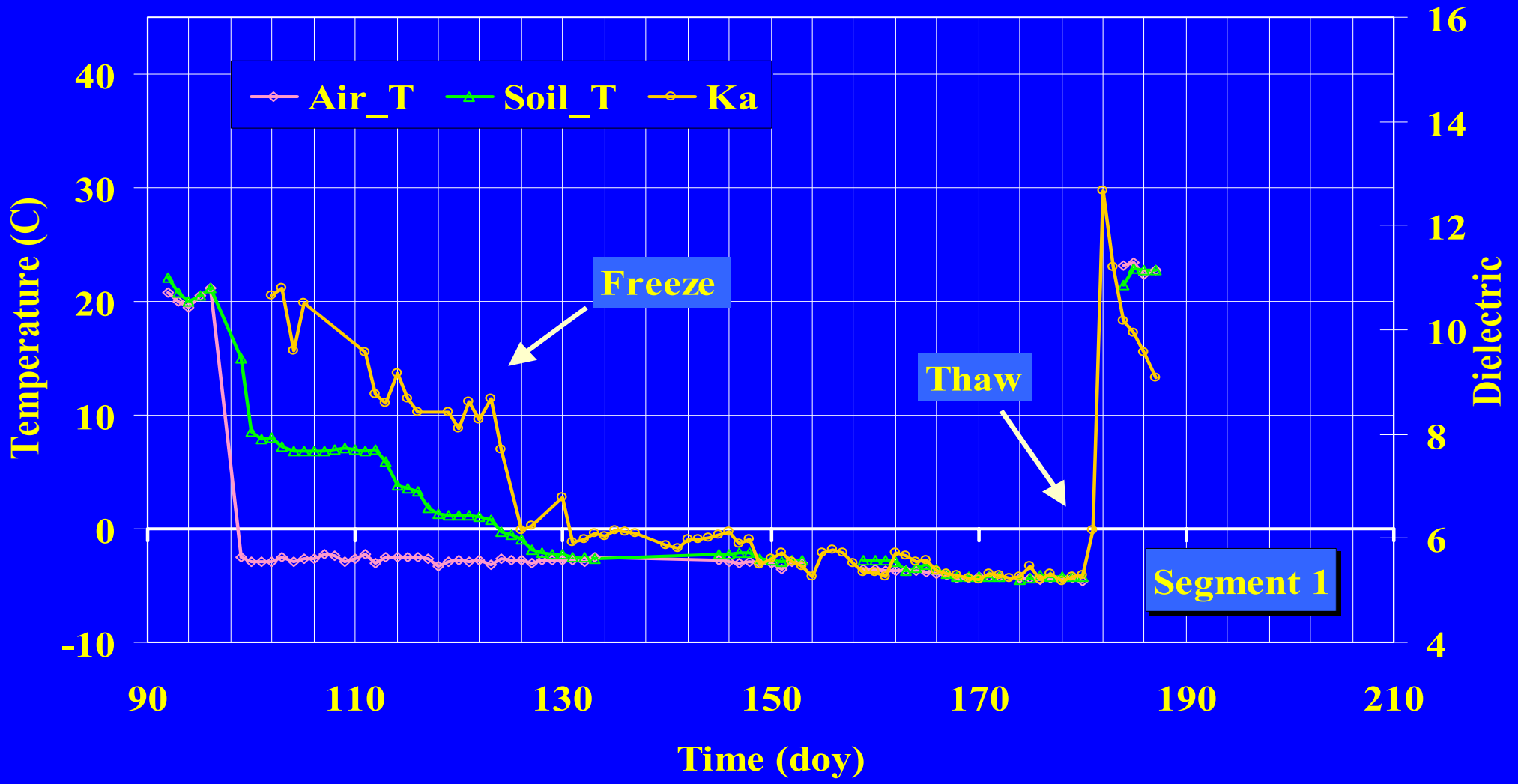


Confine Freezing to the Surface of the Soil Column



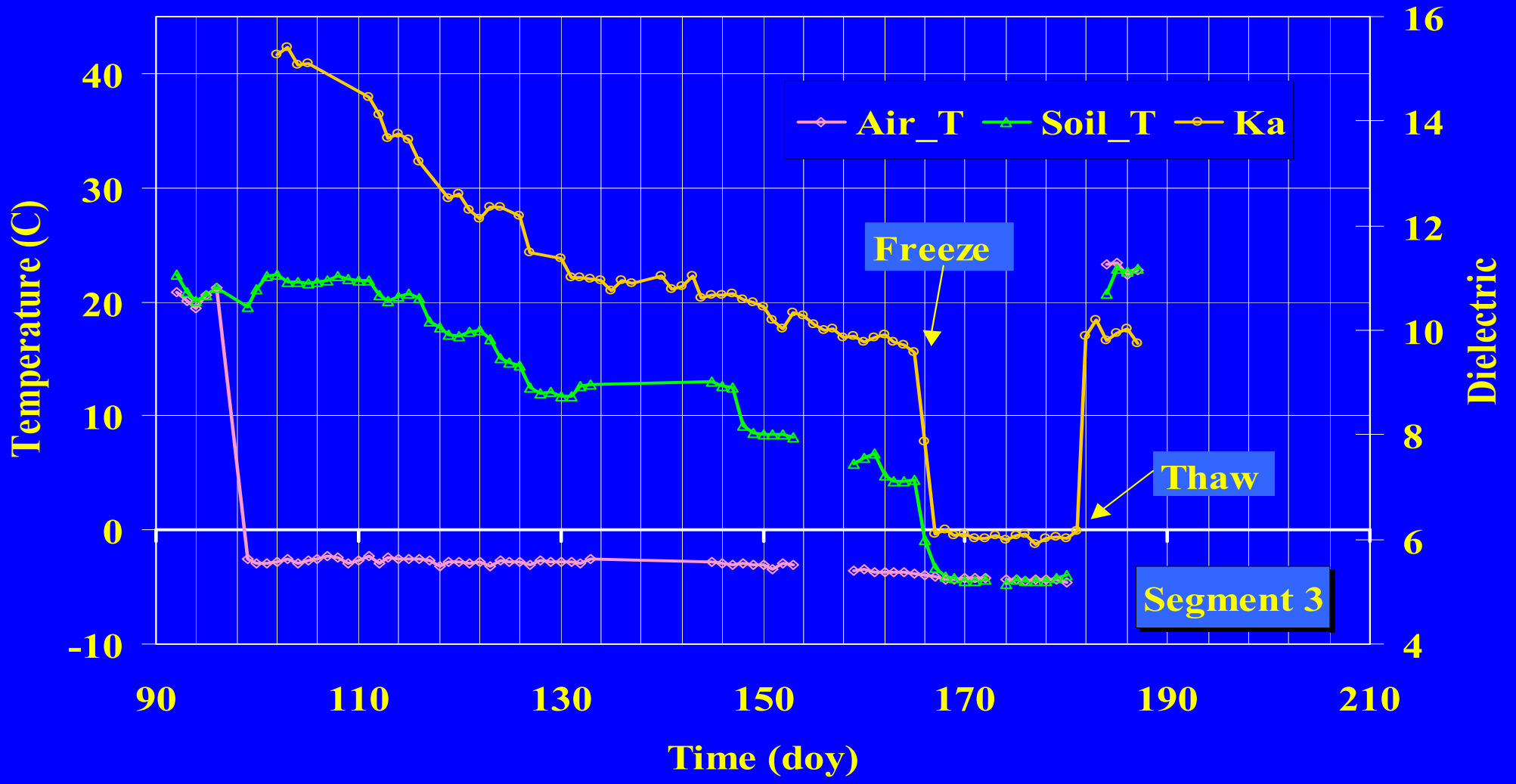
Frost Depth

(Step-wise freezing)



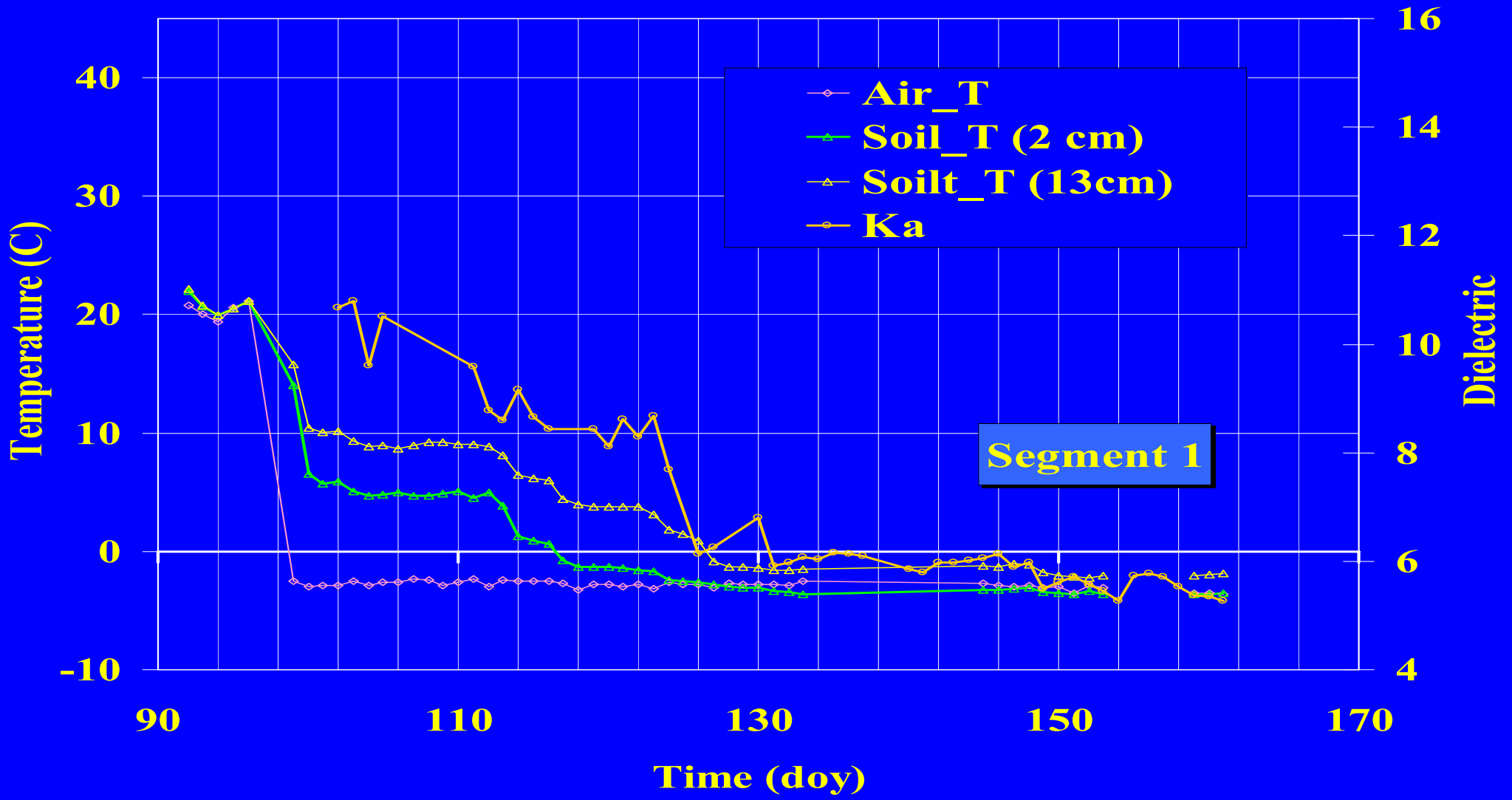
Frost Depth

(Rapid freezing)



Frost Depth

(Resolution)



RESULTS

- Measured decrease in Ka near 0° C for each segment.
- Estimated frost depths agree with temperature measurements and physical test.
- Rate of freeze/thaw and initial moisture content affect magnitude of change in Ka near 0° C.
- Resolution is limited to the length of the segment.

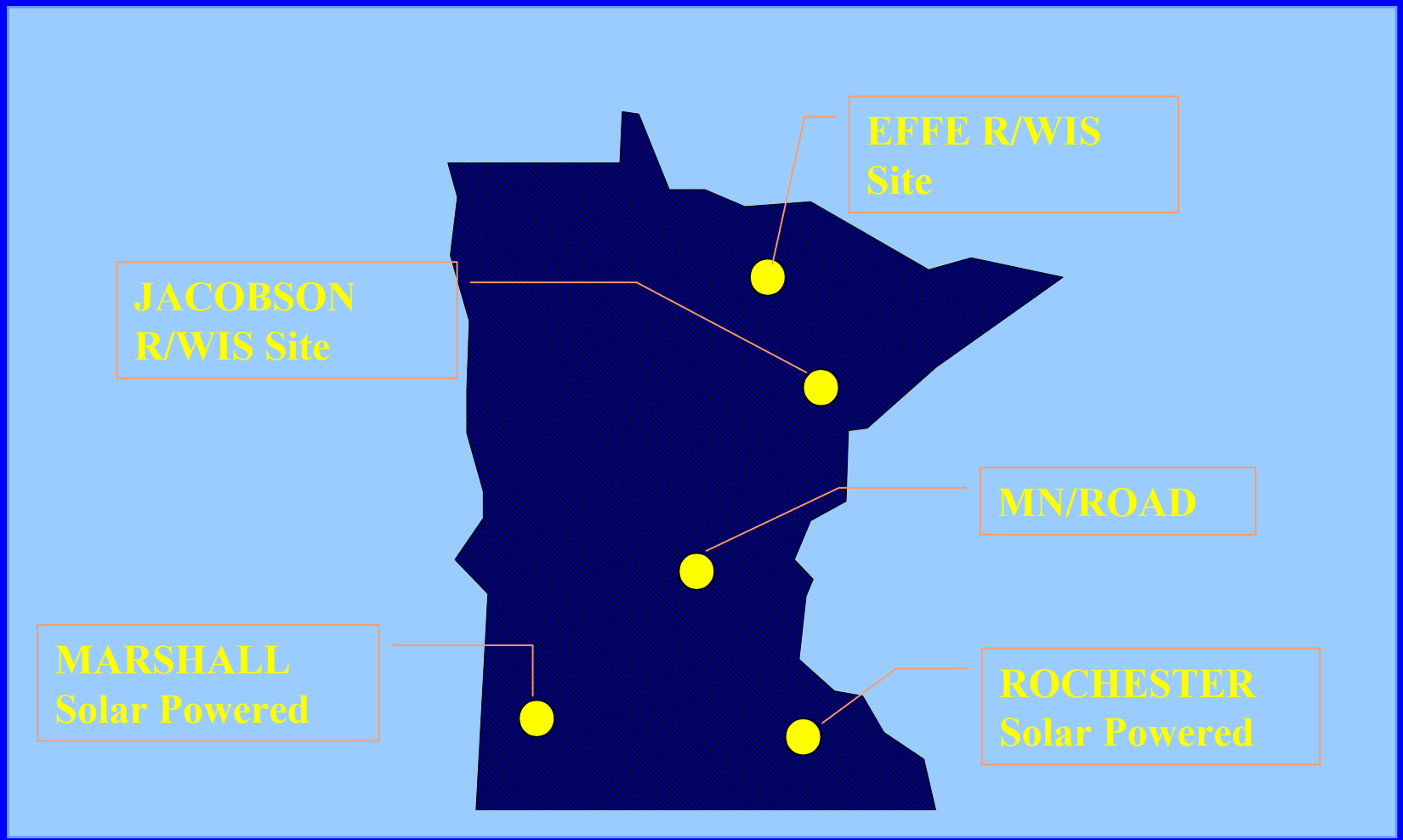
Road and Weather Information System (R/WIS)

- Main elements of RWIS are
  - environmental sensor system (ESS)
  - advanced processing systems to develop forecasts and tailor the information into an easily understood format
  - dissemination platforms on which to display the tailored information.

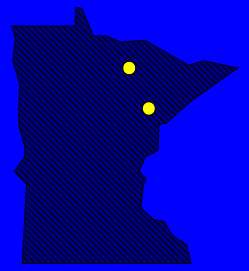
Road and Weather Information System (R/WIS) cont'd

- Specific to Minnesota
  - Implementation of a system that is able to accommodate various types of instruments.
  - Portion of the R/WIS project is dedicated to testing the system's communication architecture.
- Specific to Minnesota Road Research
  - Investigate new methods for determining frost depth as well as looking for improved data transfer protocols.

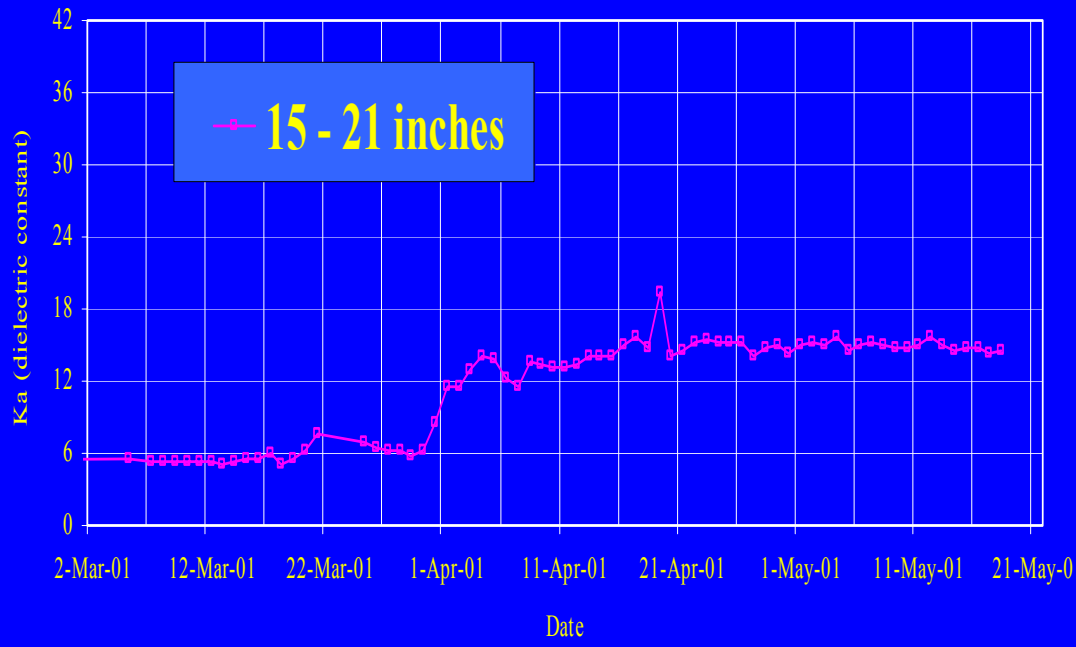
STATE-WIDE INSTALLATIONS

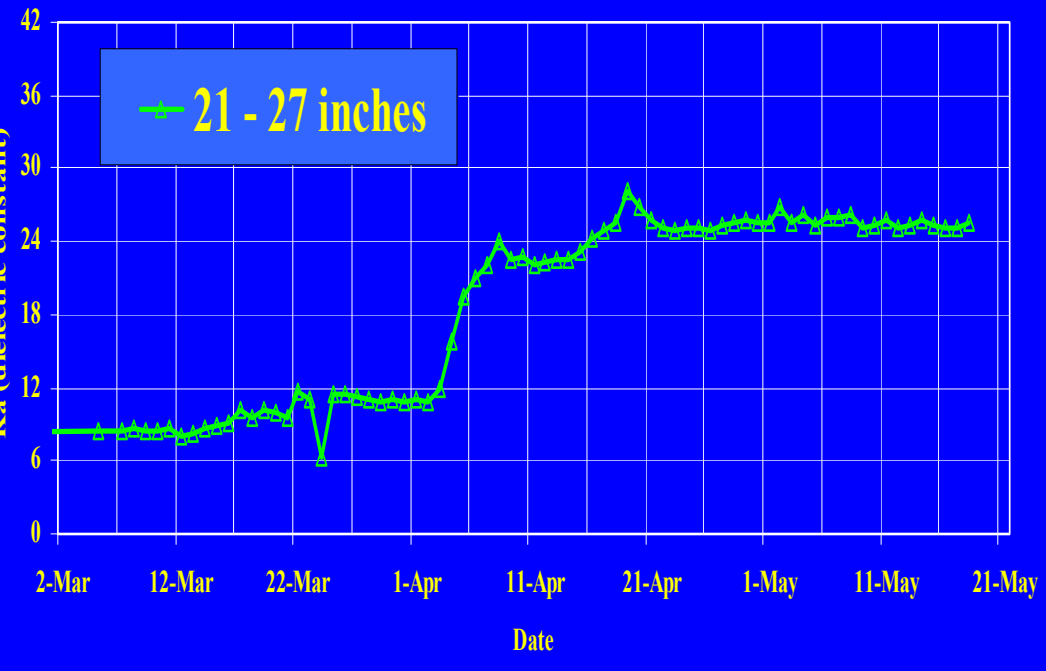


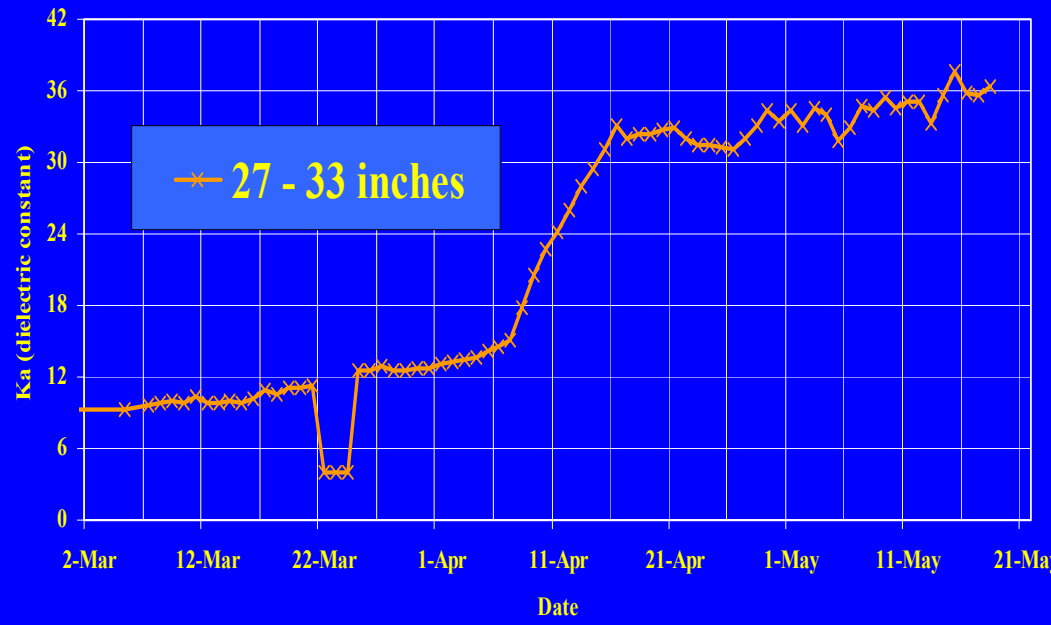
R/WIS SITES:
EFFE and JACOBSON, MN



R/WIS SITE: 52
EFFE, MN
Spring Thaw 2001







CONCLUSIONS

- Multi-segment TDR probe shows promise as instrument for measuring frost depth within pavement structures.
- TDR methods provide a means for validating air temperature based models.
- Increase the number of field sites.
- Continue research into TDR methods.

Continuing Research

- Temperature Effects on Dielectric Constant
  - Evidence of significant temperature effect on measured Ka.
  - Temperature correction for moisture content measurements.
- Calibration for Moisture Content
- Automation of data interpretation
  - Ka and raw waveform interpretation

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