Real-Time Monitoring of Bridge Scour in Clayey Sediments

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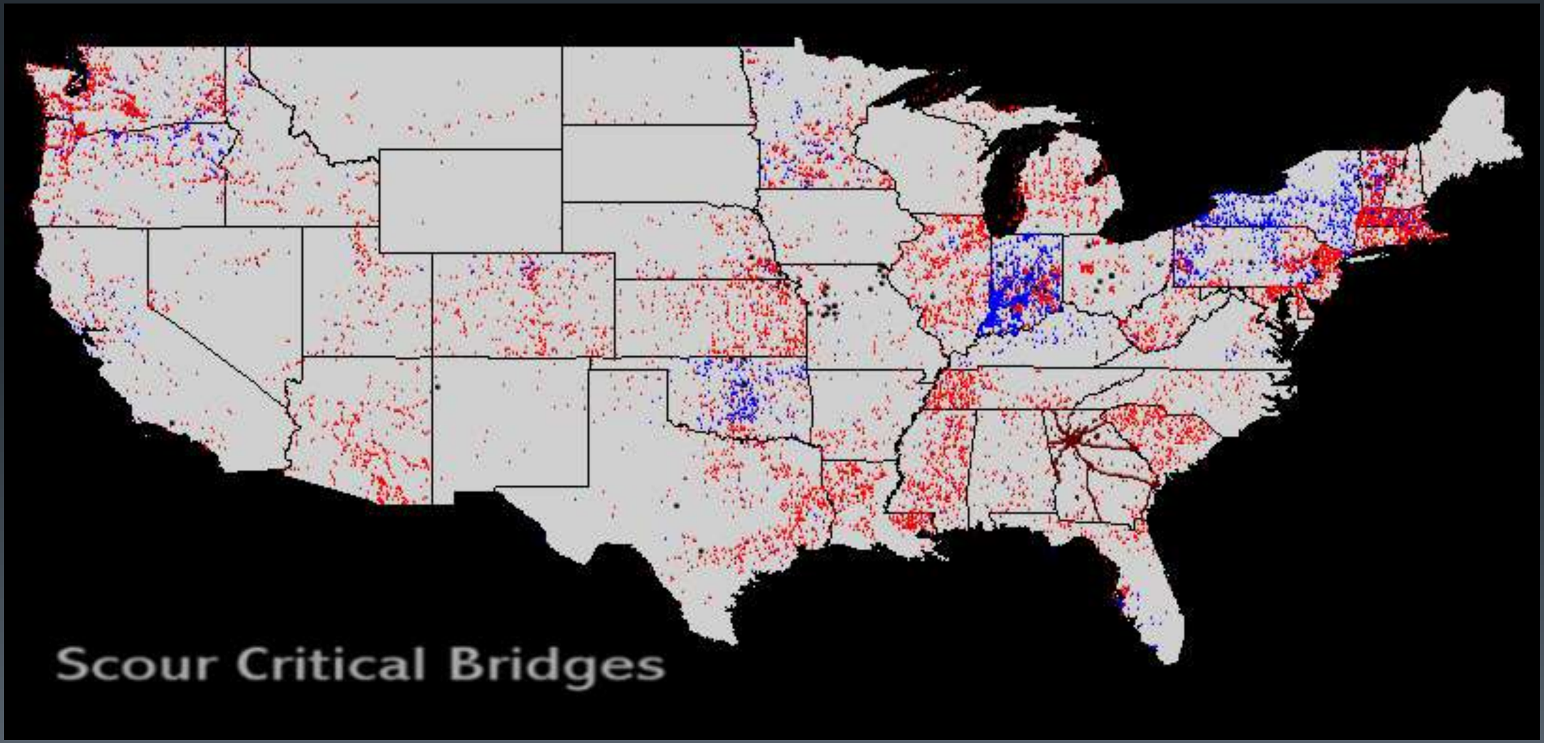
Outline

- Introduction
- TDR Background and Previous Work
- Experiment Program
- Results
- Conclusions and Recommendations

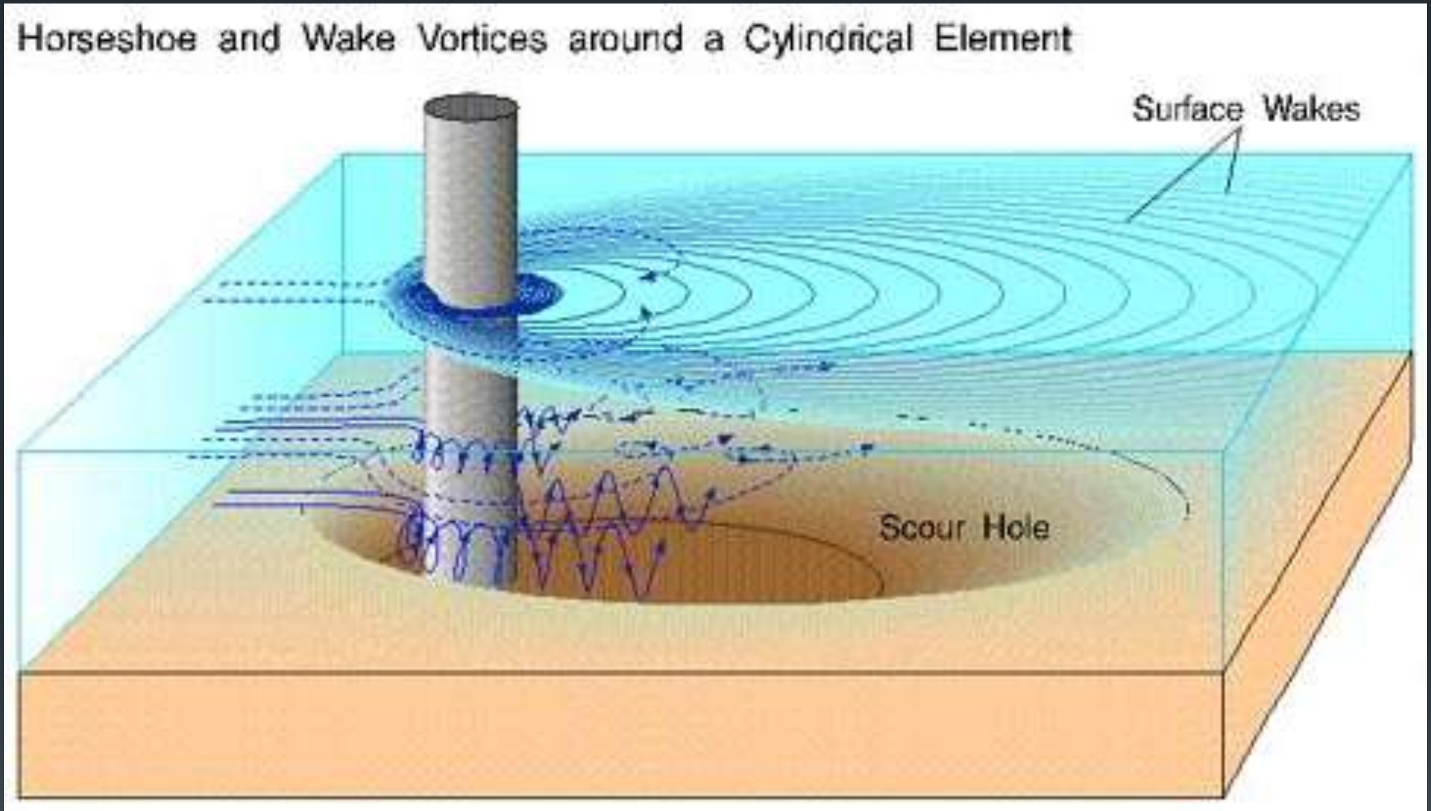
Introduction

- Scour of pier or abutment poses a most severe threat to bridge service life 503,000 bridges traverse waterways, over 20,000 are classified as scour critical (in U.S. alone)
- 1000 bridges have collapsed in 30 years in the USA and scour was responsible for 60% of those failures



Scour Critical Bridges in the United States

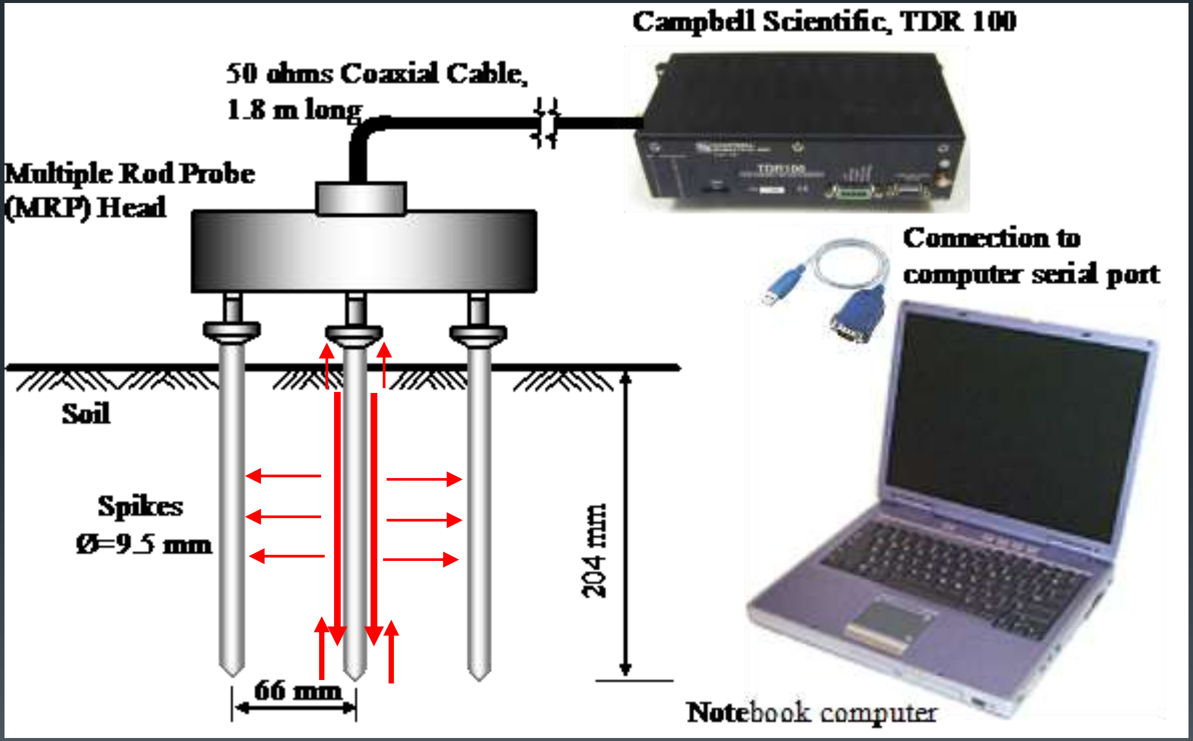
Introduction



Scour hole development – a dynamic process

TDR for Bridge Scour Monitoring

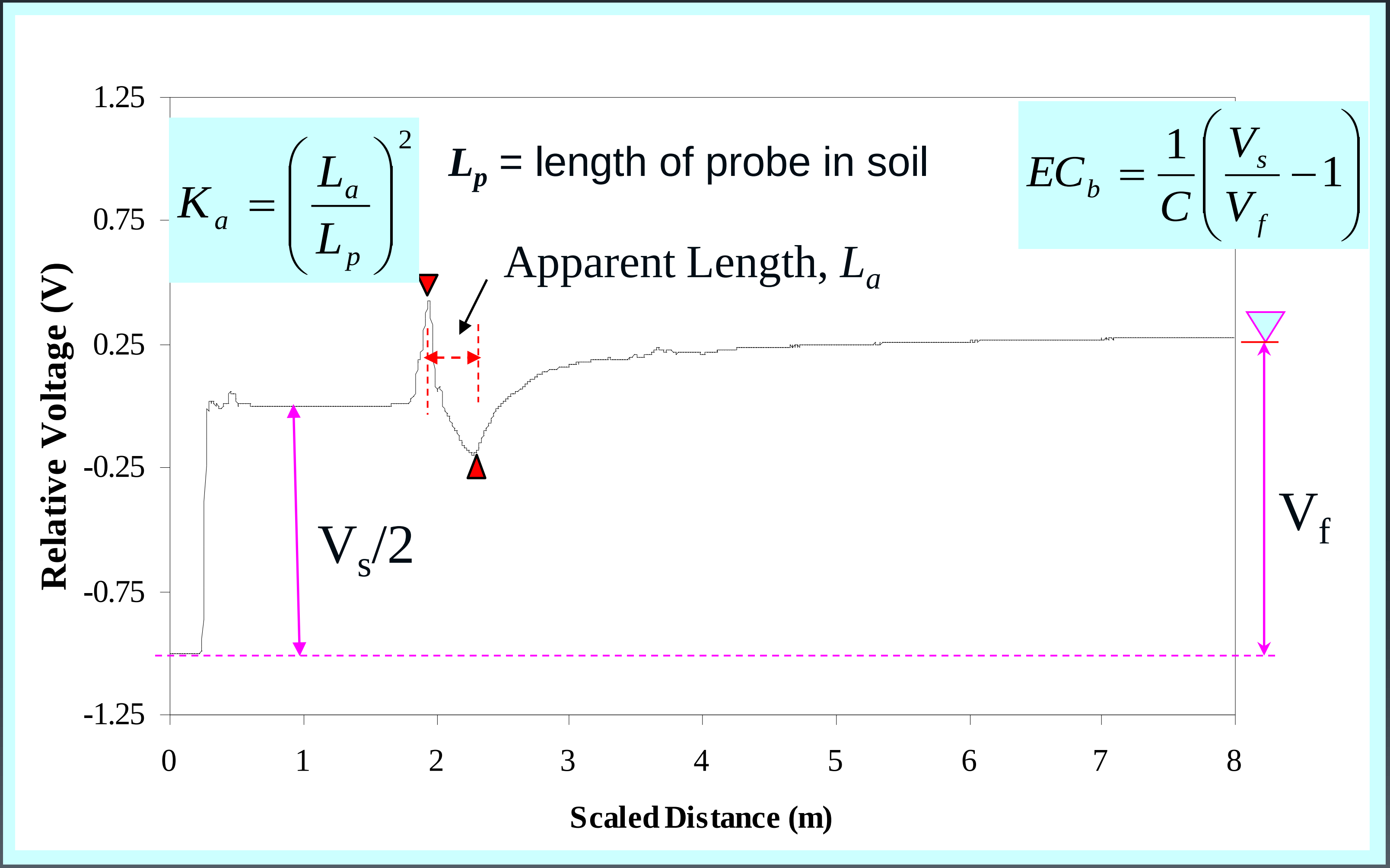
- Use guided "radar" to identify materials properties and interfaces.
- Involves fast rising EM pulse of picoseconds to identify high frequency responses



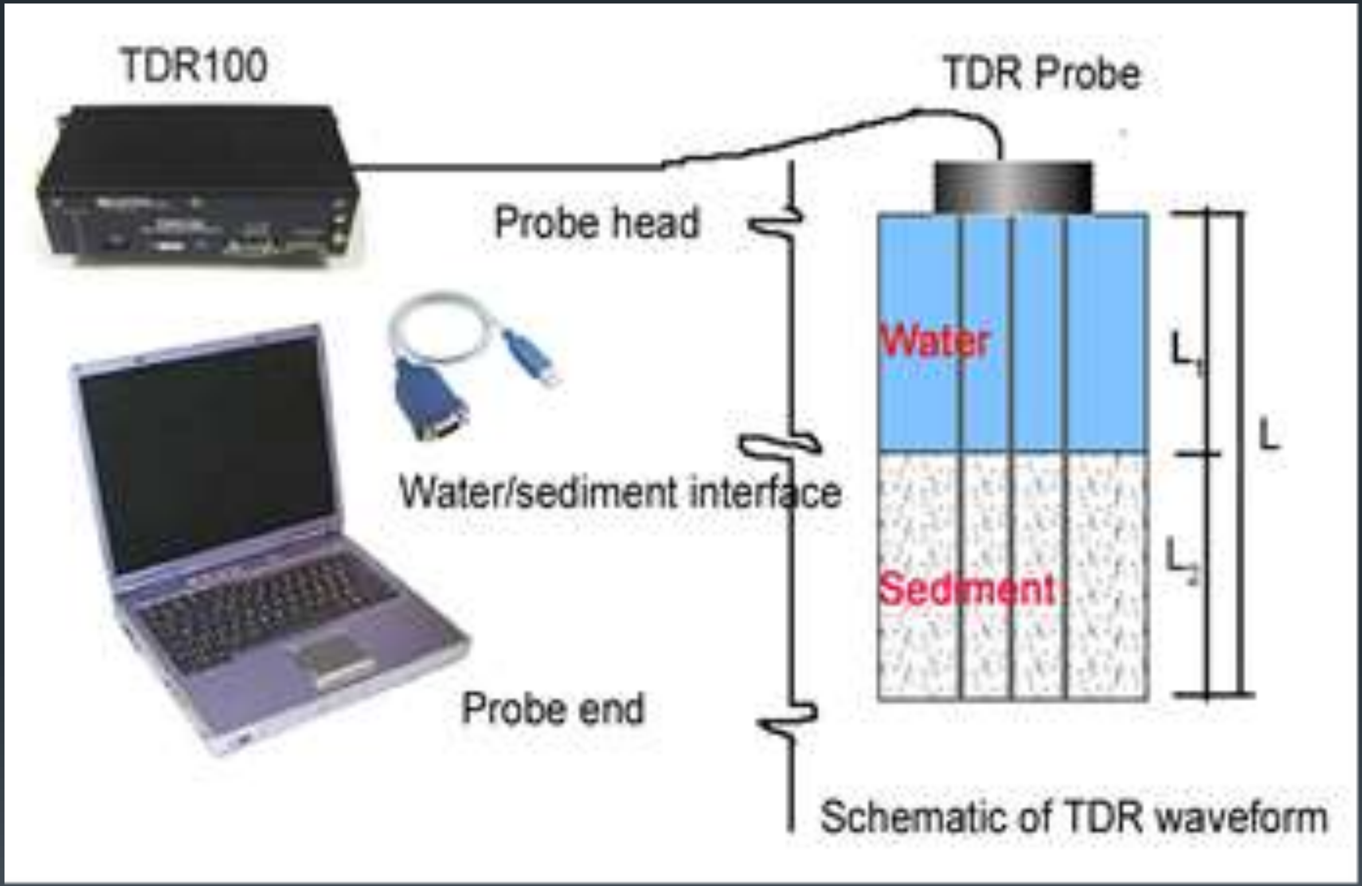
Schematic diagram of a TDR system for the application in Geotechnical Engineering

Information from TDR signal

- Dielectric constant and electrical conductivity



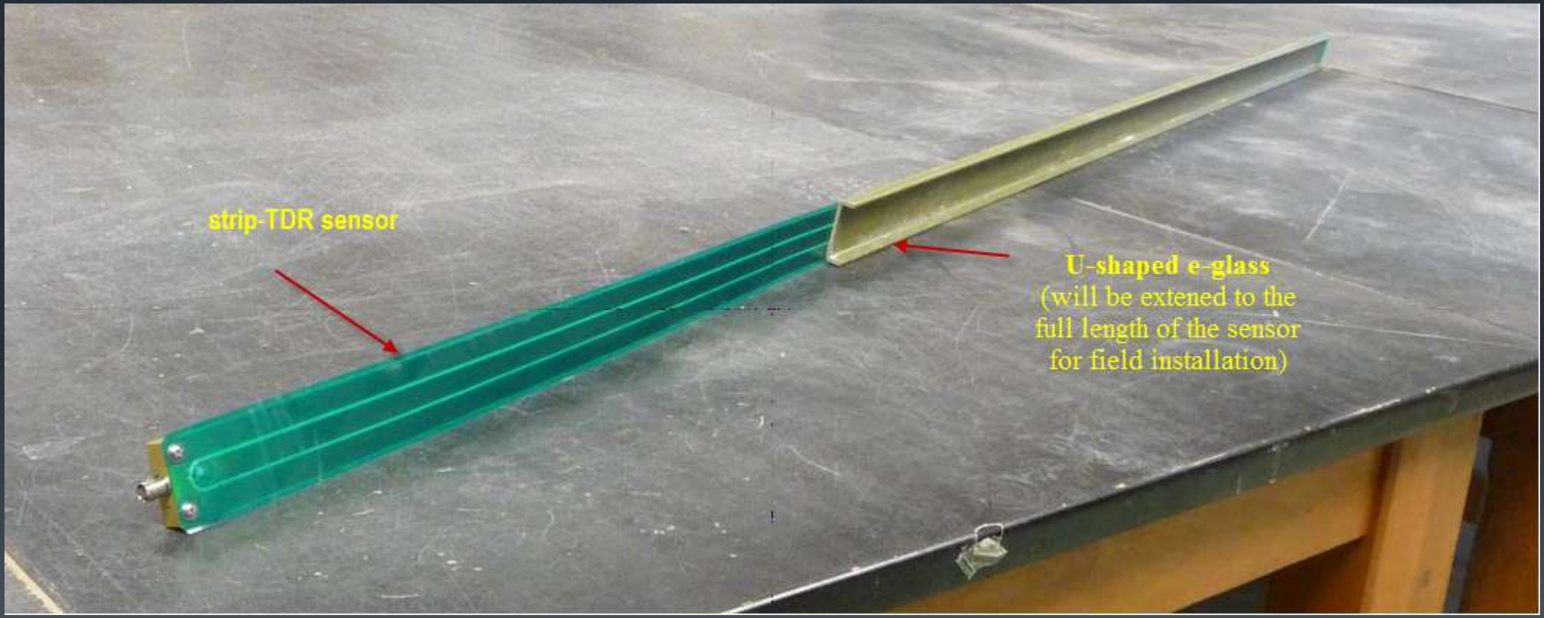
Measure simulated scour using TDR



Schematic of TDR monitoring of simulated scour

TDR Sensors

CS610 Sensor from Campbell Scientific



Strip Scour Sensor with U-Beam Support

Scour Measurement Equations

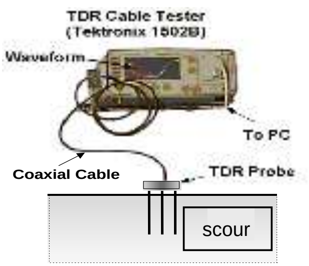
$$\frac{\sqrt{K_{a,m}}}{\sqrt{K_{a,w}}} = \frac{x}{L}\left(\frac{\sqrt{K_{a,bs}}}{\sqrt{K_{a,w}}} - 1\right) + 1 = -Cx_r + 1$$

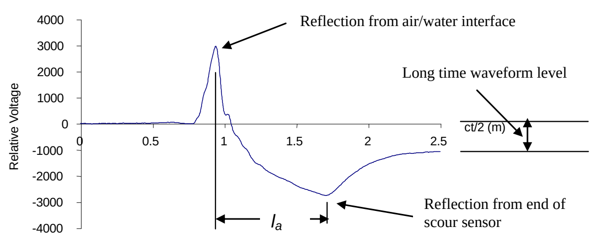
Coated TDR Sensor (Ferré et al. 1996)

$$K_c^n = wK_{coating}^n + (1 - w)K_a^n$$

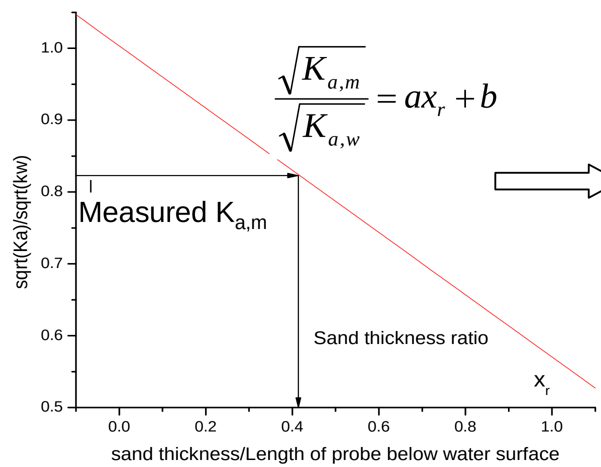
Previous Scour Measurement Equation

Step 1: Determining the bulk dielectric constant $K_{a,m}$ from TDR signal





Step 2: Determine the ratio of sand layer/probe length from design equation



Step 3: Calculate scour depth

$$S_D = (1 - x_r)L$$

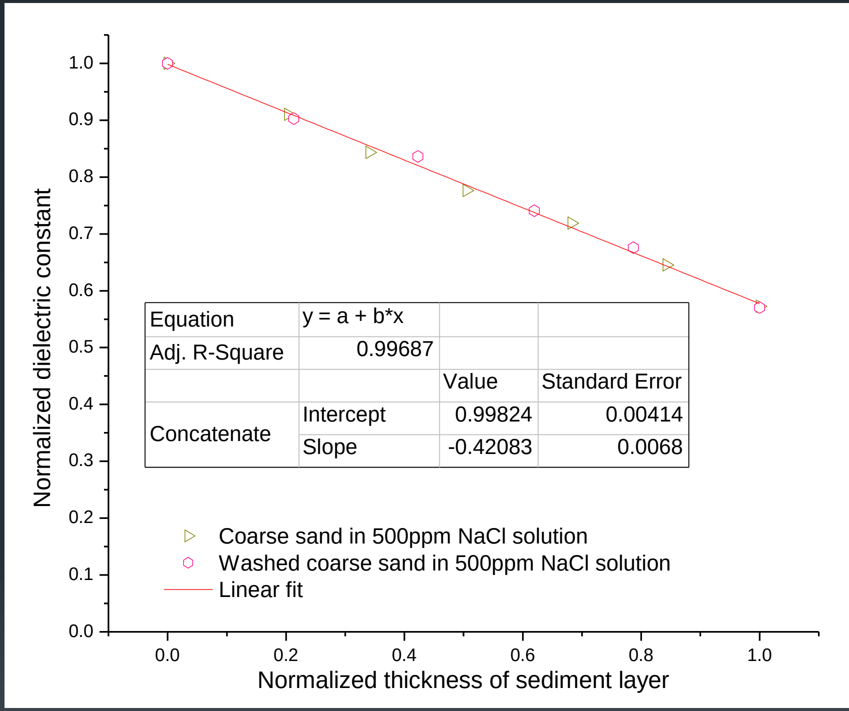
Procedure of using the measurement equation (data from fine sand)

Monitoring of Simulated Scour in Various Soil and Water Conditions

- Testing materials




Calibration coefficient for different soils



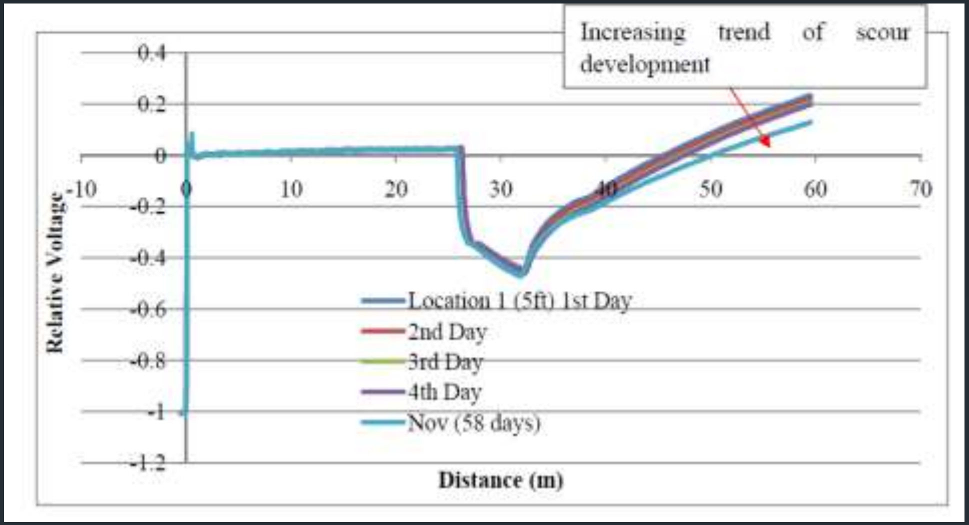
	Average porosity	Slope of equation (3.3)
Fine sand	0.417	-0.424
Coarse sand	0.422	-0.421
Gravel	0.569	-0.314
mixture	0.356	-0.468

Normalized TDR measurements for coarse sand

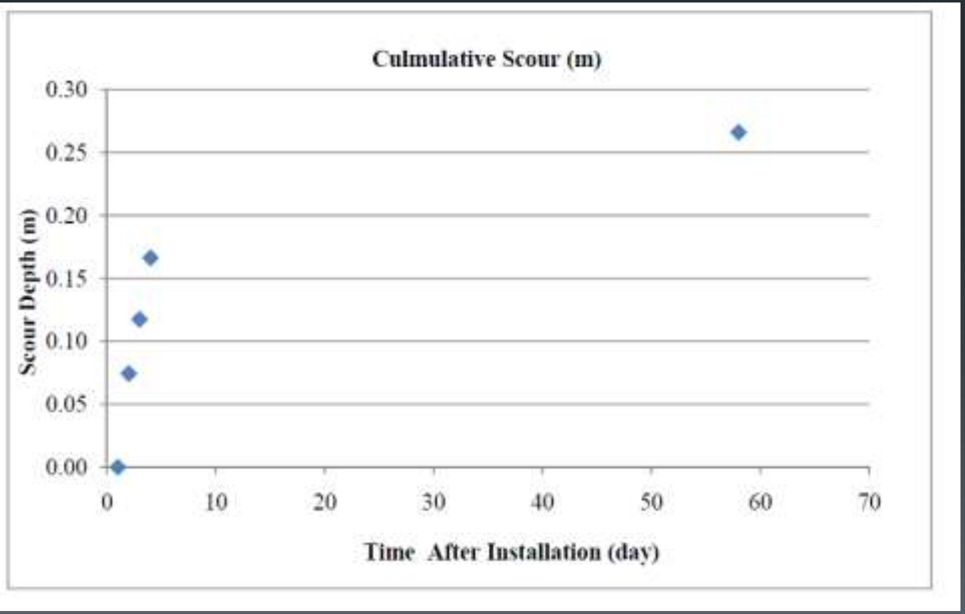
Field Installation

Ohio State Route 122 Bridge over Great Miami River

Sample Results



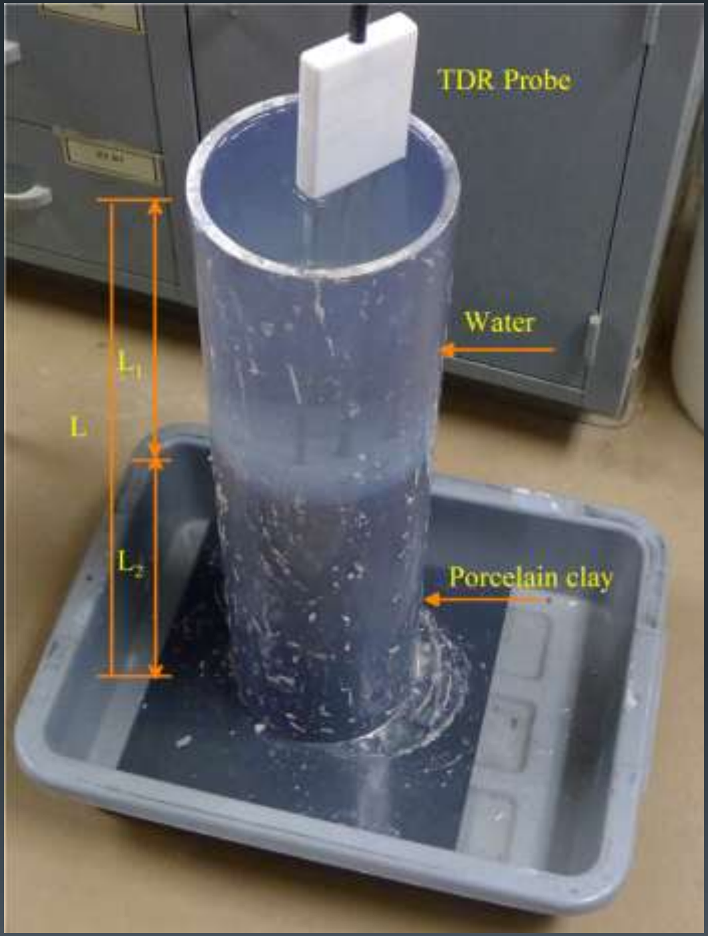
Measured Waveforms at Different Time



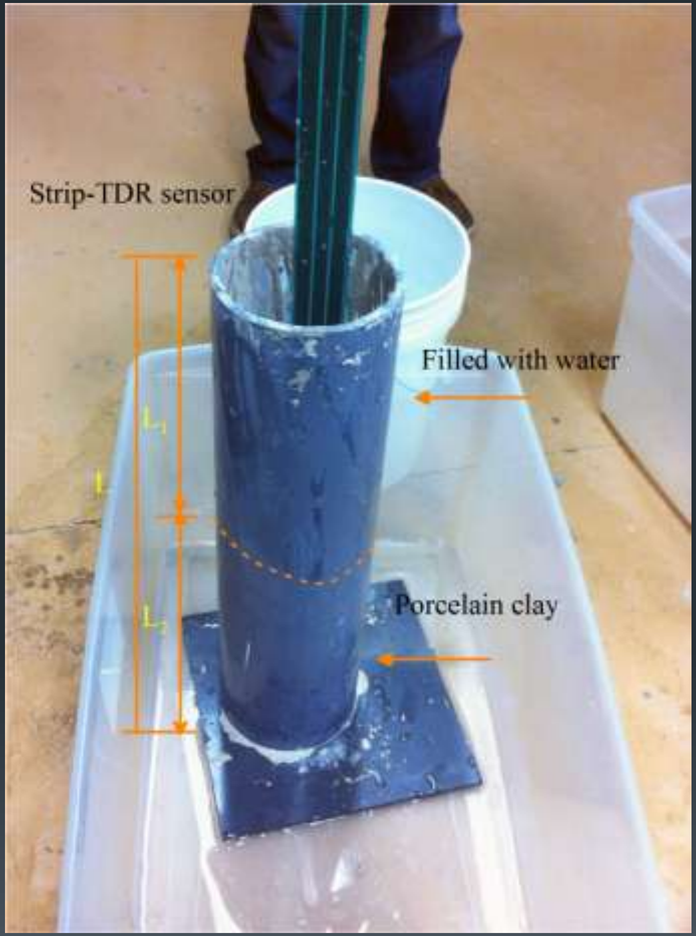
Measured Scour Depth

Lab Experiment Program

Experiment setup

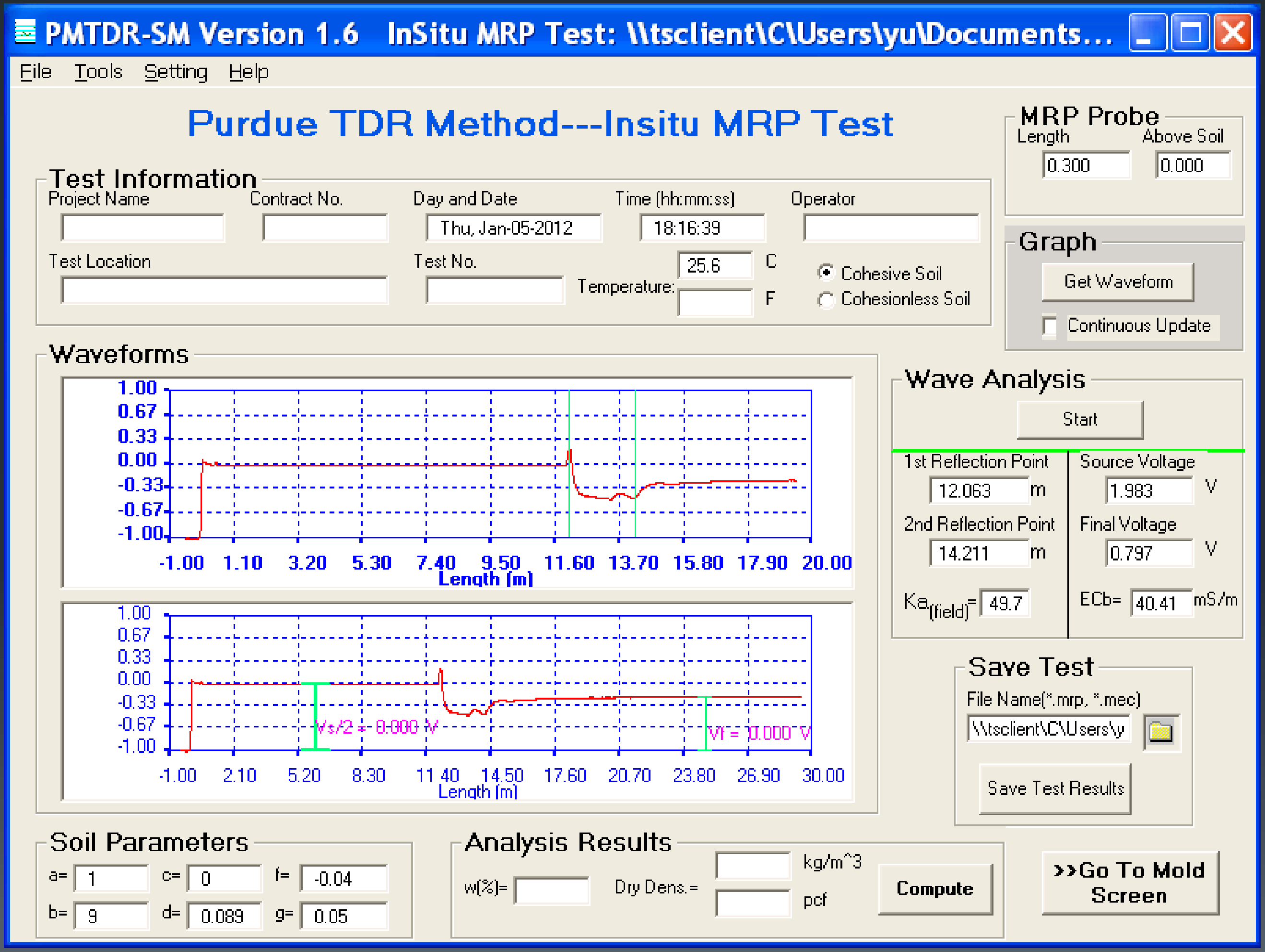


TDR CS610 Sensor

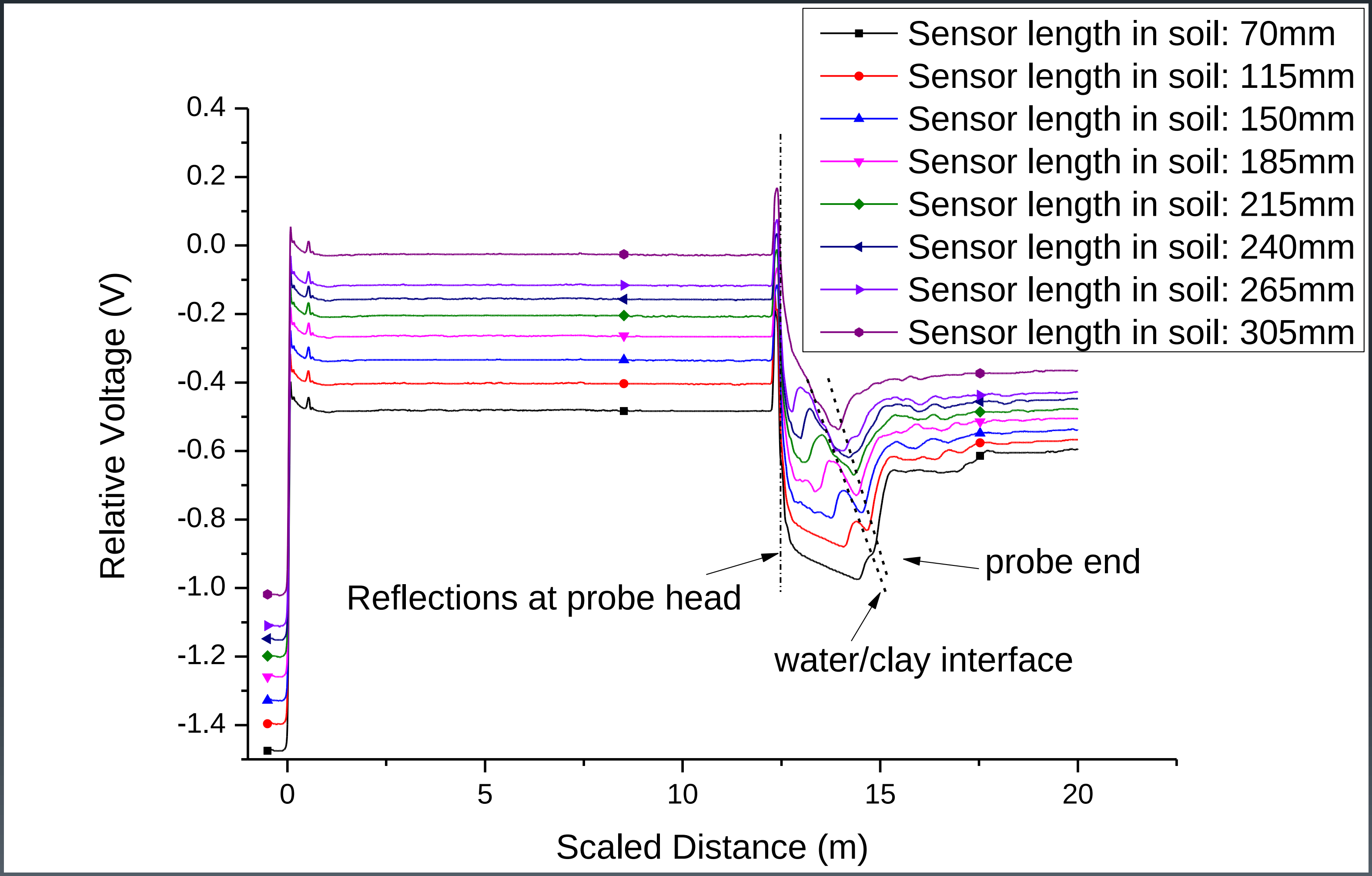


Strip-Scour Sensor

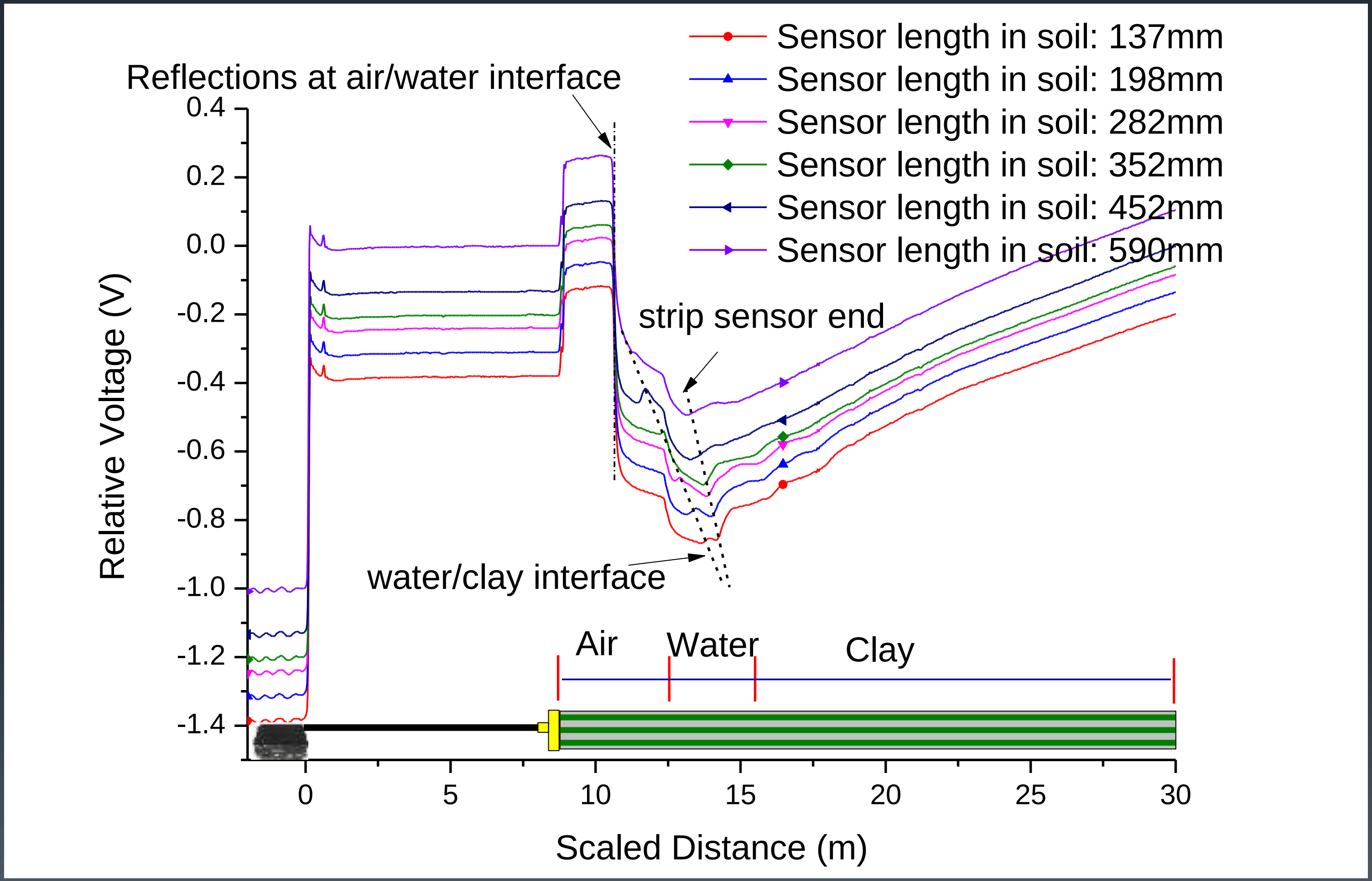
Sample Signals of Scour Measurement



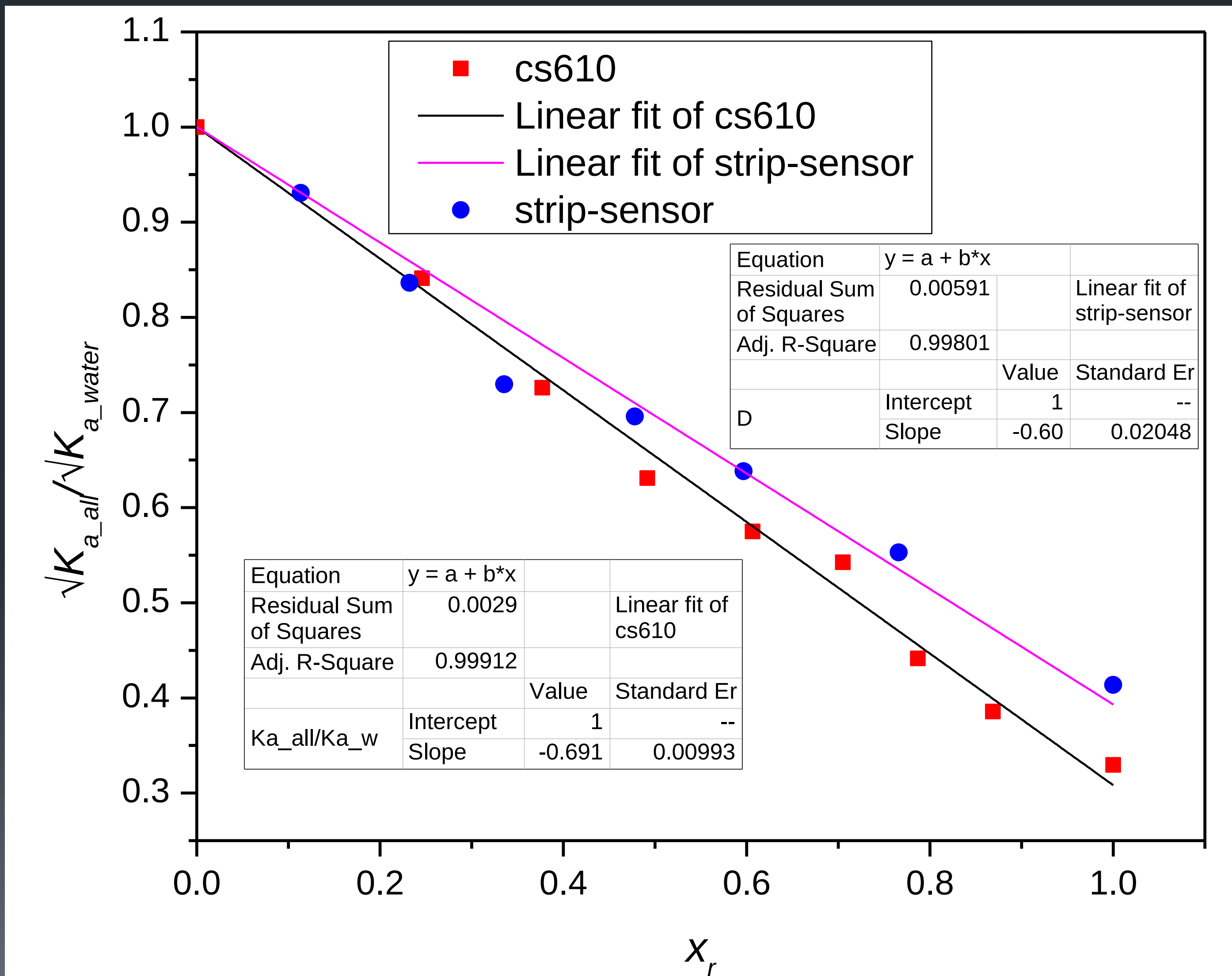
Test Results – CS610 Sensor



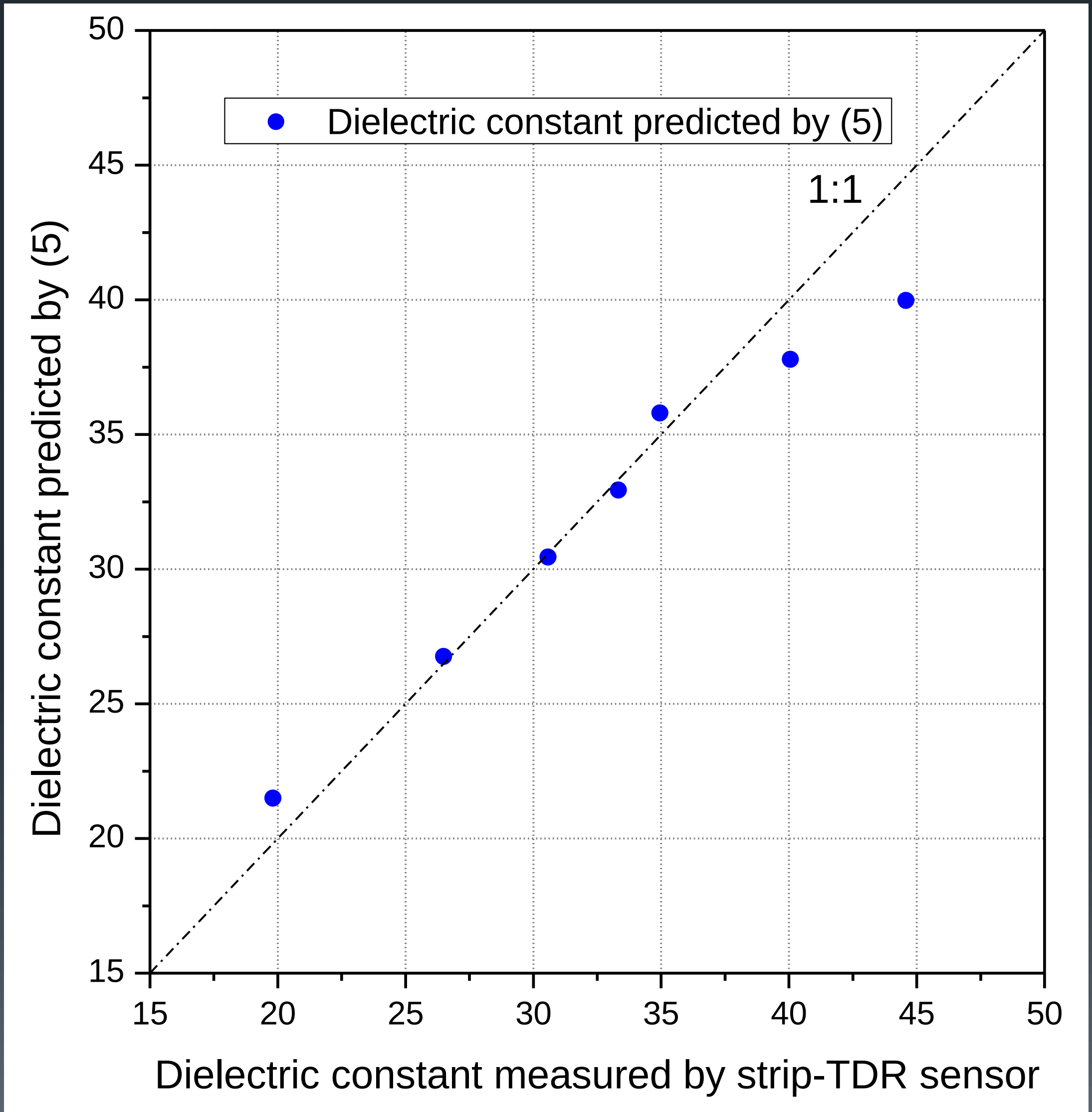
Test Results – Strip Scour Sensor



Results Analysis

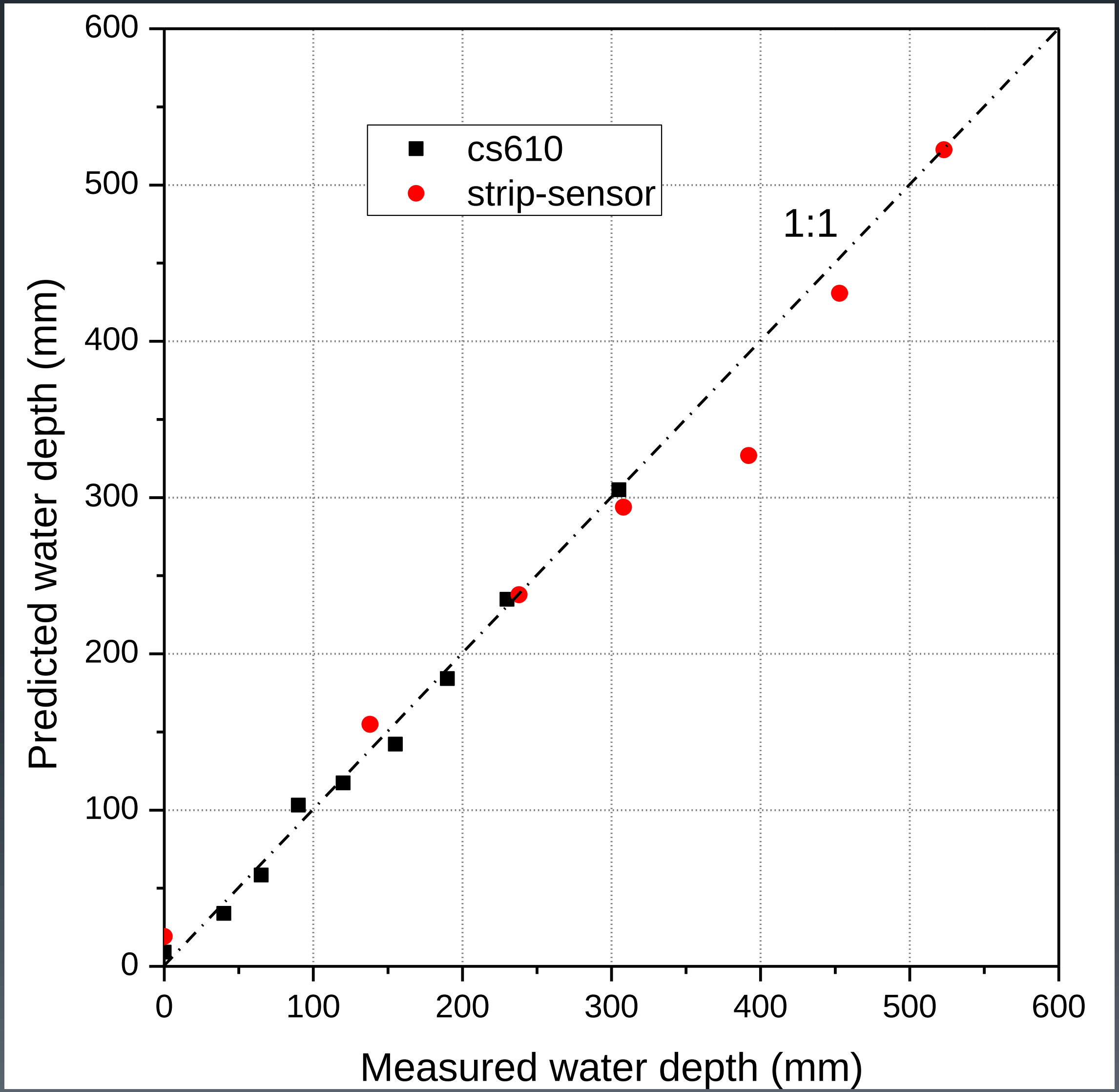


Measured Dielectric constant by Strip Scour Sensor



$$K_c^n = wK_{coating}^n + (1 - w)K_a^n$$

Measured Scour Depth



Conclusions and Recommendations

- The strip scour sensor is sensitive to scour changes in porcelain clay. Both CS610 and strip TDR sensor can measure scour in the porcelain clay.
- The previous design equation works for porcelain clay with new calibration constants.
- More studies using in-situ clay samples are needed.
- More robust design to ease the installation and prevent the damage from flow debris.

Acknowledgements

- Bill Yu
- Anand Puppala
- Jim Brella

Welcome Collaborations!