Pseudo 2D Imaging of the Mel-Price Wood River Levee via MASW and Resistivity

Clinton M. Wood, PhD

Michelle L. Bernhardt, PhD

Tim Moody

Behdad Mofarraj

Non-Intrusive 3D Levee Imaging Workshop

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MACK-BLACKWELL TRANSPORTATION CENTER

Maritime Transportation Research & Education Center

Presentation Outline

1) **Motivation for Work**
2) **Data available at Mel-Price Wood River Levee**
3) **Data Collection and results at the Mel-Price Wood River Levee**
    1) **Ohmmapper resistivity**
    2) **Multi-channel Analysis of Surface Waves (MASW)**
4) **Pitfalls associated with inversion problems**
5) **Final Thoughts**

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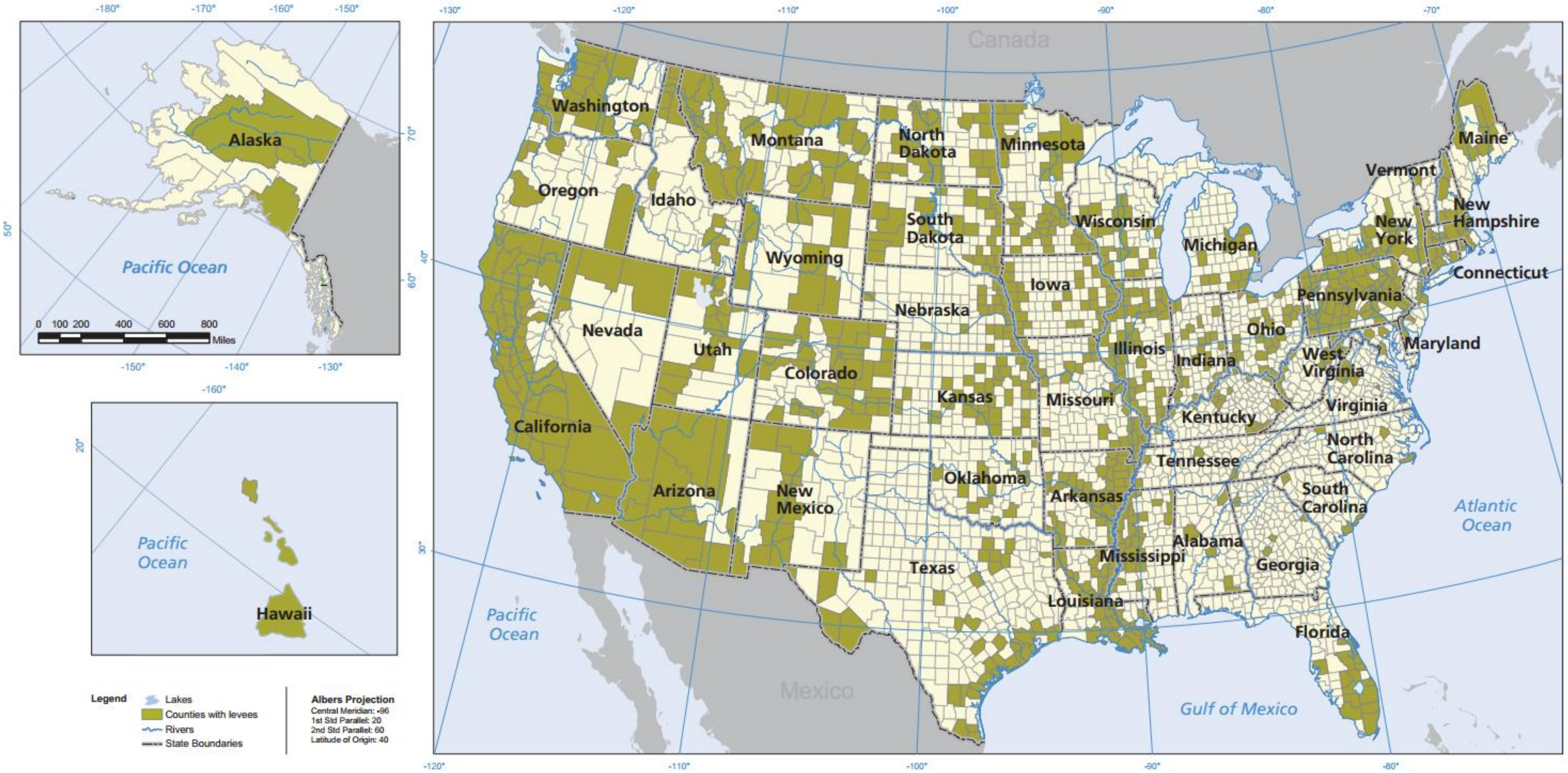
Levees in the US

ASCE Report Card (2013)

WATER & ENVIRONMENT		TRANSPORTATION		PUBLIC FACILITIES	
Dams	D	Aviation	D	Public Parks & Recreation	C^-
Drinking Water	D	Bridges	C^+	Schools	D
Hazardous Waste	D	Inland Waterways	D^-	ENERGY	
Levees	D^-	Ports	C	Energy	D^+
Solid Waste	B^-	Rail	C^+	Previous Report Cards	›
Wastewater	D	Roads	D		
		Transit	D		

Levees in the US



Note: A national levee inventory project is underway. Information shown on this map is current as of August 2009 but may change in the future.

The Problem$

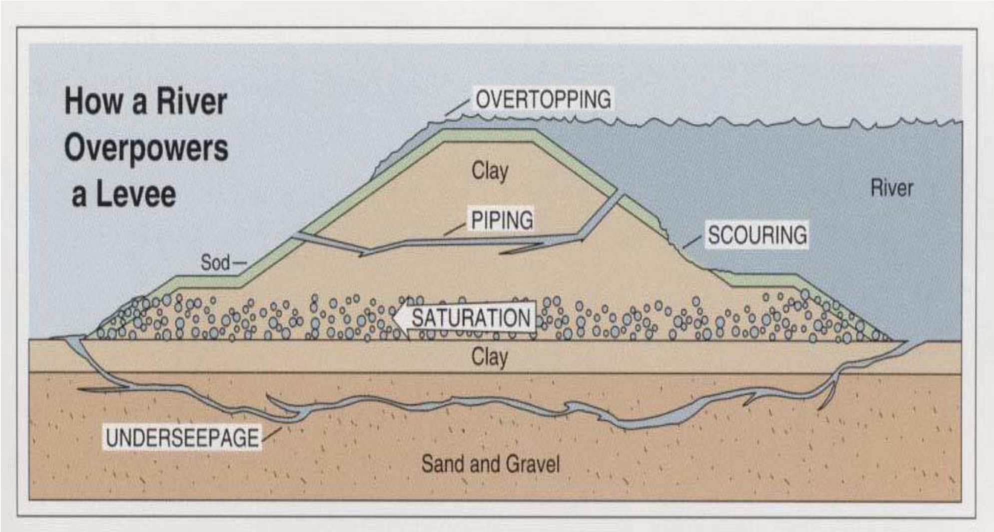
1) **Limited funding to assess the estimated 100,000 miles of levees**
    - Currently only about 15% of the nation's levees are in the National Levee Database
        - Over 22% of those levees are rated as unacceptable
    - Only about 37% are documented in FEMA's Midterm Levee Inventory

2) **Limited funding for necessary or cautionary repairs**
    - ASCE estimates over $100 billion is needed to repair and rehabilitate the US levee system
    - Only $415 million is allocated for the entire flood control program annually

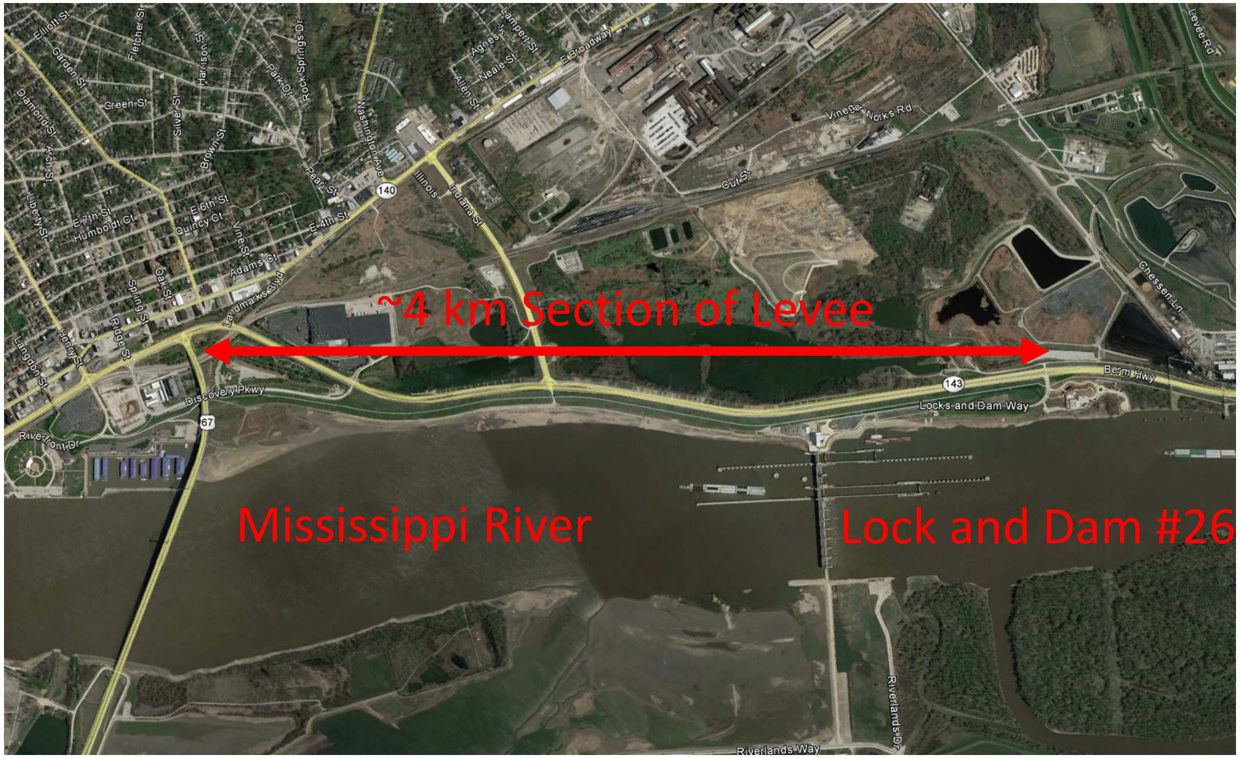
The Approach

Develop and refine a rapid and non-destructive assessment procedure which can cost effectively address both problems

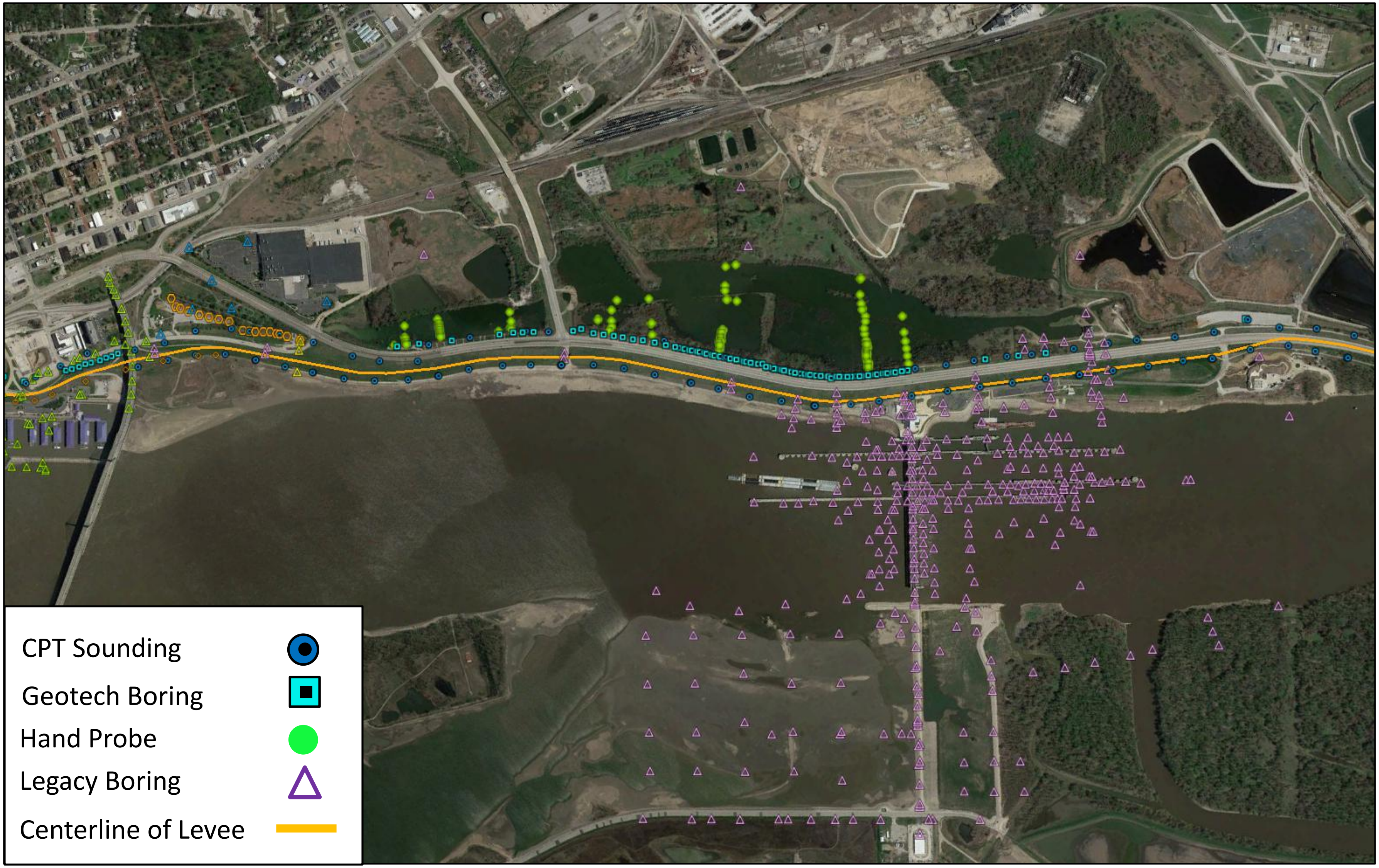
1) Geophysical field testing
2) Statistical analysis of data to determine most effective methods
3) Probabilistic framework to assess performance



Mel-Price Wood River Levee Section



Geotechnical Information Mel-Price Wood River Levee



Mel-Price Wood River Levee Data Collection

A combination of geophysical methods were used with the goal of determining both soil type and stiffness of the levee material

A. Resistivity testing via a Geometrics Ohmmapper Capacitively Coupled Resistivity Instrument

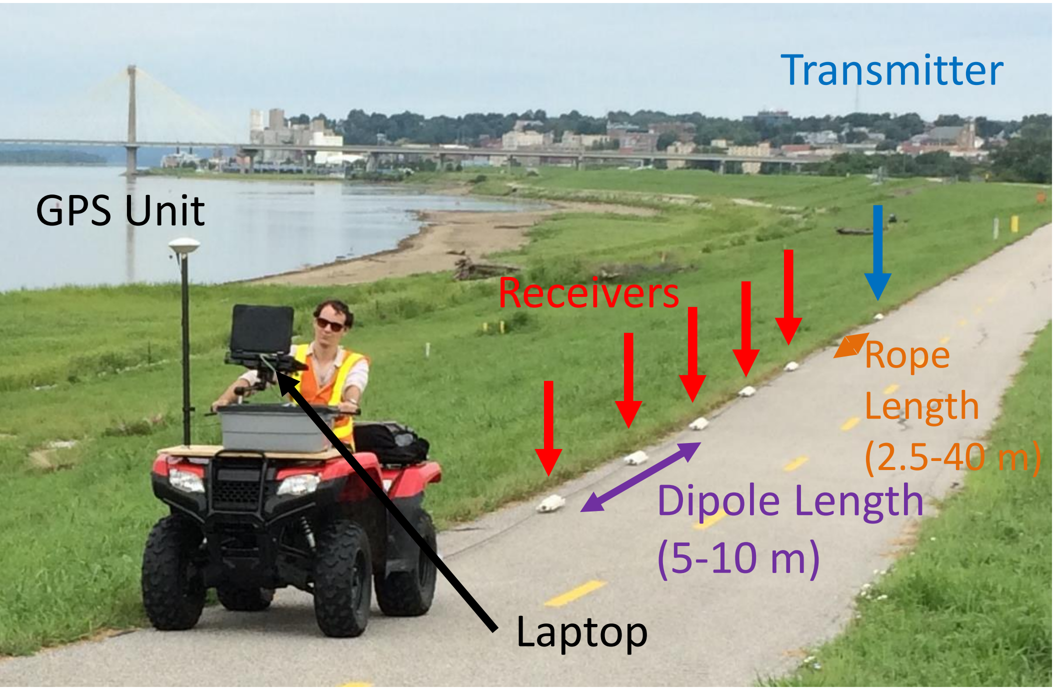
B. Surface wave testing (MASW) via landstreamer, 4.5 Hz geophones, and sledgehammer source

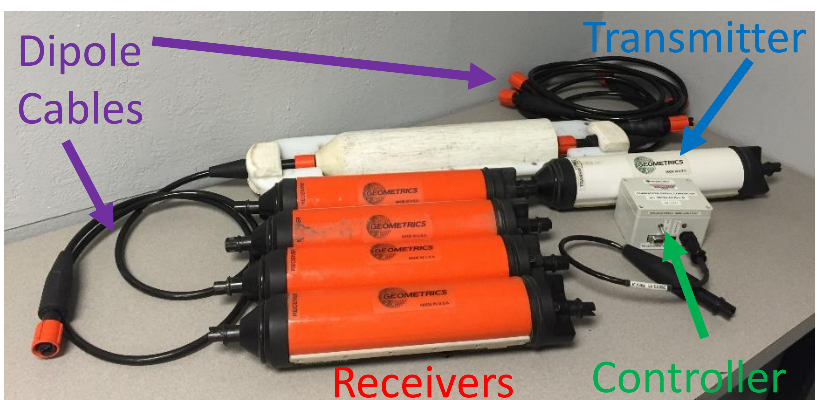
Mel-Price Wood River Levee Data Collection
Resistivity

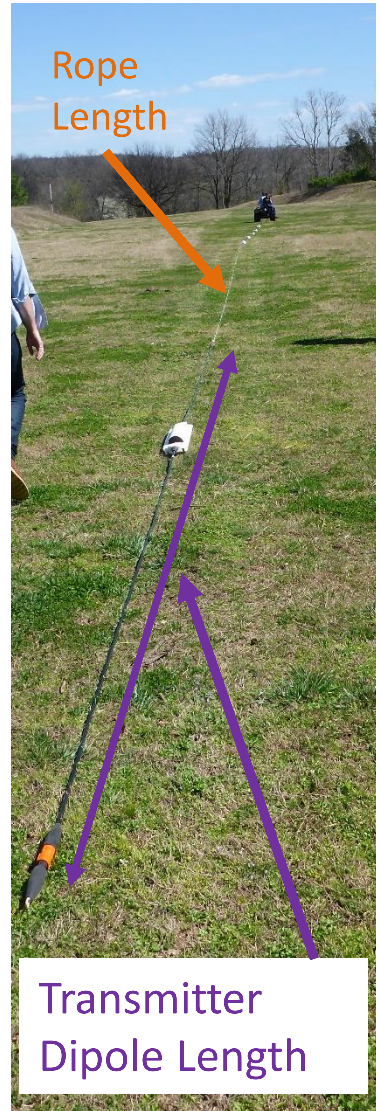
Testing Parameters

1) Ohmmapper TR5 system with five receivers was used.
2) Dipole length of 5 meters with a rope length of 2.5 meters
3) Dipole length of 10 meters with rope lengths of 5, 20, and 40 meters

Resistivity Testing on Mel-Price Wood River Levee

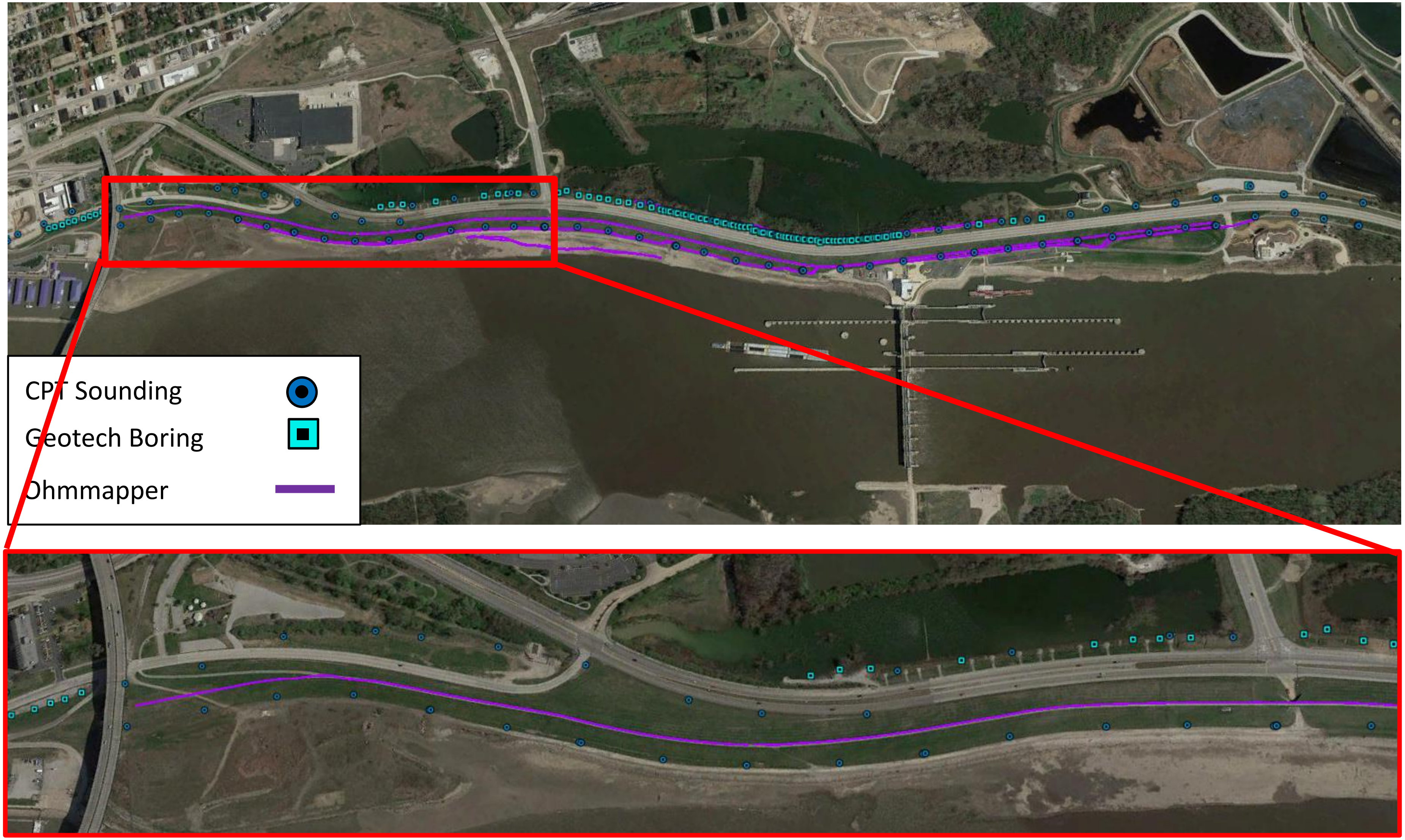






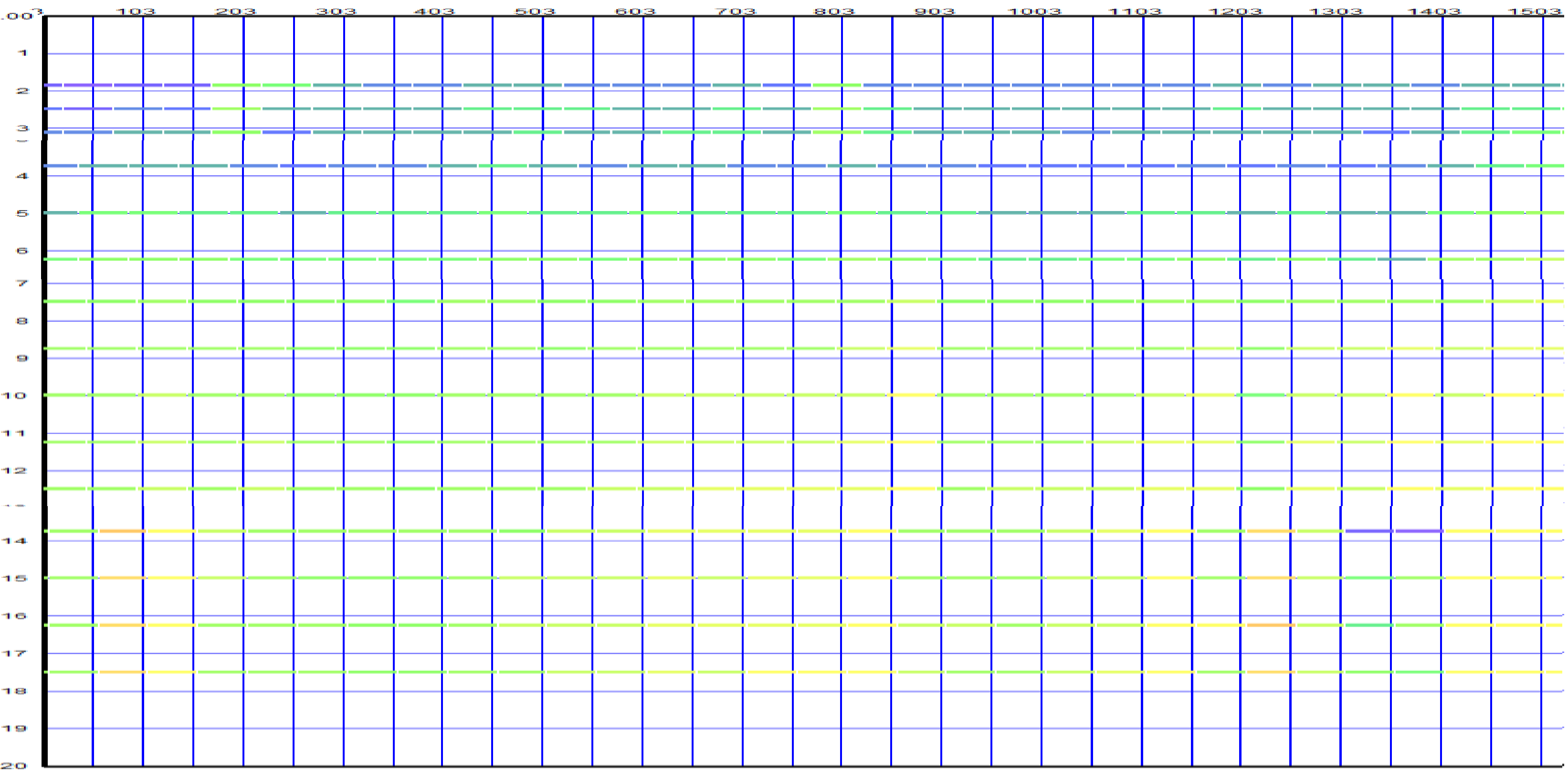
Resistivity Processing

Resistivity Processing for Mel-Price Wood River Levee



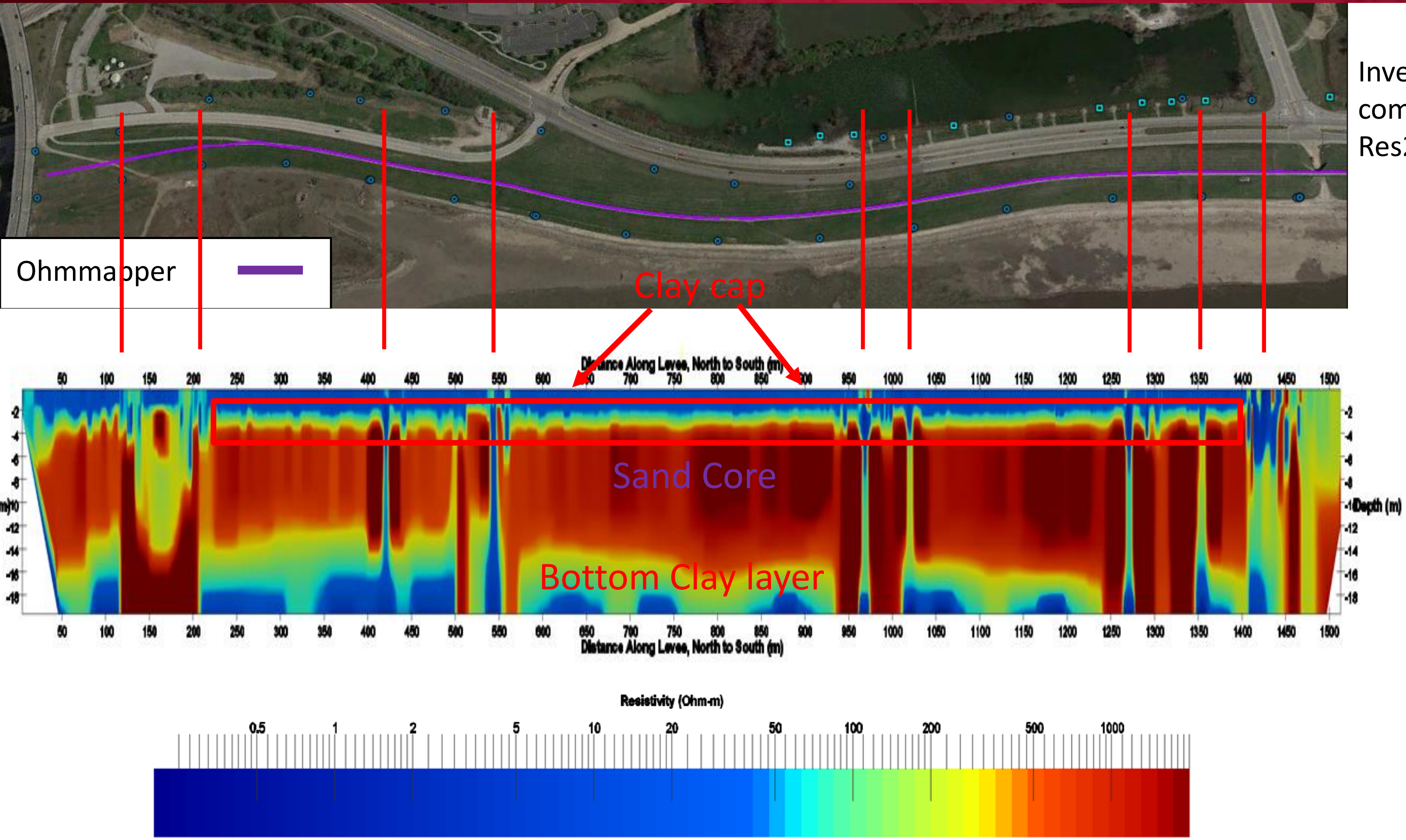
Resistivity Processing

Four separate passes along Levee to obtain full Apparent Resistivity



Dipole length (m)	Rope length (m)
5m	2.5m
10m	5m
10m	20m
10m	40m

Resistivity Processing



Inversion completed using Res2D software

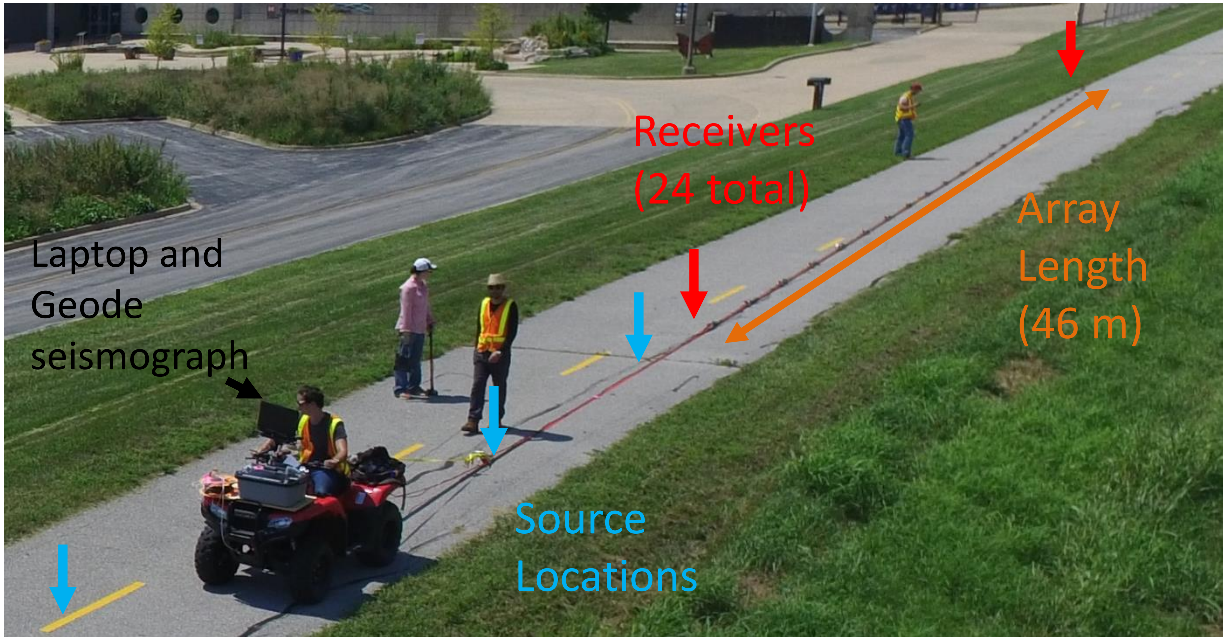
Much more processing to come

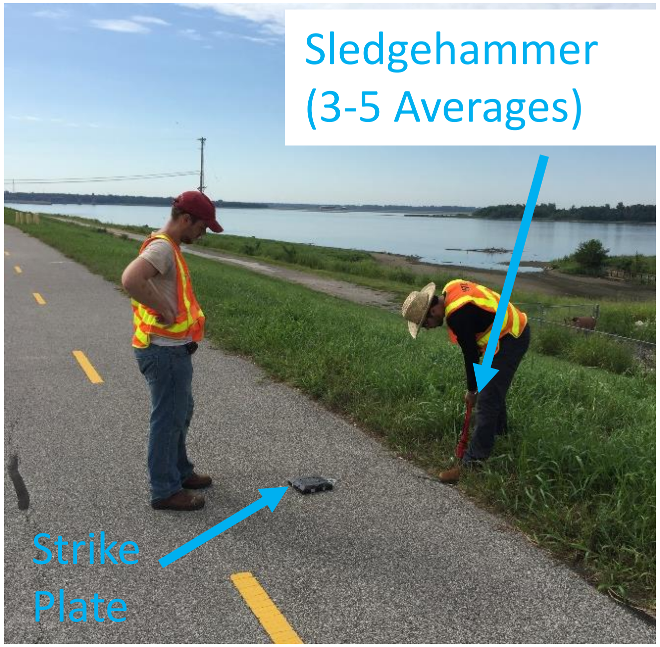
Mel-Price Wood River Levee Data Collection
Surface Wave Testing (MASW)

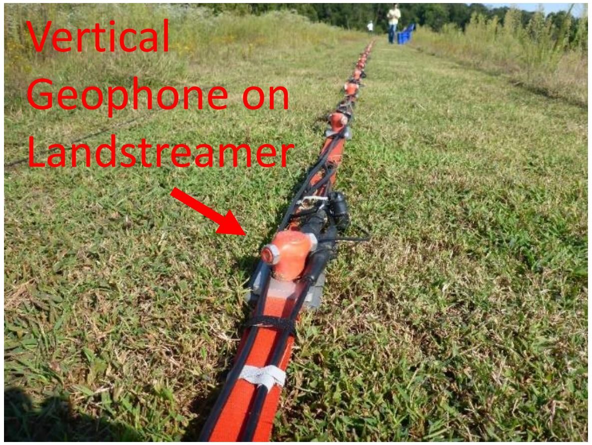
Testing Parameters

1) Geostuff landstreamer with 24, 4.5 Hz vertical geophones setout with a 2 m spacing between geophones (total array length of 46 m).
2) Measurement spacing between 25-50 meters depending on line
3) Sledgehammer source with source locations of 5, 10, 20 meters from the first geophone and 3-5 shots per location

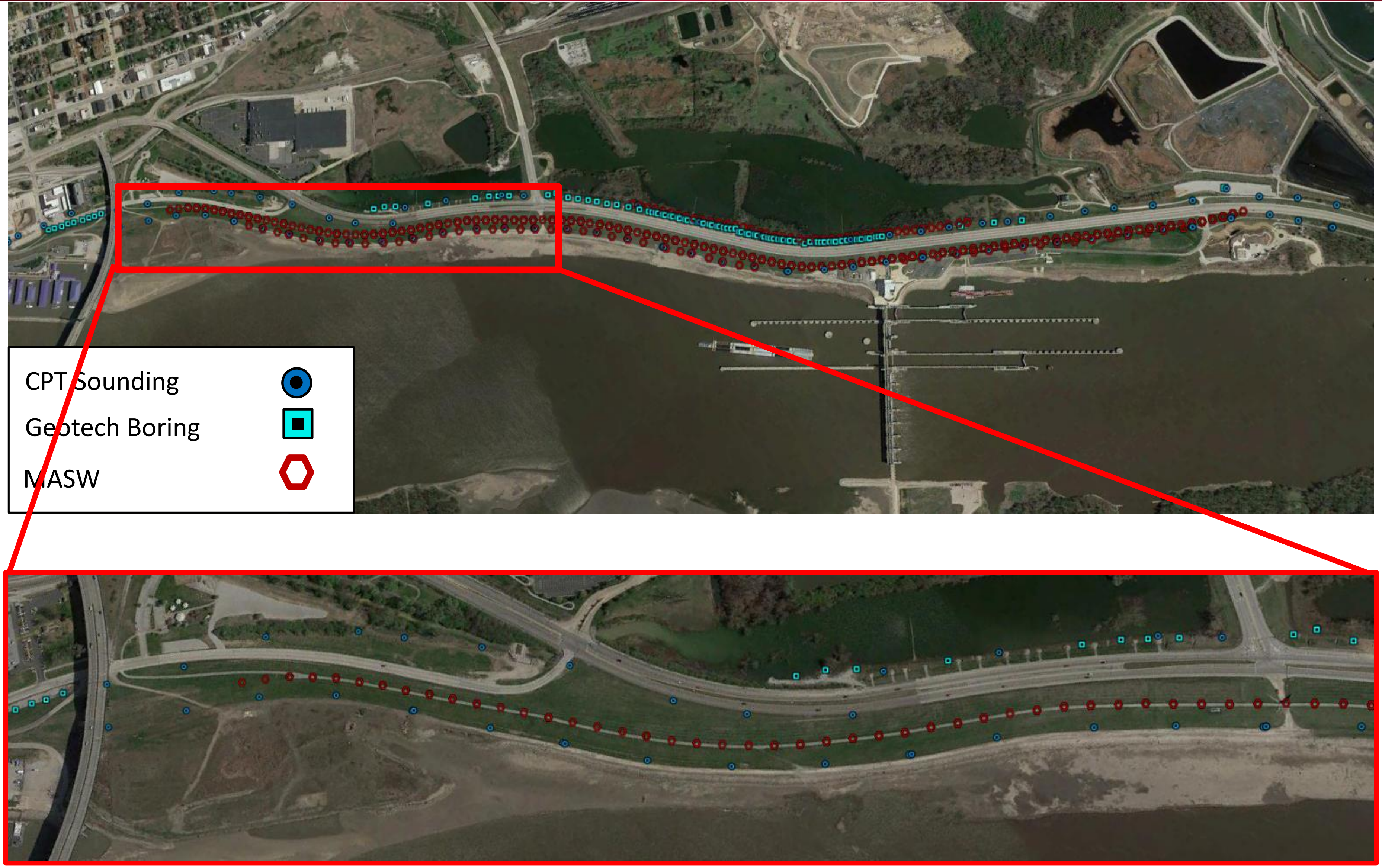
Surface wave Testing on Mel-Price Wood River Levee







Surface Wave Testing (MASW)



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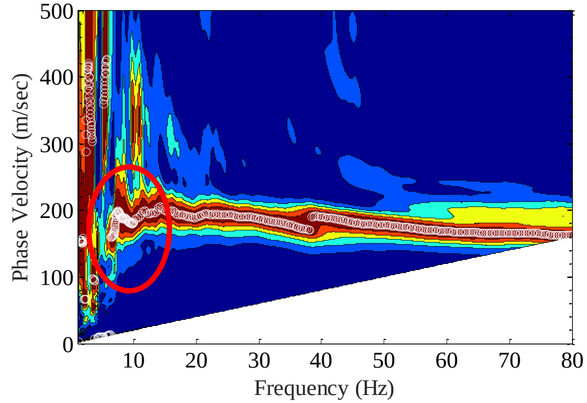
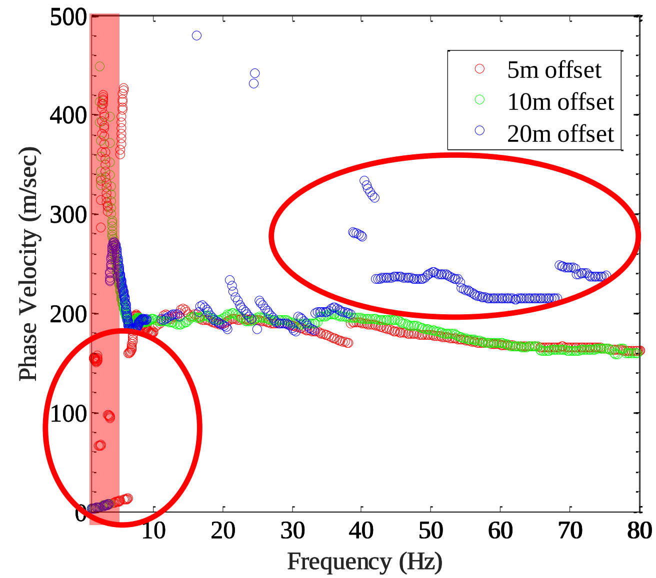
Surface Wave Testing (MASW)

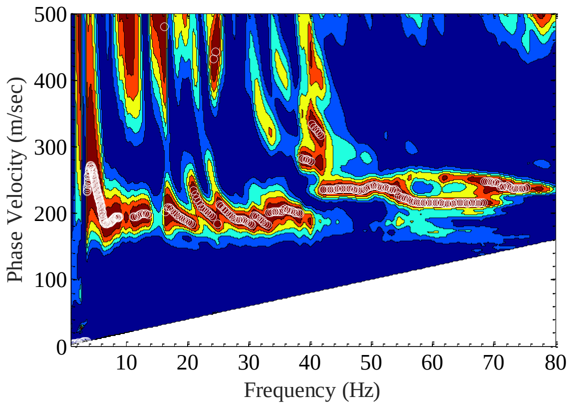
Dispersion Processing

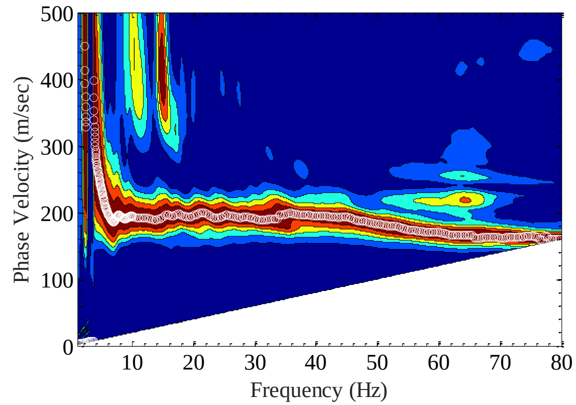
Frequency Domain Beamformer Method

Combined with multiple source offsets

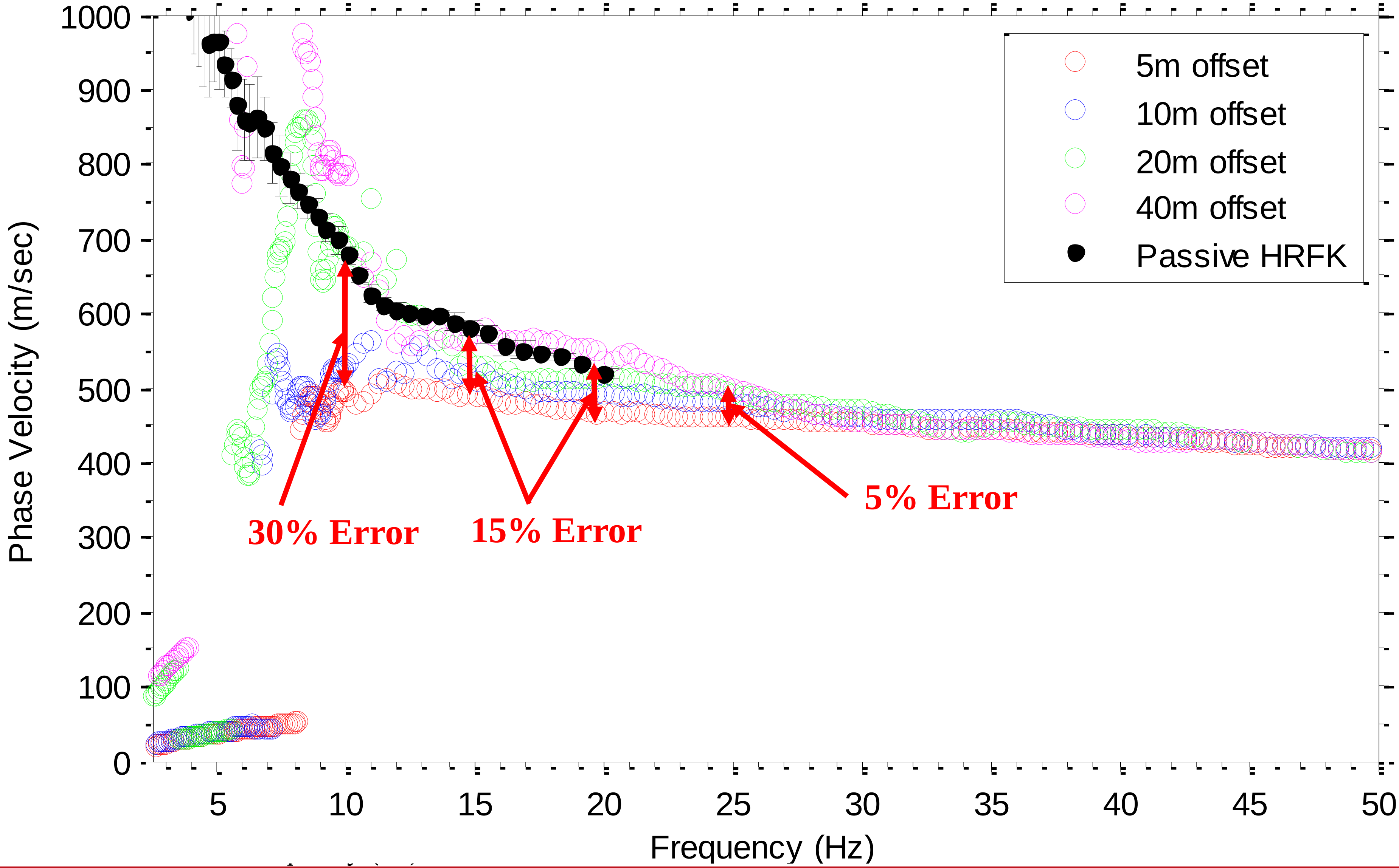








Nearfield Effects

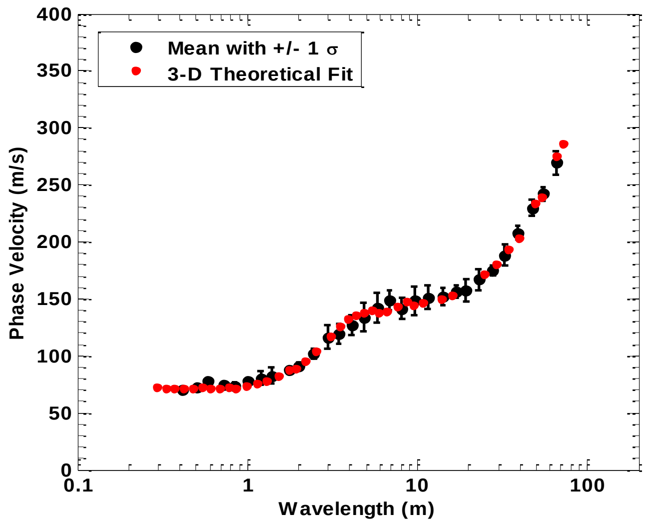


Surface Wave Testing (MASW)

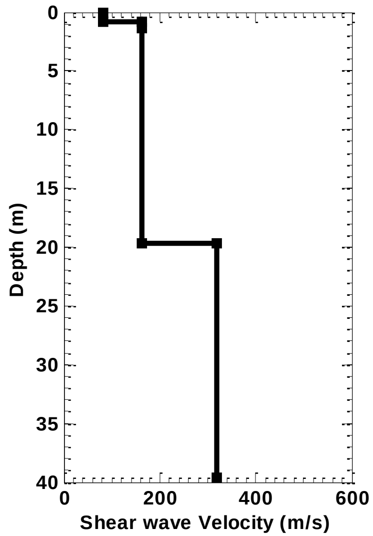
Unfortunately the surface wave results are still under construction for the Mel-Price Wood River Levee

Potential Pitfalls and Limitations in Inversion Process

Dispersion Curve



Shear wave velocity Profile



Apparent Resistivity

True Resistivity

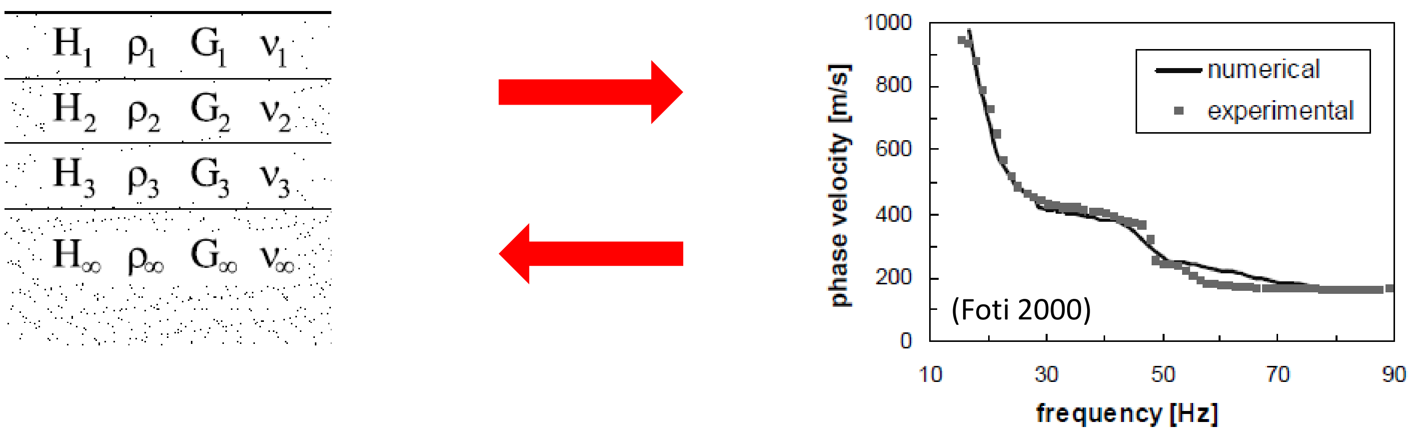
Inversion Process

a) Assume a system of linear elastic layers over a half-space (H, ρ, Vs & Vp)

b) Calculate theoretical dispersion curve (DC) for system (forward problem)

c) Compare theoretical DC to experimental DC acquired in field (misfit function)

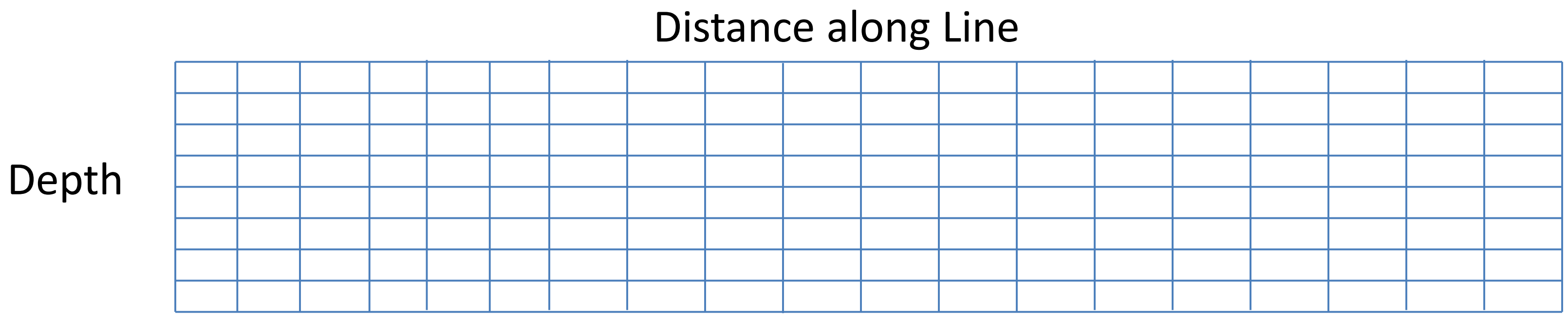
d) Revise layers (i.e., thickness, Vs, etc.) until satisfactory fit is achieved (backward problem)



Inversion Challenges

- Nonlinear
  - Relationship between the data space (Vr vs. freq or wavelength) and the model space (Vs vs. depth) is nonlinear
- Ill-Posed
  - Attempting to recover 4 model parameters (H, ρ, Vs & Vp) indirectly from two data parameters (Vr, freq)
- Mixed-Determined
  - The model solution for deeper layers is dependent on the model solution for shallower layers
- Result…Non-unique Solution!
  - Many models can fit the experimental data “equally well”
  - The choice of layering parameterization has a **HUGE** impact on the ability to recover the “true” layered model

How do many 2D and Pseudo 2D methods solve the inversion problem?



The use of lots of unconstrained layering in the inversion models can lead to

1) Unrealistic layering that does not make sense geologically and geotechnically
2) Smearing of layer properties at interfaces making it difficult to recover true properties

Example of recovering unrealistic geotechnical properties

No evidence of inversion/LVL in dispersion data

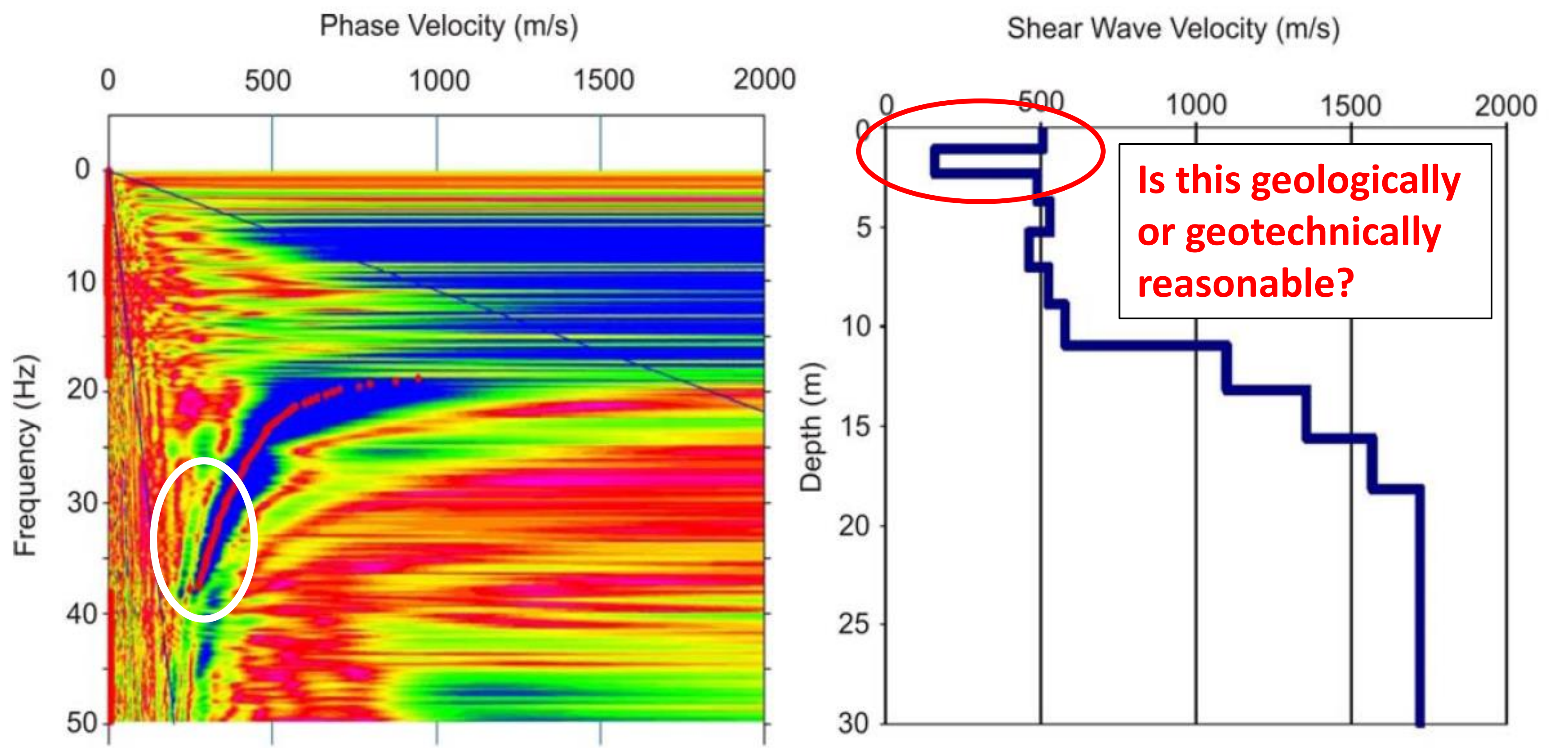
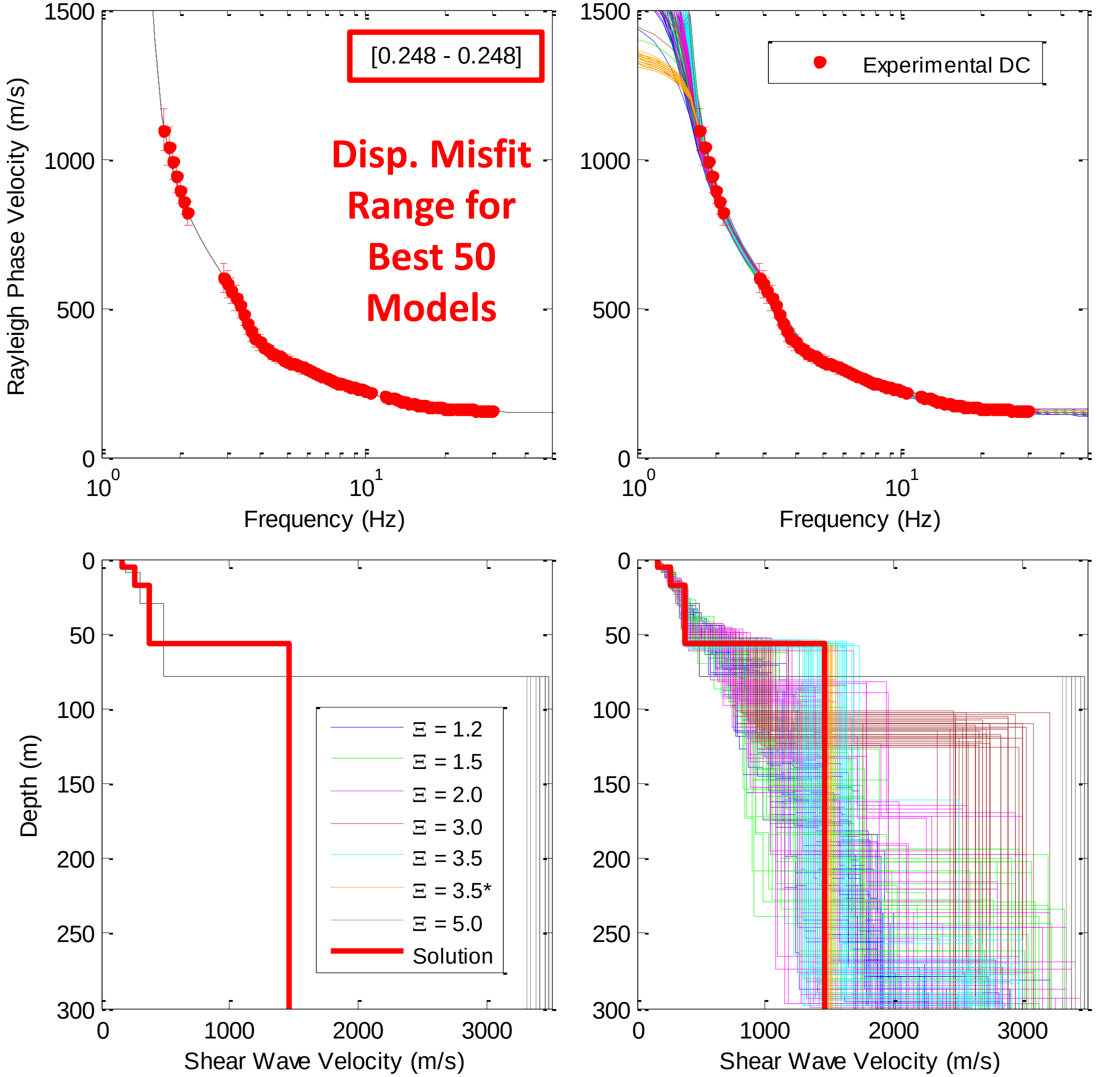
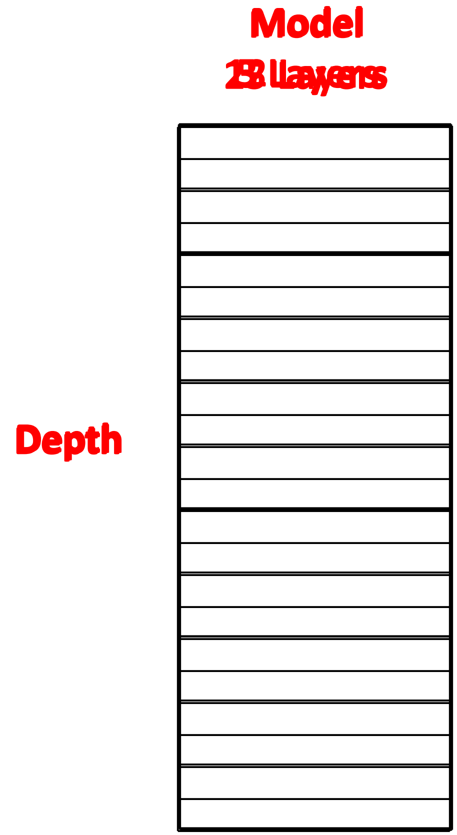


Figure 2.2.3-3: Field data example of a dispersion curve with identification of the fundamental mode (red dots) (left) and resulting shear wave velocity profile (right).

Example of smearing layer properties





From Teague and Cox 2016

Final Thoughts

1. Pseudo 2D methods such as Resistivity and MASW can be powerful tools to rapidly evaluation geotechnical infrastructure. However, care must be taken from the data collection to the data process to insure valuable results are obtained and not just fancy color contour plots.
2. Pseudo 2D methods still have ways to go in the inversion process to be able quickly determine realistic layering and material parameters.

Acknowledgements

- USDOT and MarTREC
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