Advances in Geophysical Technologies and Techniques as Applied to Geotechnical Engineering Projects

GEO-Omaha 2021

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Introduction

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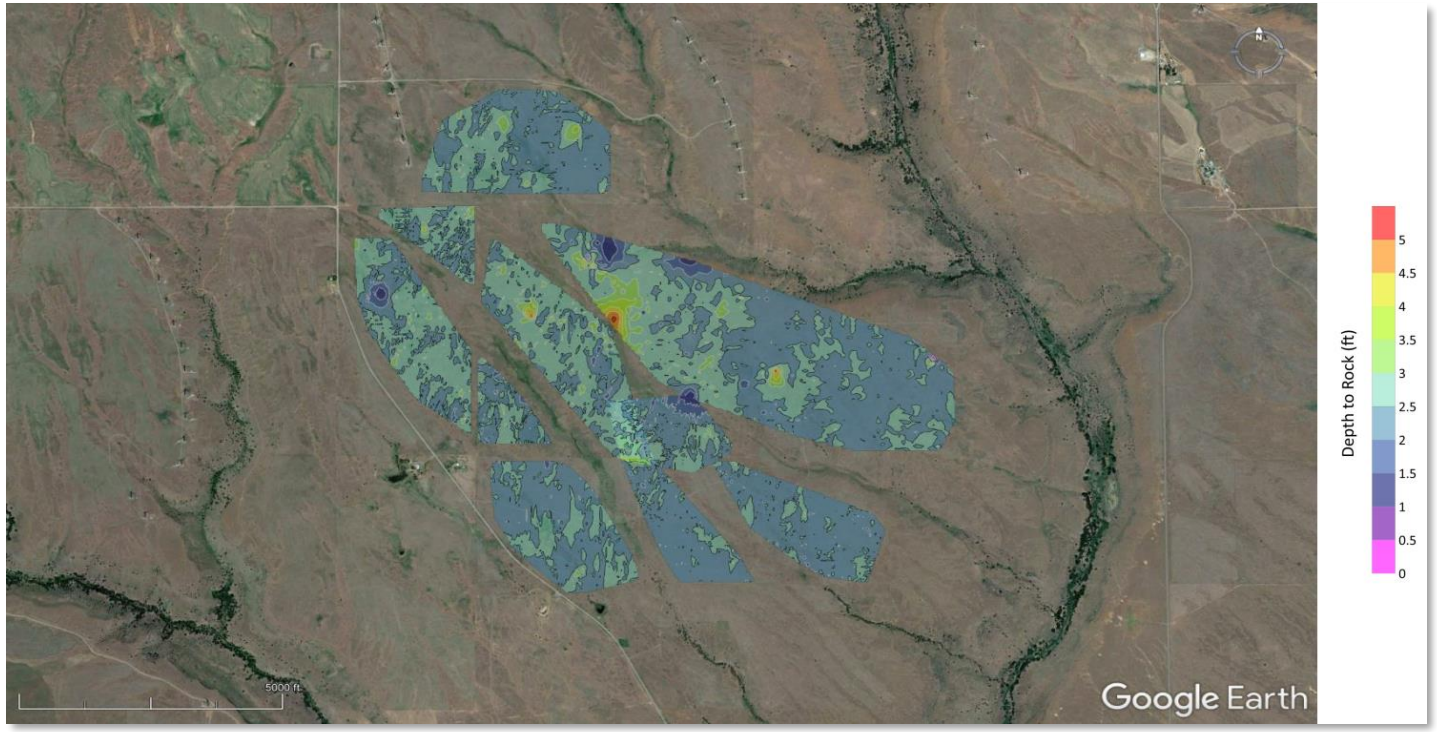
Agenda

- Introduction
- Current State of Practice
  - Project Examples
- Advances in Geophysical Practices
  - Project Examples



What is Geophysics?

- Using some physical property or process to determine *something* about the subsurface
- Levels of Confidence
- Reducing below-surface uncertainties
  - Soil/Rock Properties
  - Unknowns: Foundations, Utilities, Tanks, etc.

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When is Geophysics Commonly Used?

- High Risk Sites
  - Site Recon and desktop study discovers:
    - Karst/sinkholes, mines, previously developed sites
  - Geotech Exploration: Soft soils, voids, undocumented fill, buried objects
- Large or Inaccessible Sites
  - Help reduce borings on large sites or linear corridors
  - Steep slopes that rigs can't access
  - Wooded areas where tree removal is unavailable
- Locating objects to drill, excavate, or avoid
  - Dam seepage, suspected tunnels/mine workings
  - Constructability: Utilities, underground storage tanks, buried foundations, etc.

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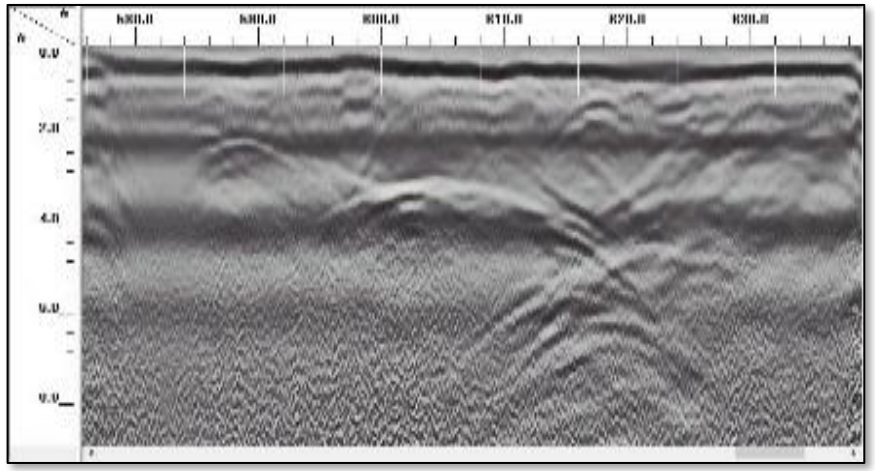
Typical Limitations

- Limited Coverage + Data Gaps
- Data Density, Number of Methods vs Cost
- Depth vs Resolution
- Weather
- Geology + Terrain Considerations



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Surgically Destructive

- Direct exploration is an essential part of site characterization.
- Direct exploration is an essential part of Geophysics.
- Use of geophysics to be more surgical in our direct exploration.

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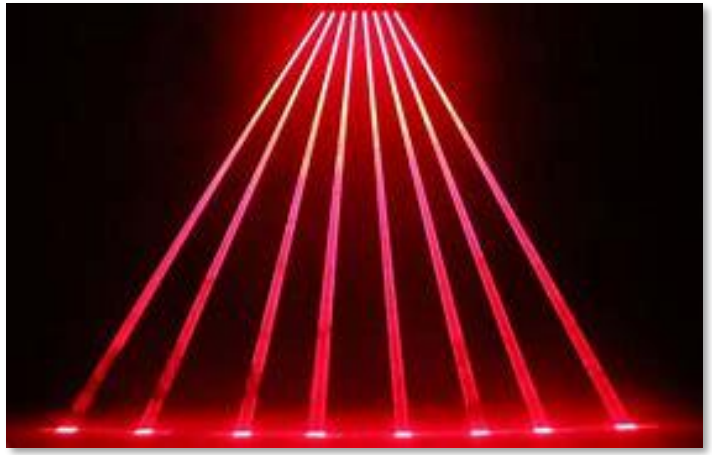
Surgically Destructive

- “Goal of a good geophysical survey should be to provide enough subsurface data to reduce the need to drill boreholes or excavate test pits, and in doing so minimize environmental impacts.”

  McClymont et al., 2016, CSEG Recorder

Direct Exploration (LASER/Flashlight)



Geophysics (Floodlights)

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Current State of Practice

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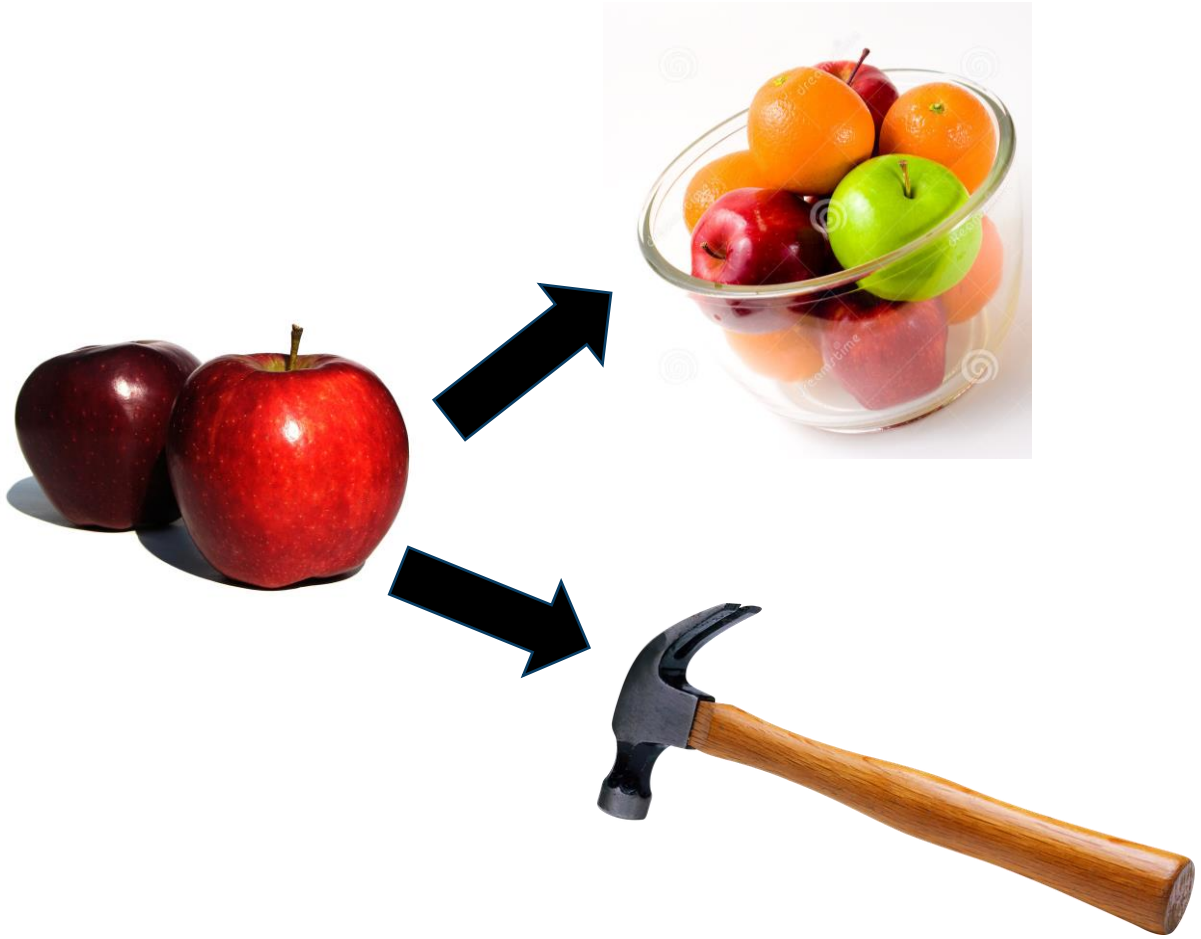
Current State of Practice

- Not dead yet, but still not well understood
  - Language used in the RFPs is important
  - Conversations with relevant parties
- Method Selection – ASTM D6429-20
  - Site specific
  - Survey specific
  - Geophysicist specific
- Data Acquisition – Spacings, coverage
  - Comparing disparate products
- Processing
  - Variability in software used
- Output/Display Methodology
  - Simple reports vs complex CAD



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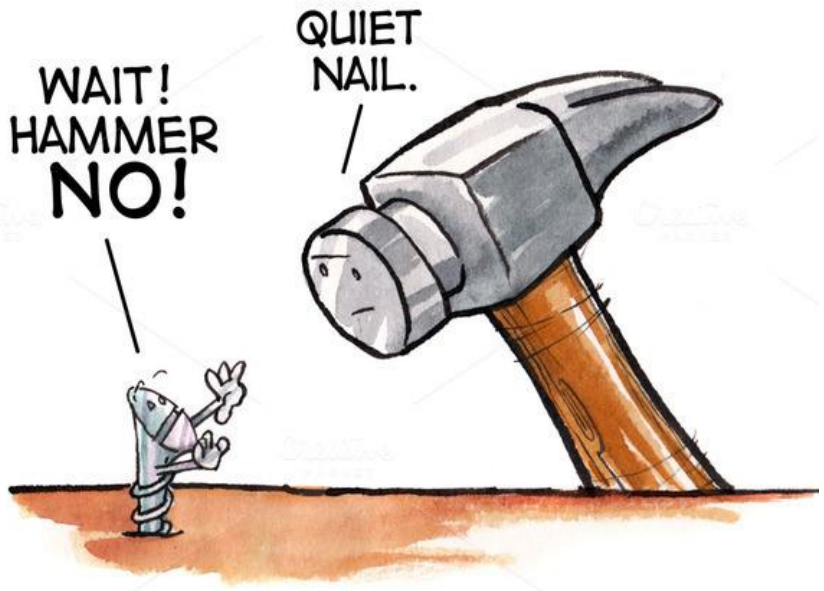
Method Selection

- **Near-surface**: 0-2 feet (impact-echo, ultrasonic pulse velocity (UPV), high frequency ground-penetrating radar (GPR), thermal, spectral analysis of surface-waves (SASW))
  - Often referred to as Non-destructive exploration (NDE) or non-destructive testing (NDT)
- **Mid level**: 2-20 feet (low-frequency GPR/multi-channel (MCGPR), frequency-domain electromagnetic (FDEM)/time-domain (TDEM), magnetics, PCL/RFEMI/Sondes).
- **Deep**: 20-200 feet (seismic refraction/reflection/surface-wave, electrical resistivity tomography (ERT), resistivity, gravity)
- **Borehole**: Crosshole seismic, downhole seismic, suspension logging, televiewers, gamma, etc.

Method Selection



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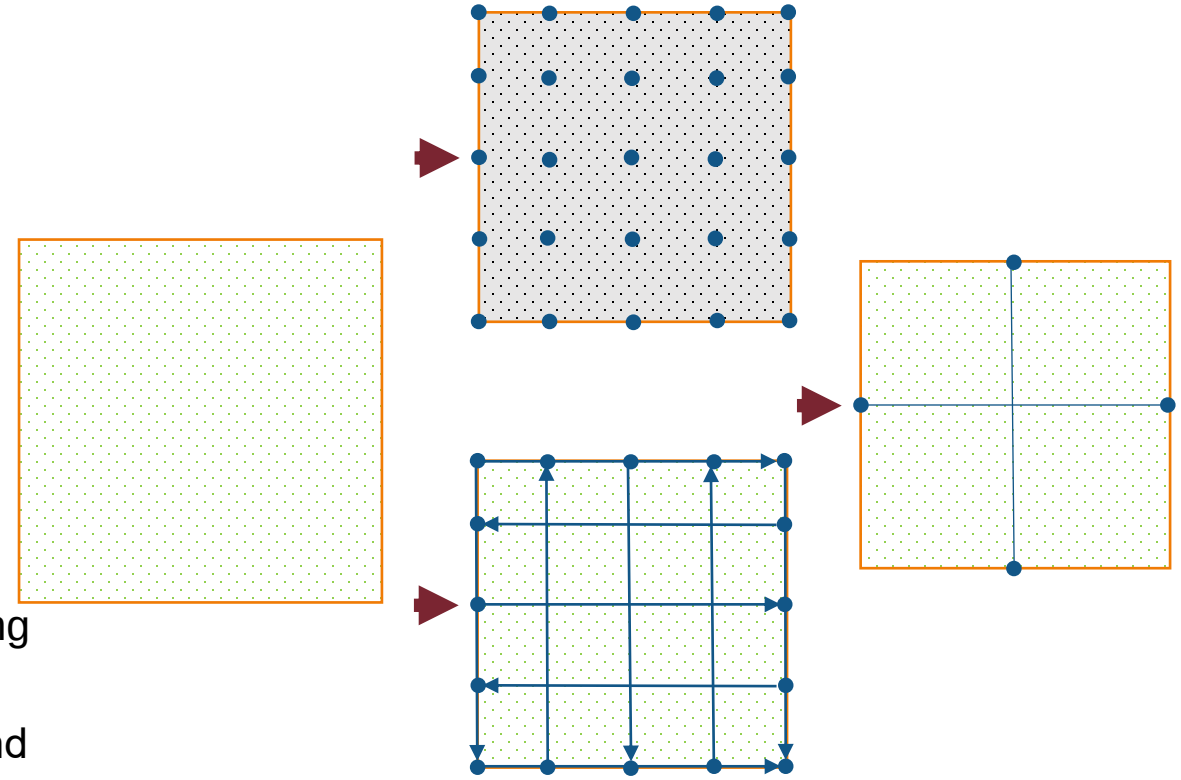
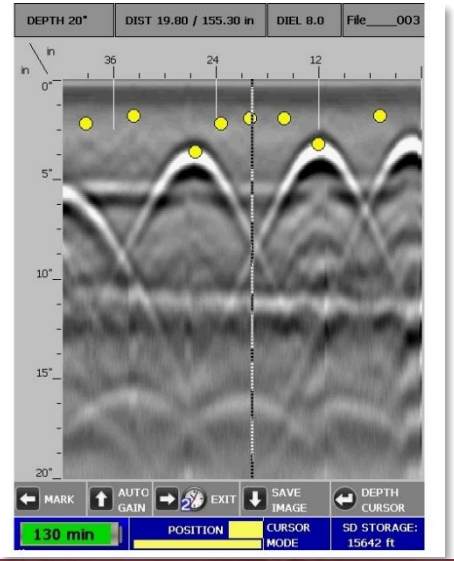
Data Acquisition

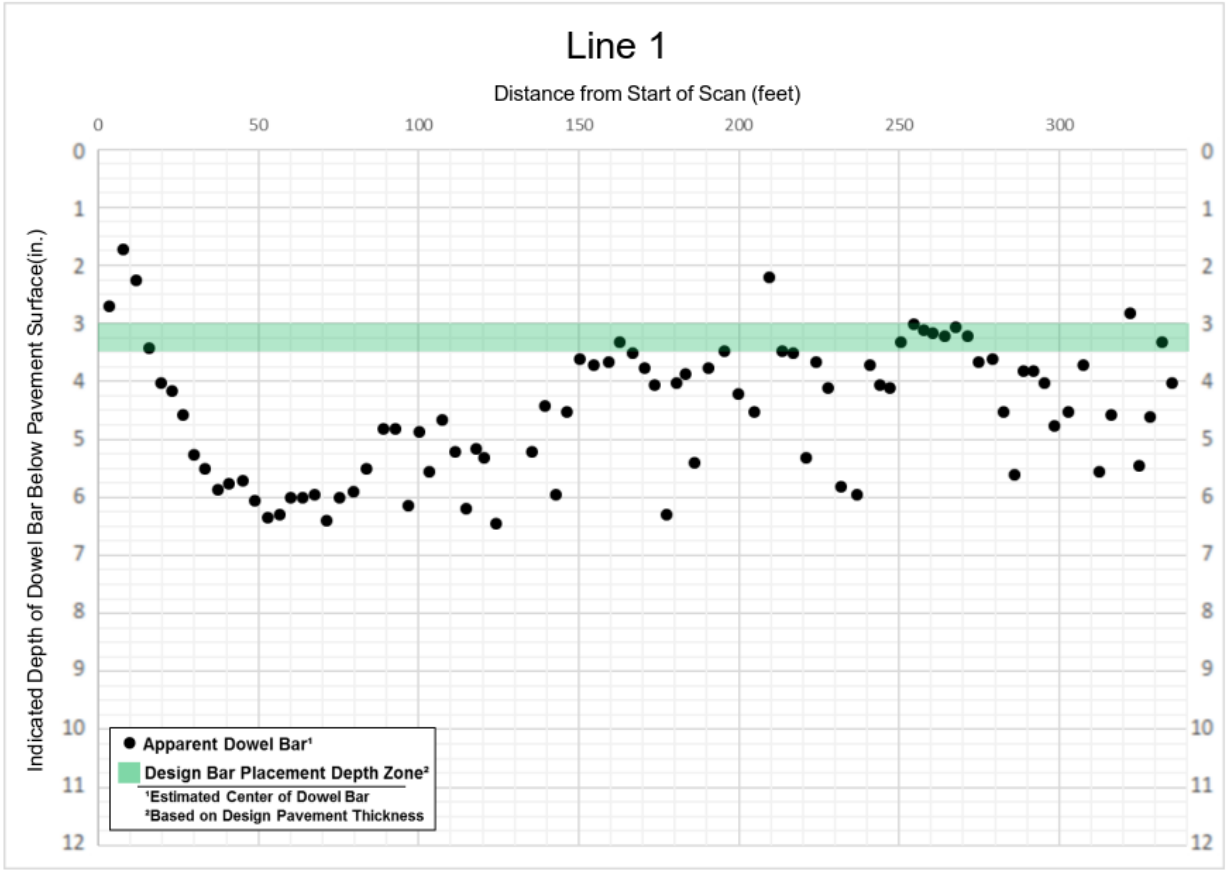
- Point Collection on a Grid
  - Borings on a grid
  - Most time consuming
- Cross-Section/Linear
  - Resistivity/ Seismic
  - Occasionally 2.5D
- Grid Collection
  - Collect in two directions of a grid using a set spacing
  - Can use GPS or staked points
  - Spacing represents ‘smallest’ object you want to find



Reinforcing Steel Locations

- Grid or cross-section collection
- GPR





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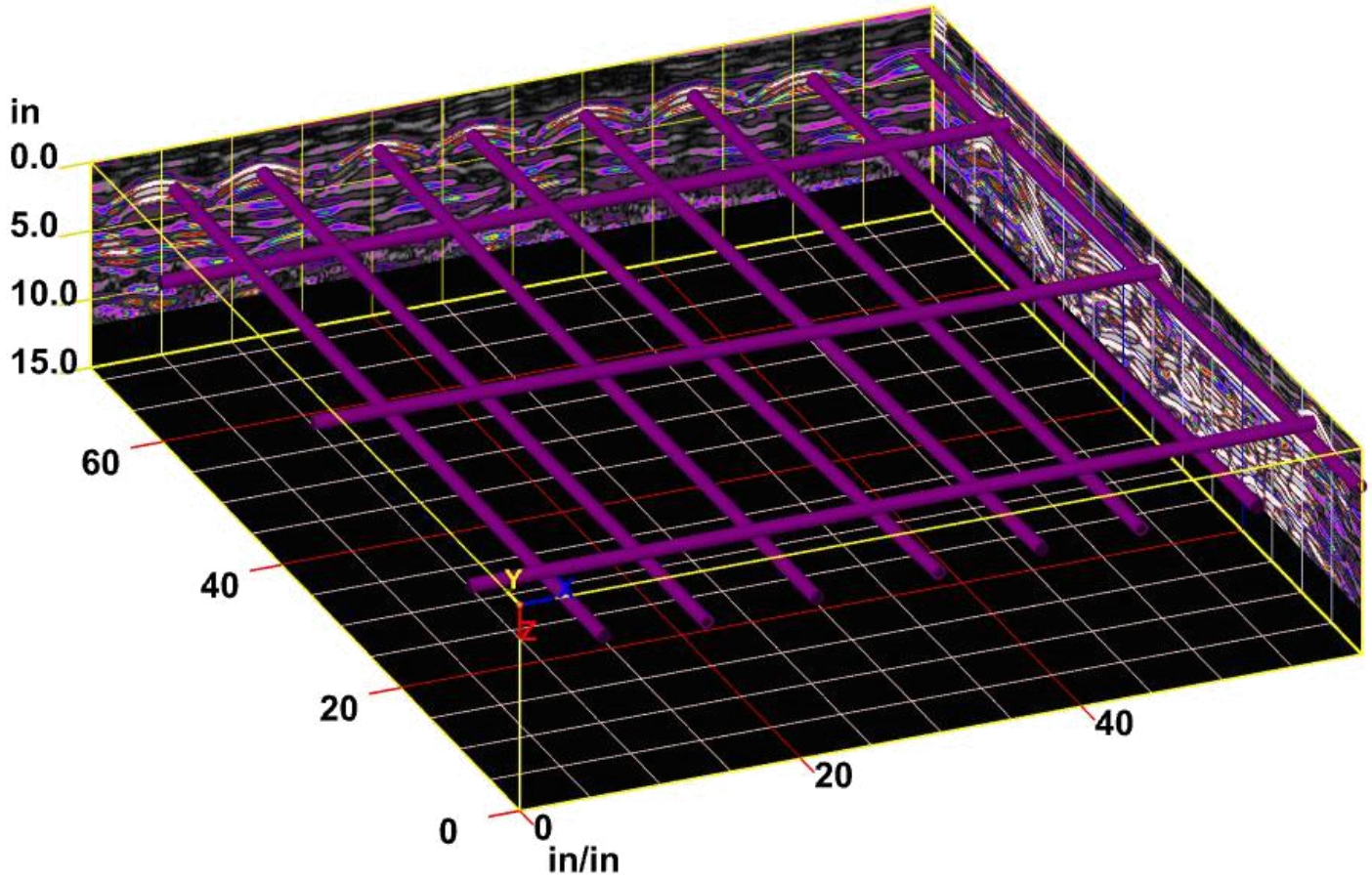
Reinforcing Steel Locations

- Grid collection
- GPR



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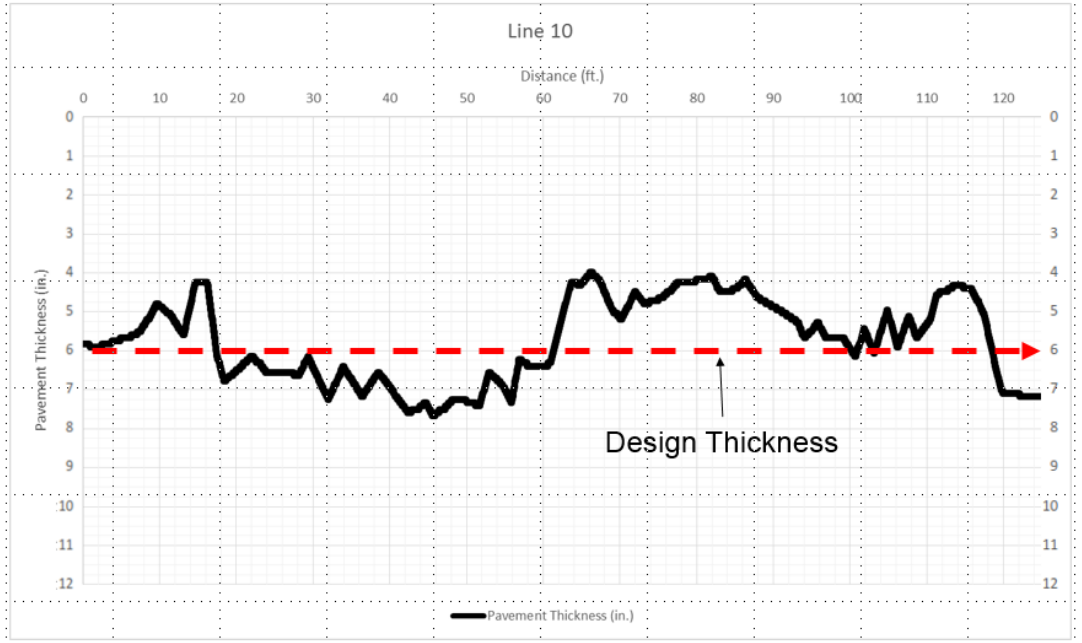
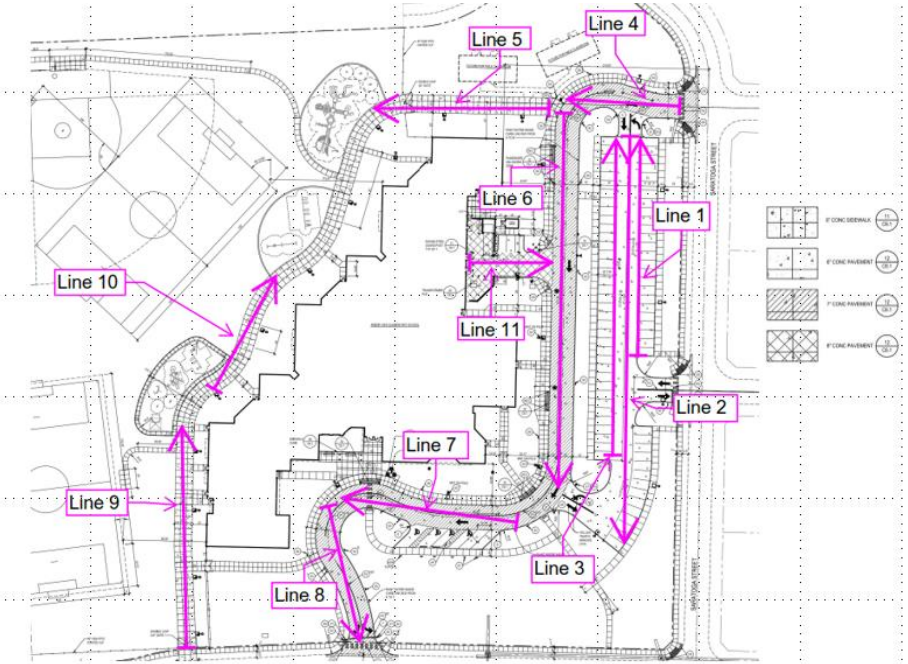
Pavement Thickness

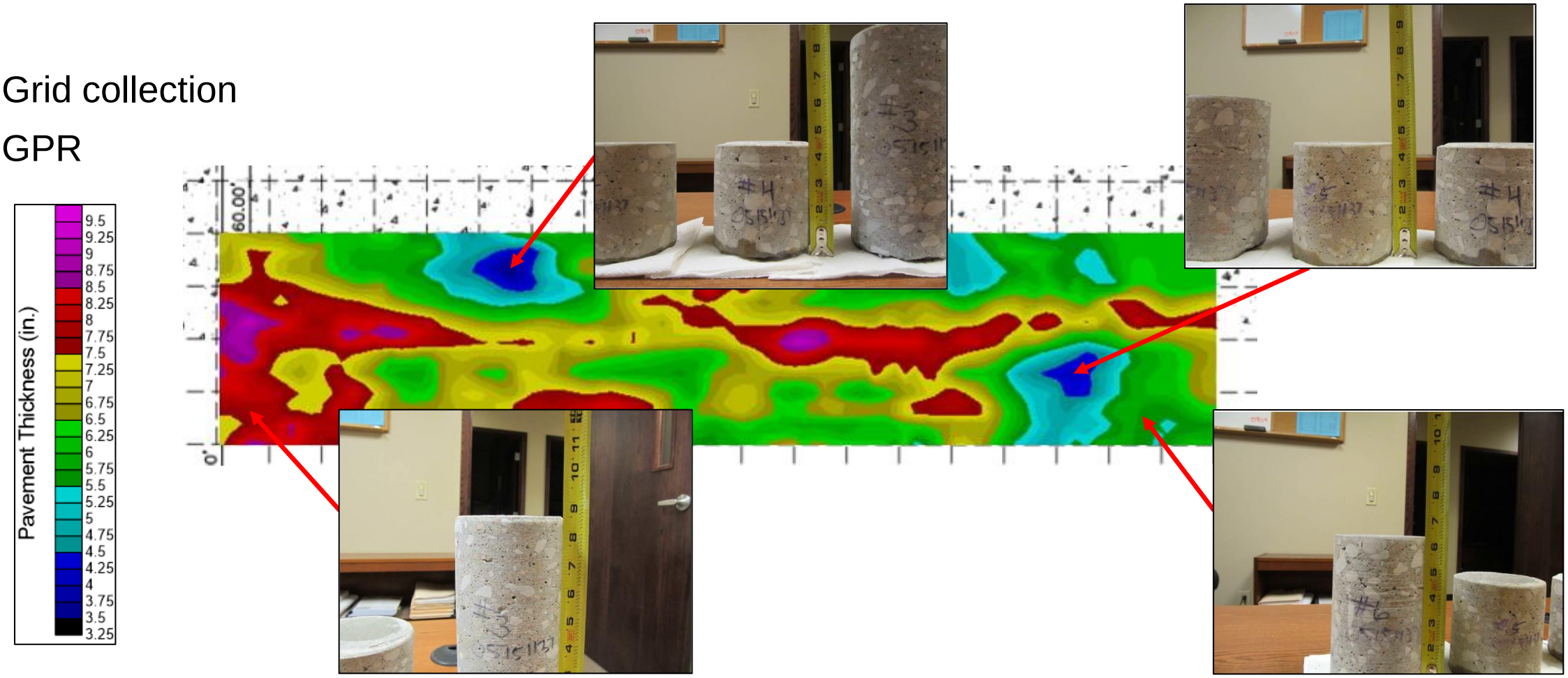
- Cross-section collection
- GPR



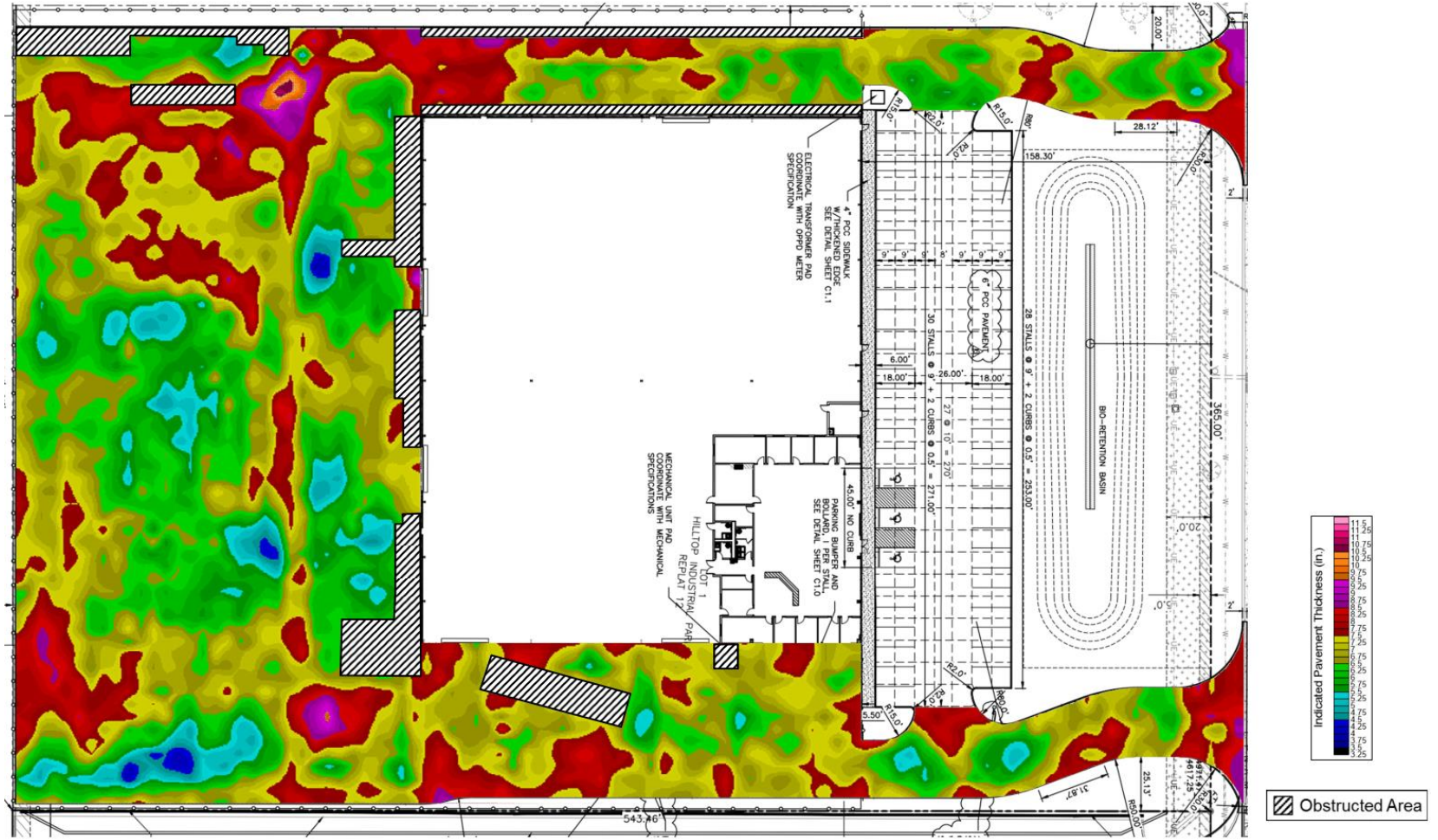


Slab Thickness

- Grid collection
- GPR



Slab Thickness



Voids

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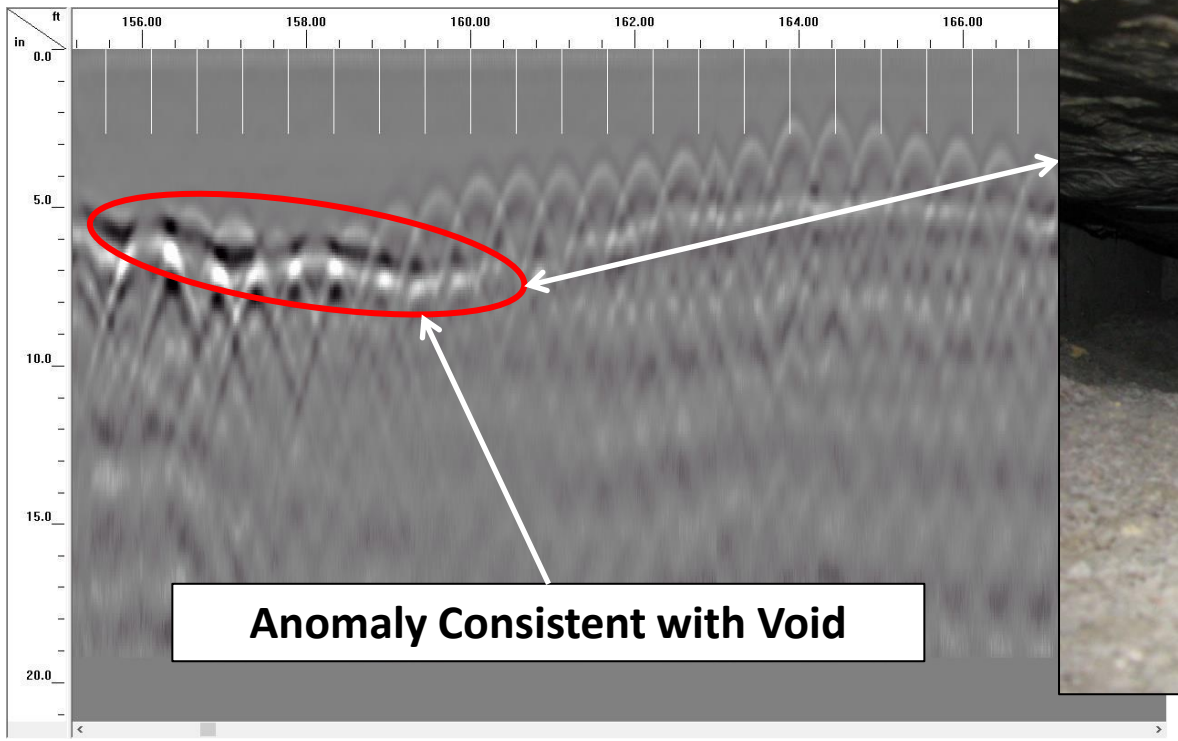
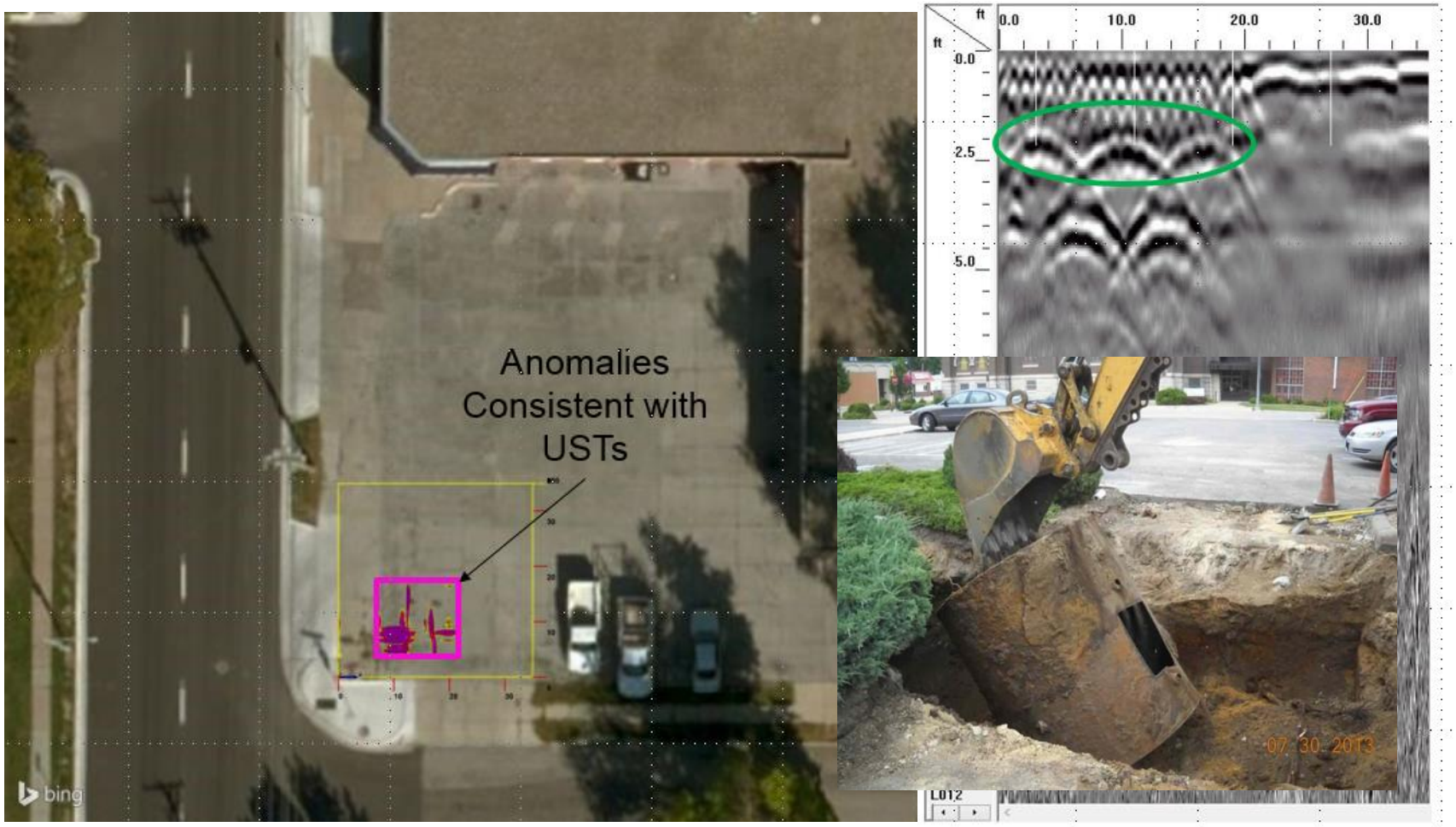
Voids

- Cross-section collection
- GPR



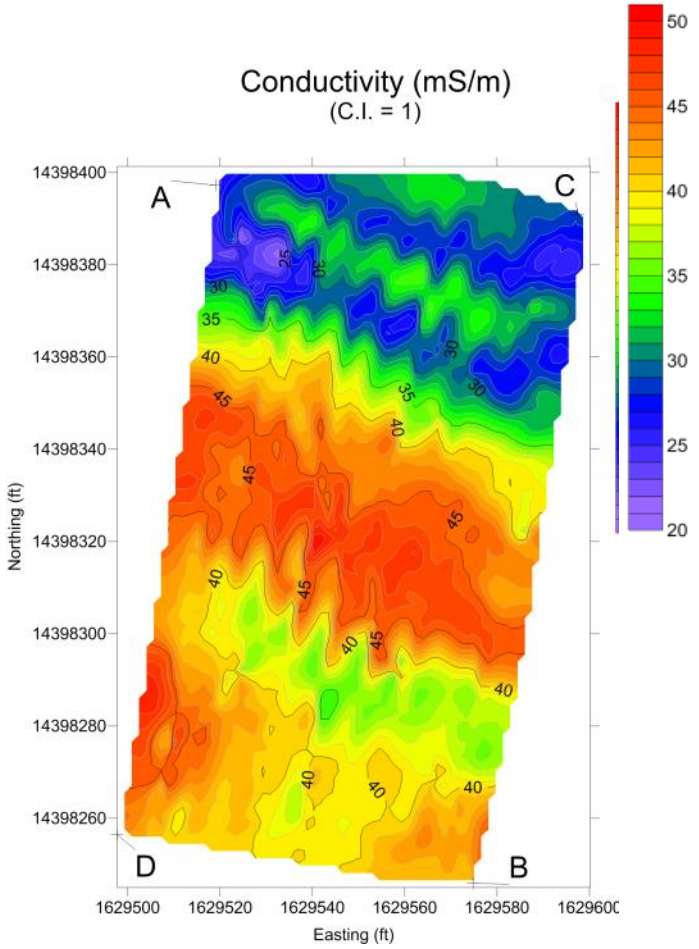
Underground Storage Tanks (USTs)

- Grid collection
- GPR



Extent of Waste/Fill Material

- Grid collection
- EM



Archaeological Studies

- Grid or cross-section collection
- GPR/EM

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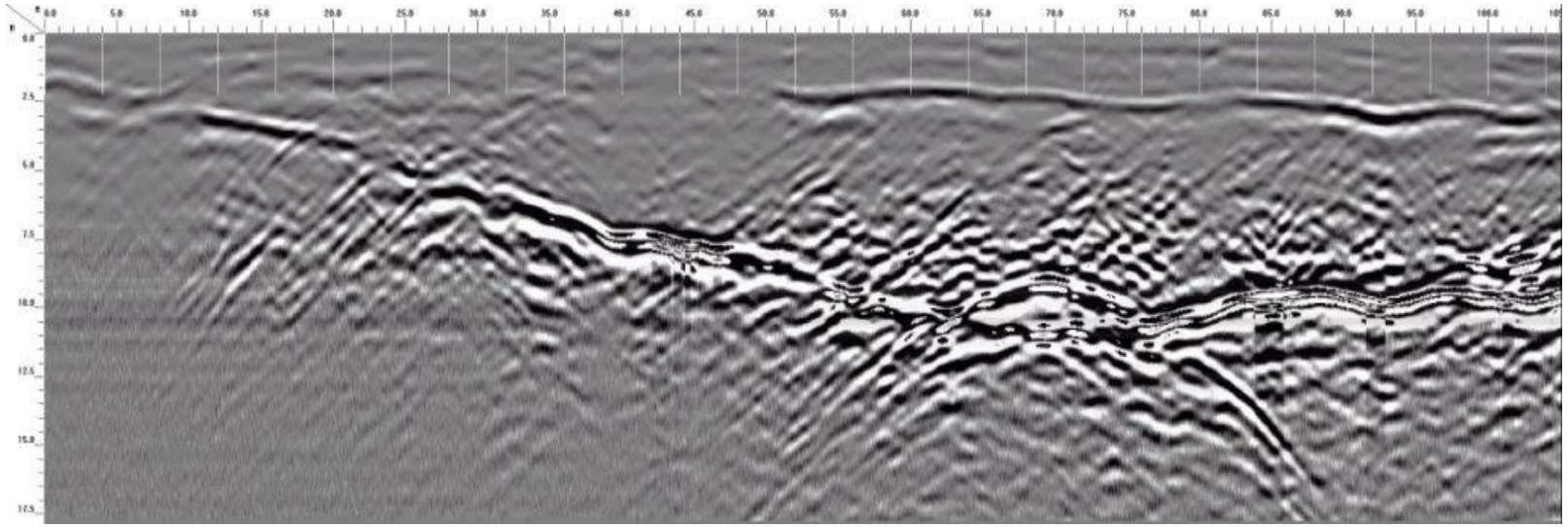
Geological Studies

- Grid or cross-section collection
- GPR/EM



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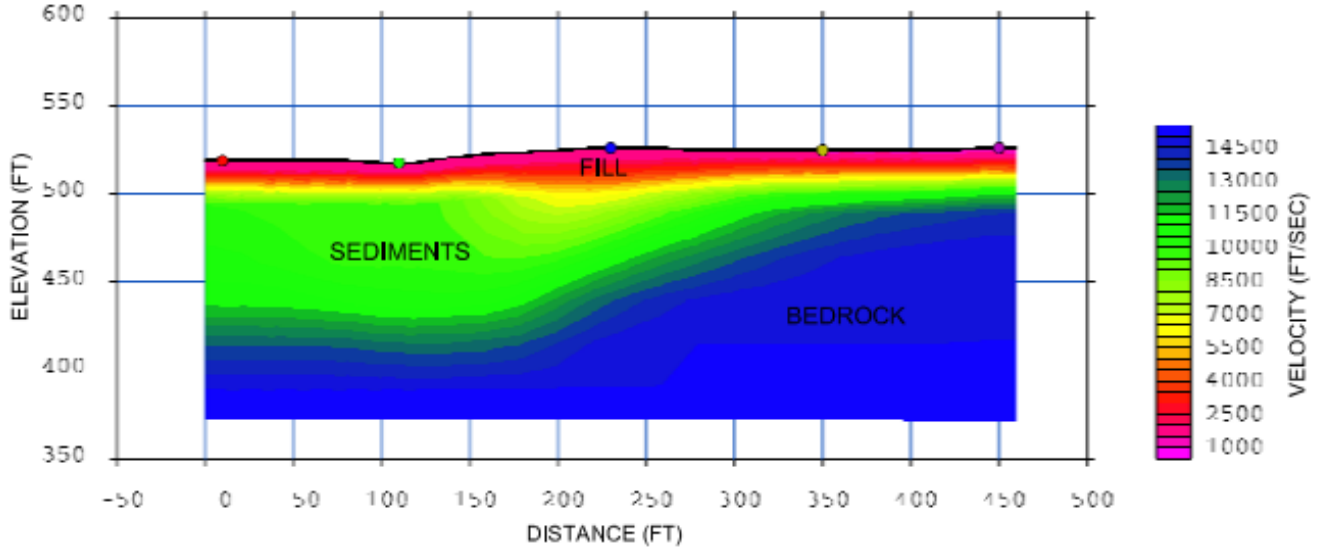
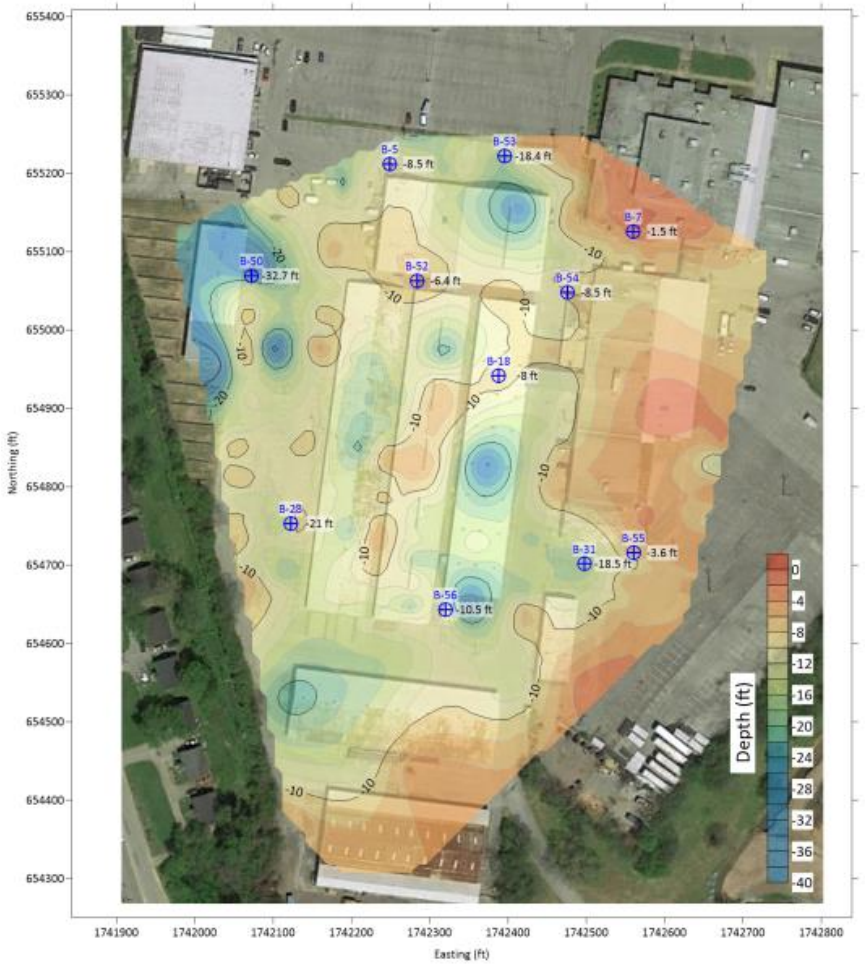
Geological Studies

- Cross-section collection
- Seismic refraction
- Bedrock Depth





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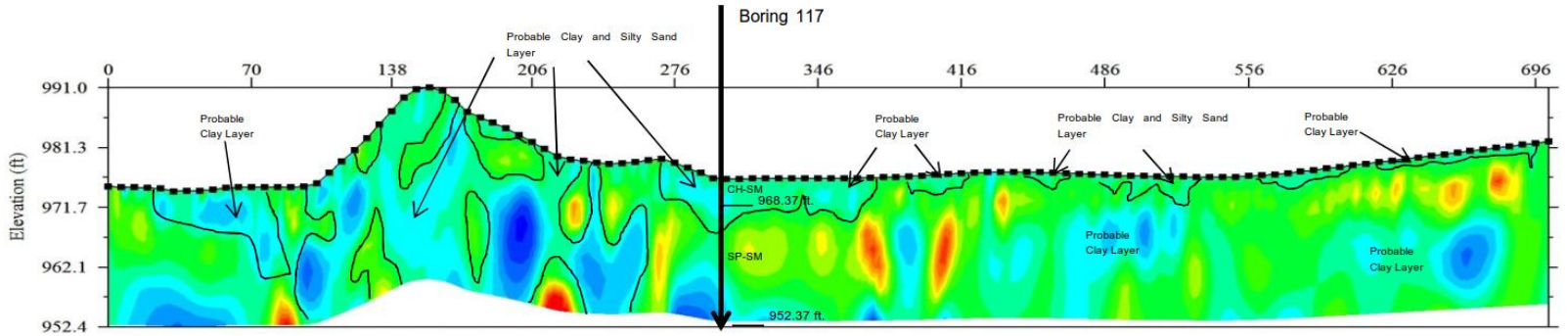
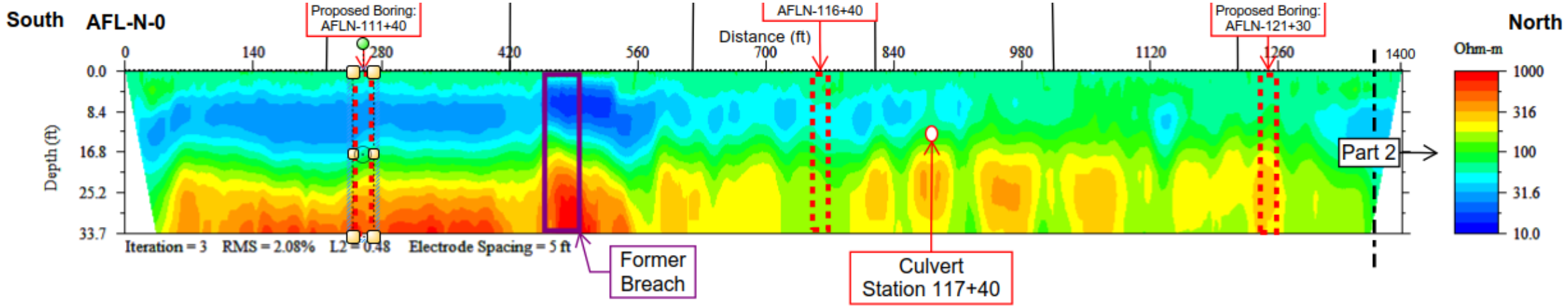
Levees

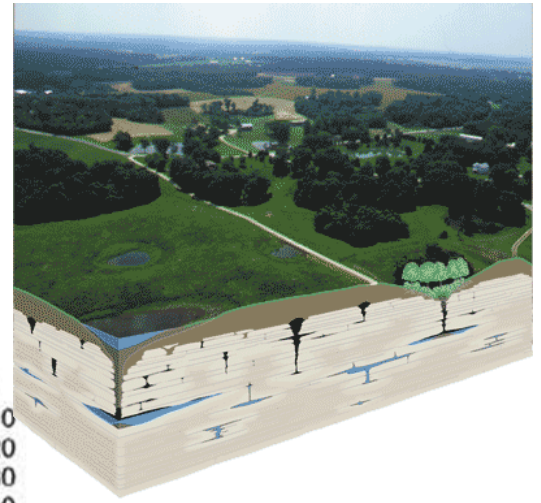
- Cross-section collection
- ERT

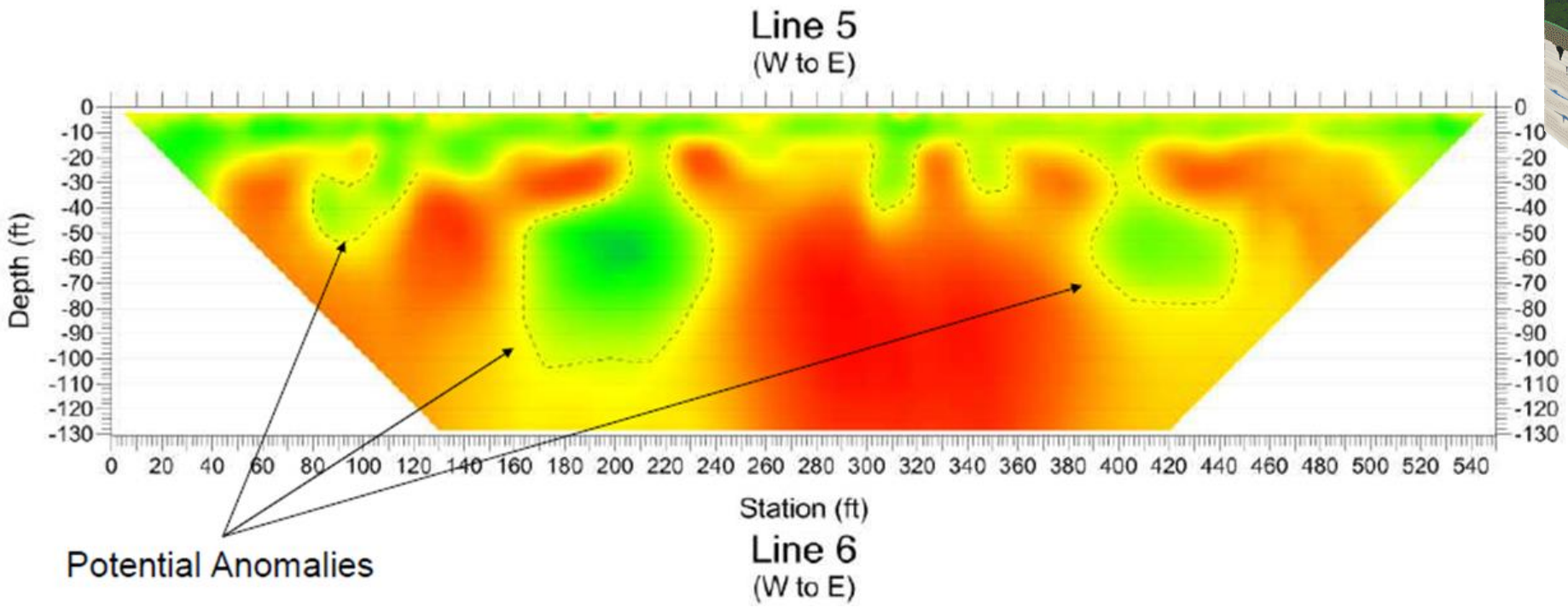




Karst/Sinkholes

- Cross-section collection
- ERT





New Advancements

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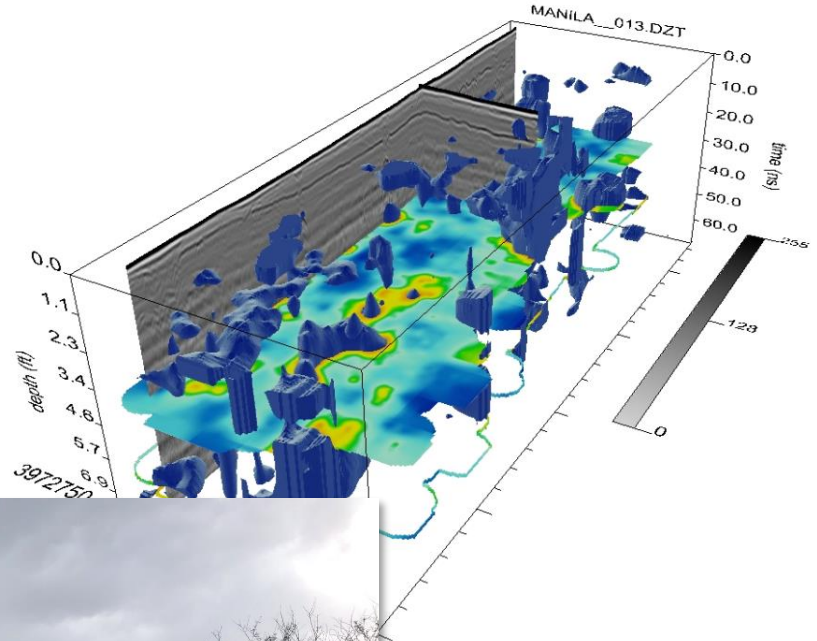
New Advancements

- GPS Integration
- *Advances in Software/Computing Power/Electronics*
  - *Electronics: Hi-stacking/Hyper Stacking*
  - *Larger data sets*
- *Modeling Algorithms and 3D Modeling*
  - *Better refinement of data*
  - *Faster and more efficient*
- Increased Data Density
- Simultaneous Method Collection
- CAD Integration
- Drone Geophysics
- Marine Geophysics



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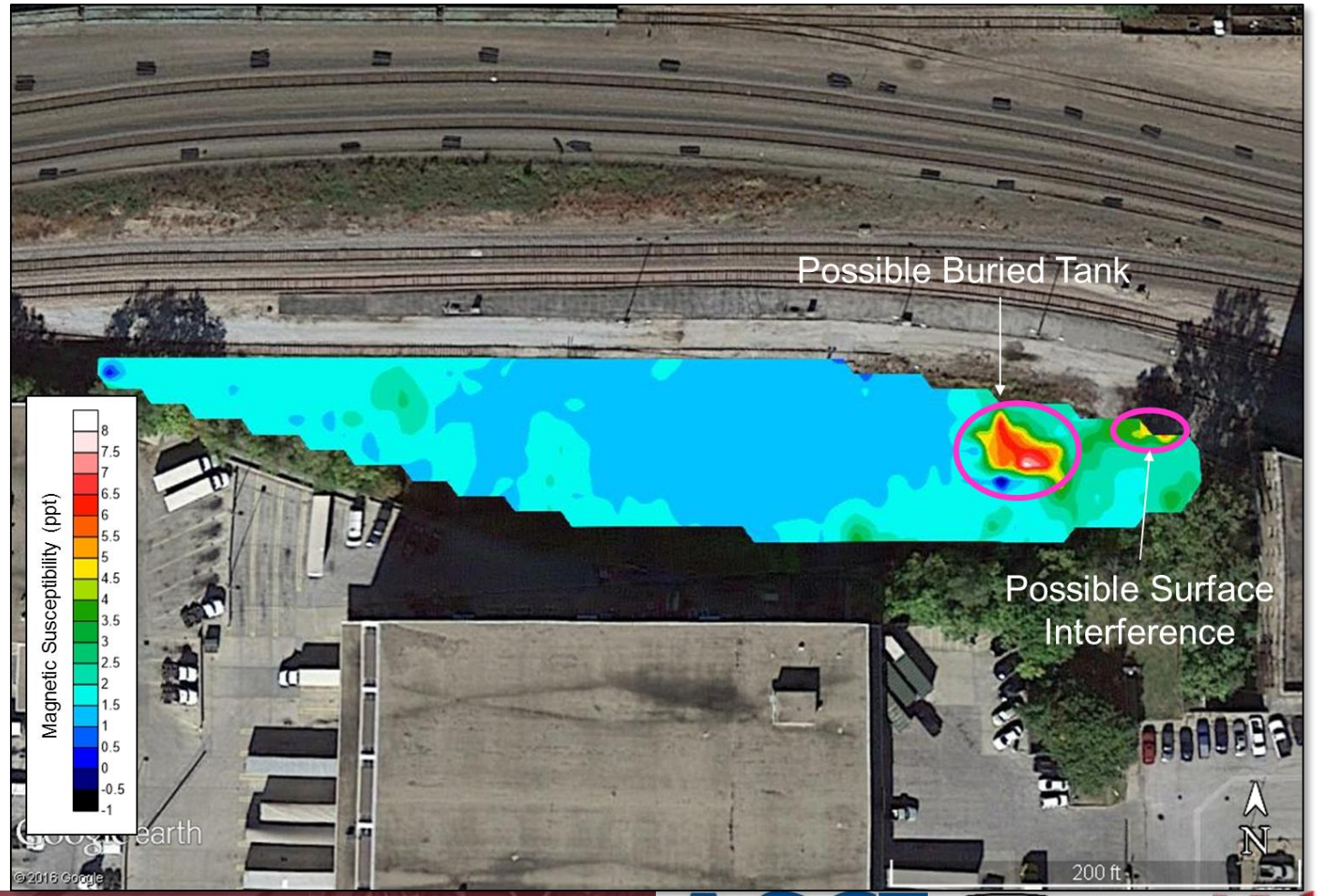
Underground Storage Tanks (USTs)

- Geo-referenced collection
- EMI



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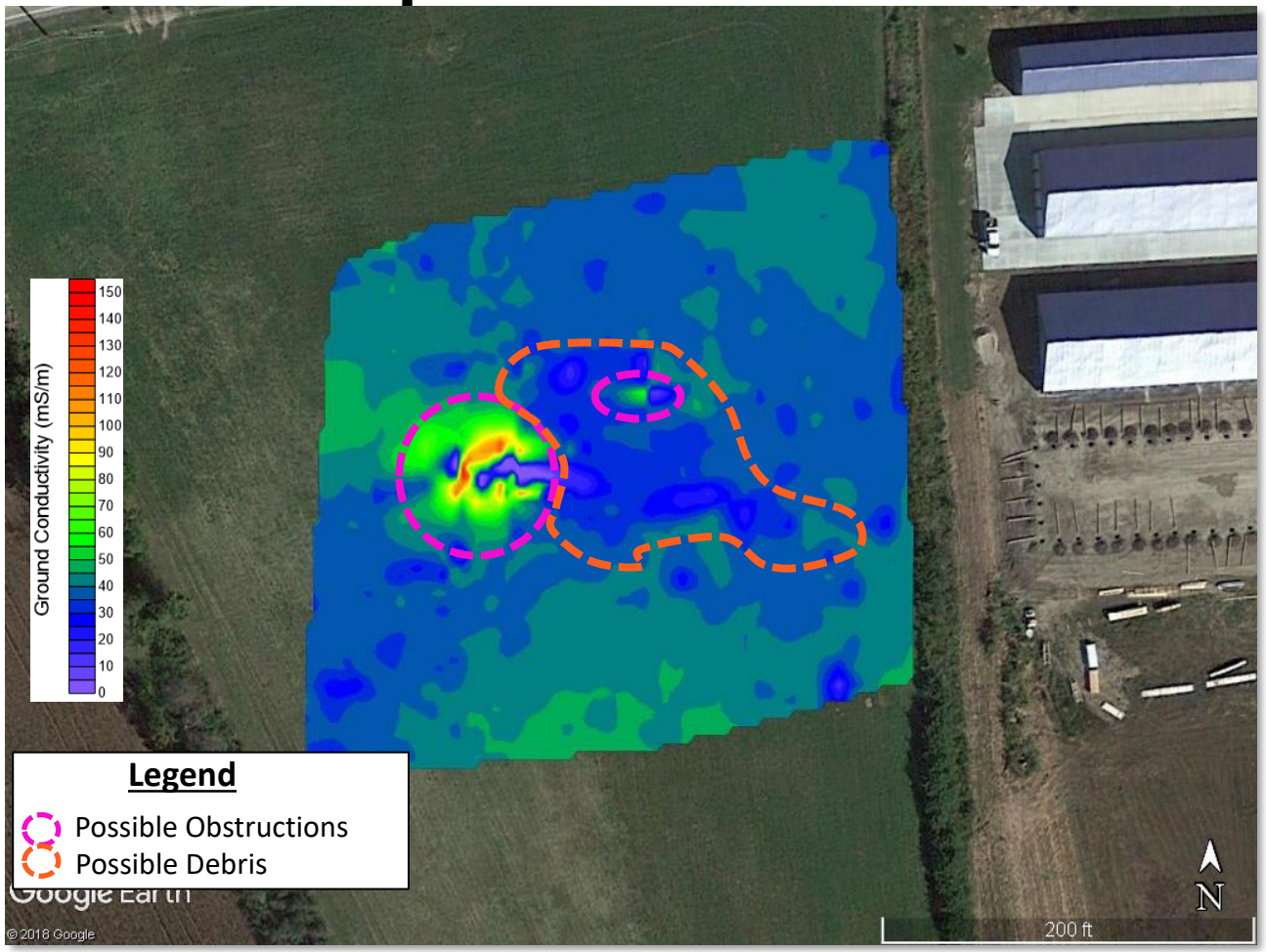
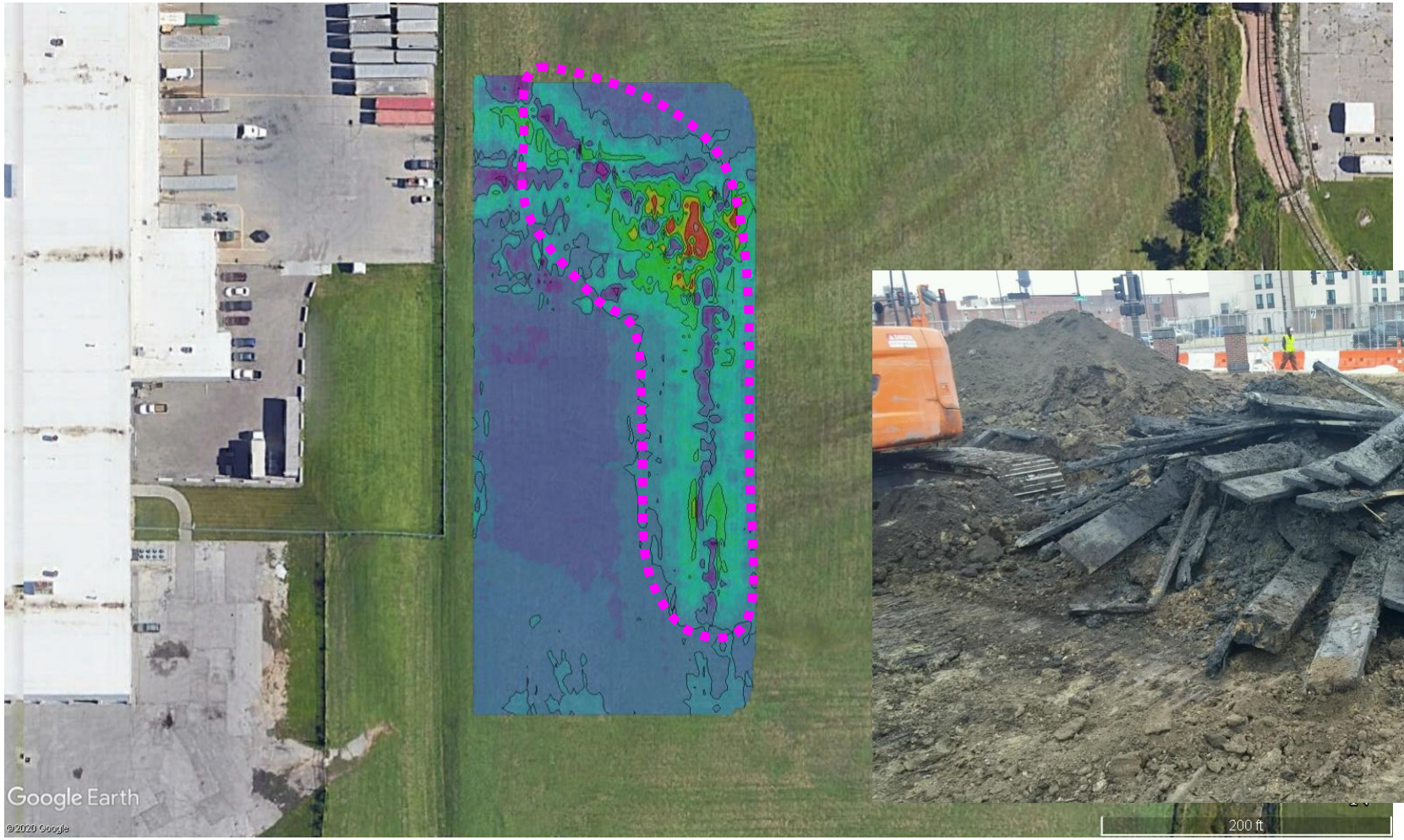
Buried Foundations/Impacted Soils

- Geo-referenced collection
- EMI



Construction Debris



Construction Debris

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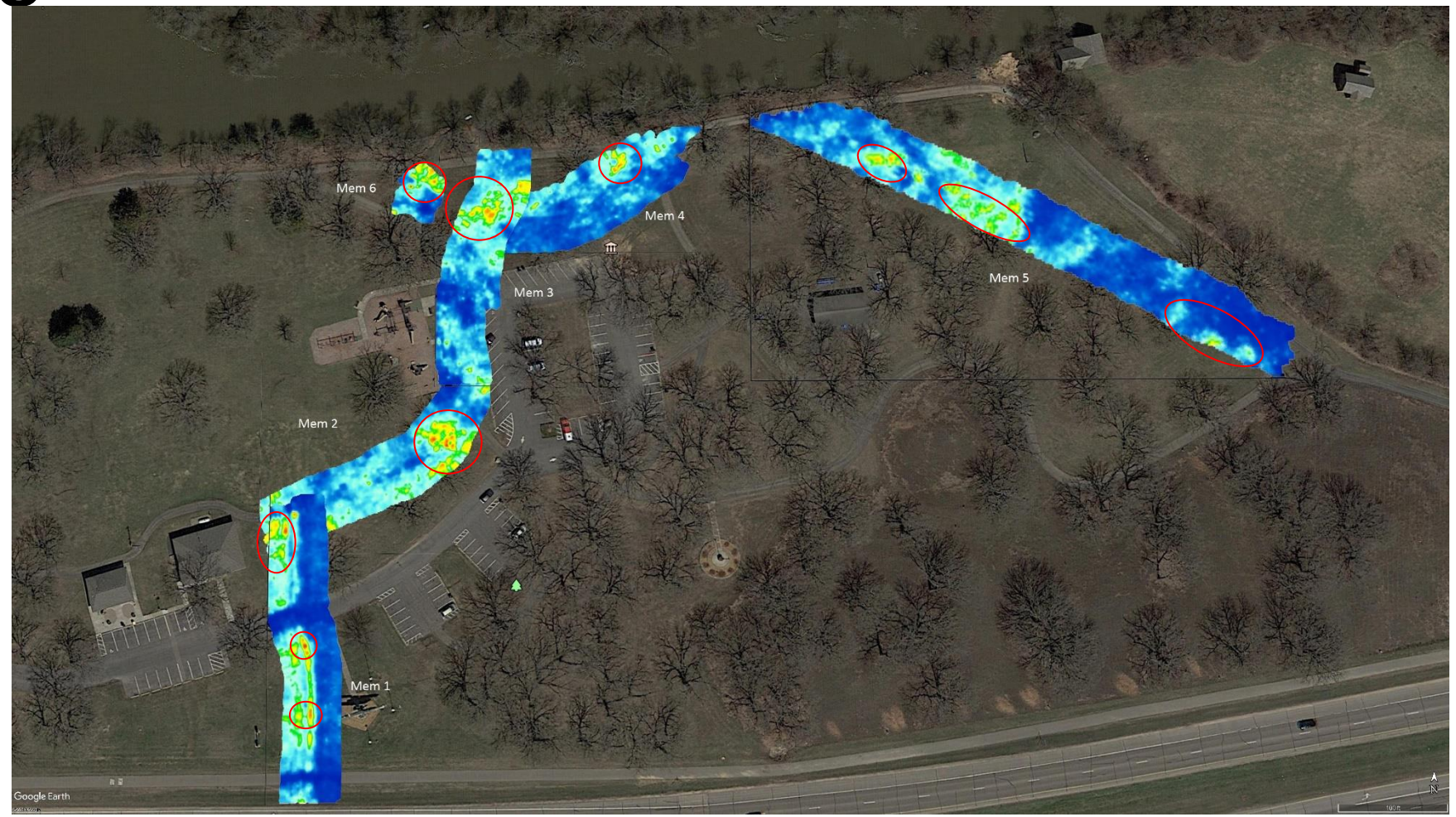
Archaeological Studies

- Geo-referenced collection
- Single-channel GPR



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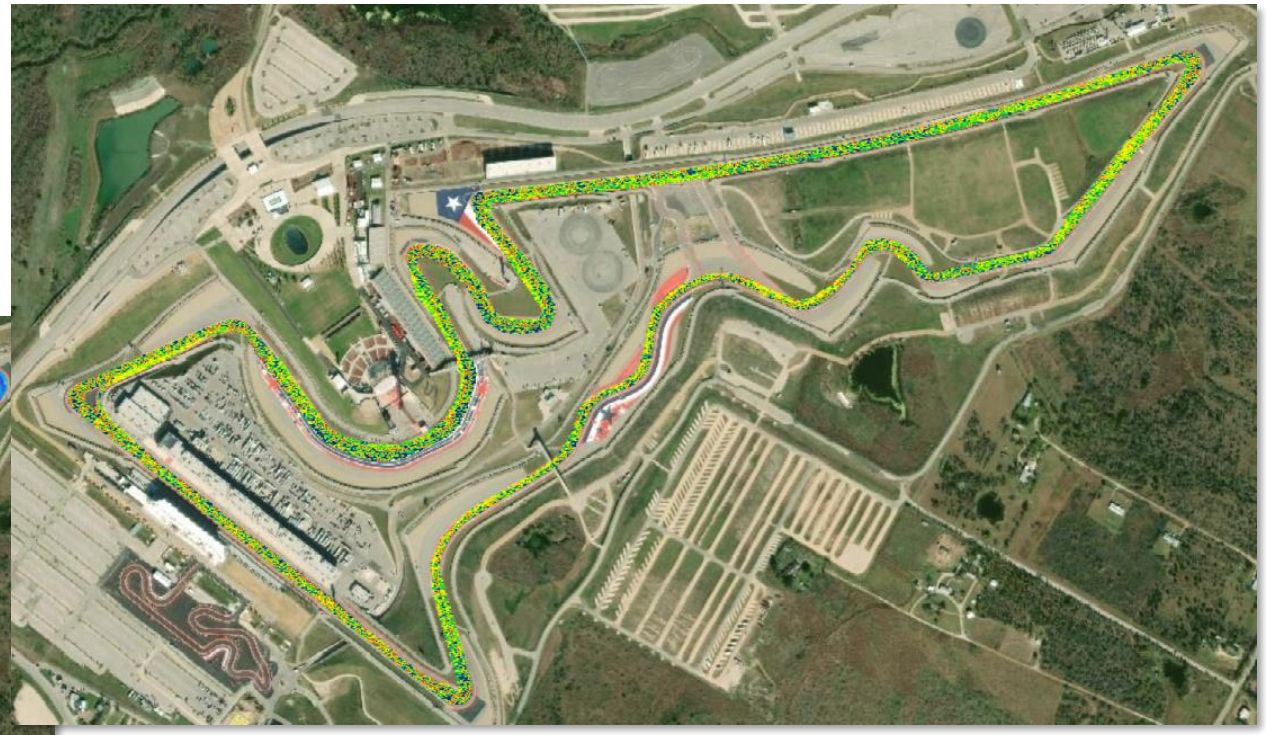
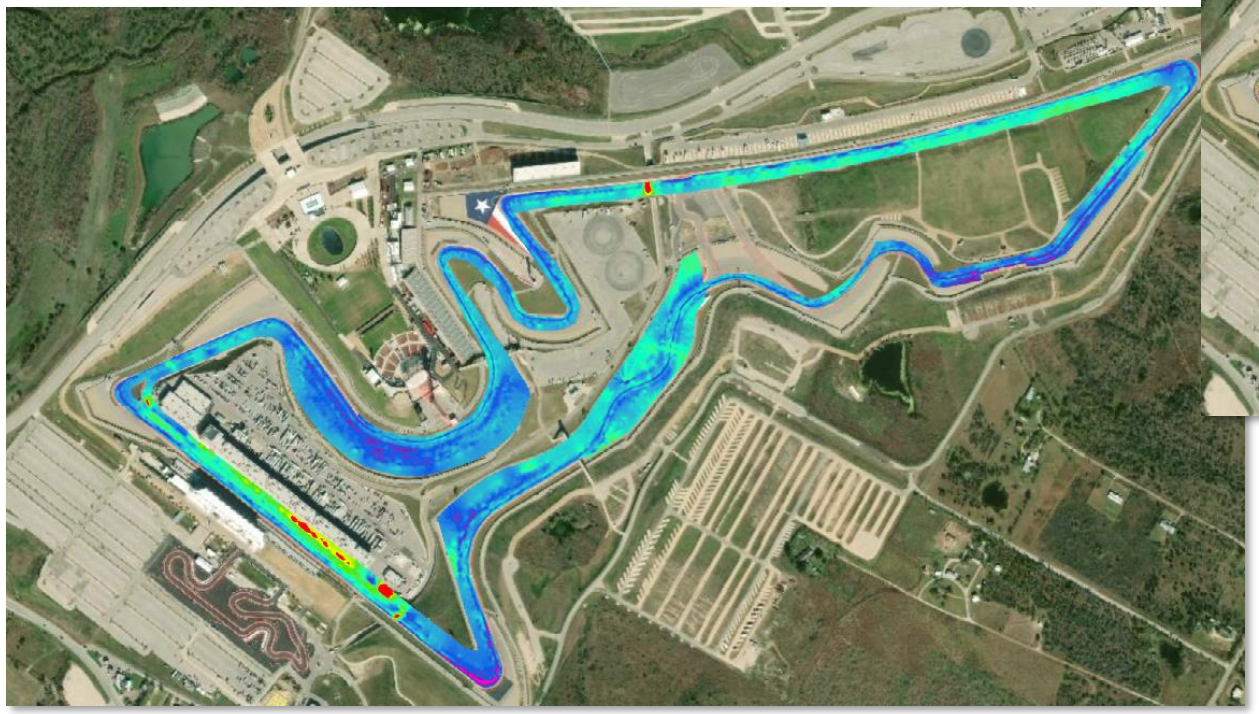
Anomalies

- Geo-referenced collection
- GPR+EMI





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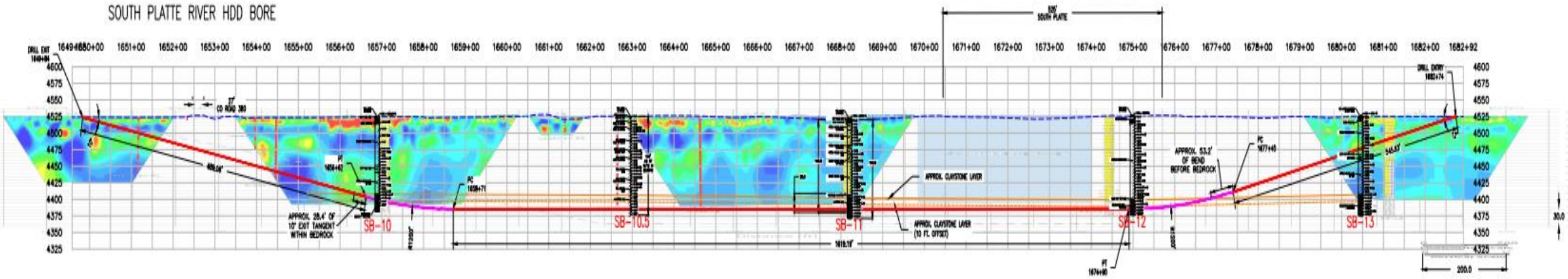
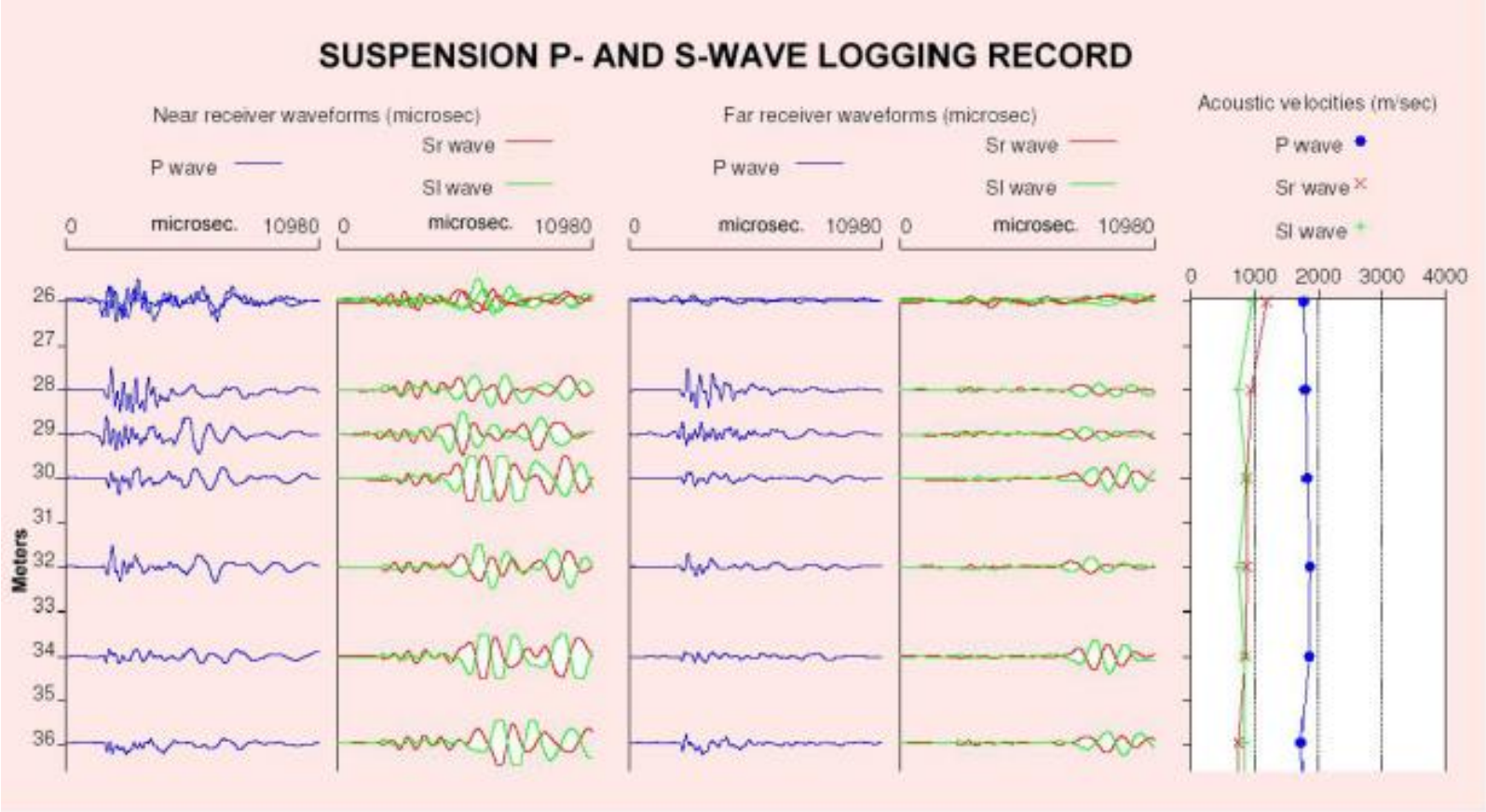
HDD Crossings

- Geo-referenced collection
- CAD Integration
- ERT



Borehole Geophysics

- Simultaneous Collection
- More Efficient
- Cross hole tomography
- Downhole GPR
- Downhole EM



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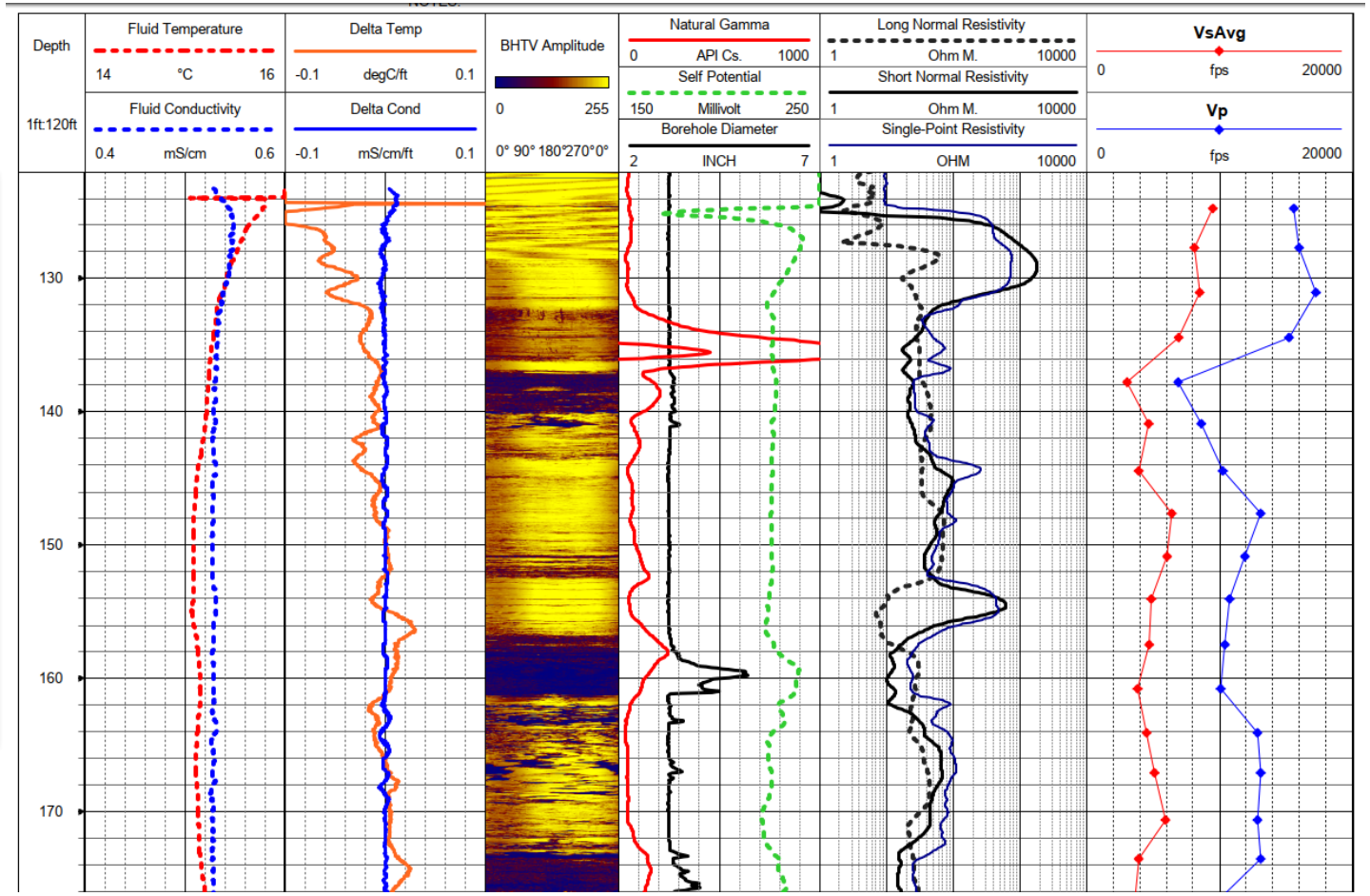
Borehole Geophysics



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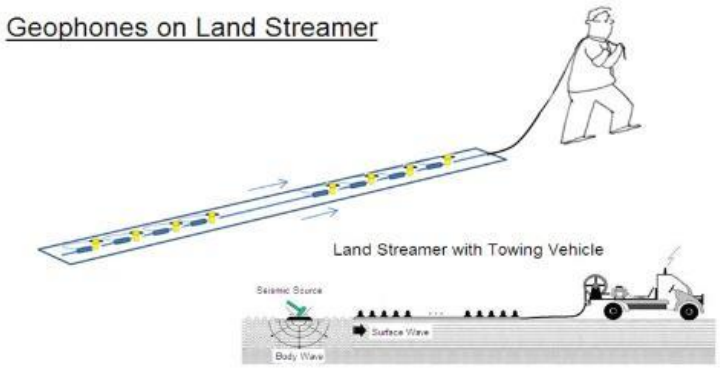
Efficiency

- LandStreamer
- OhmMapper

Geophones on Land Streamer

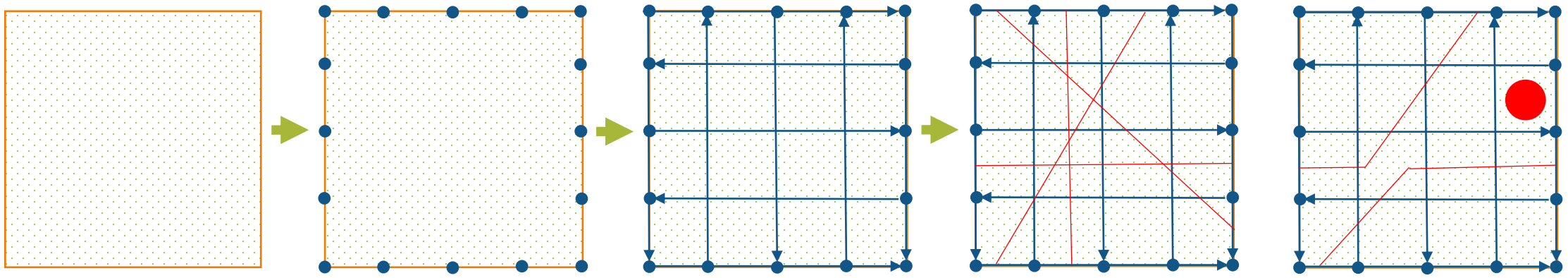
- A land streamer can **increase survey speed by an order of magnitude**.



http://www.masw.com/LandStreamer.html

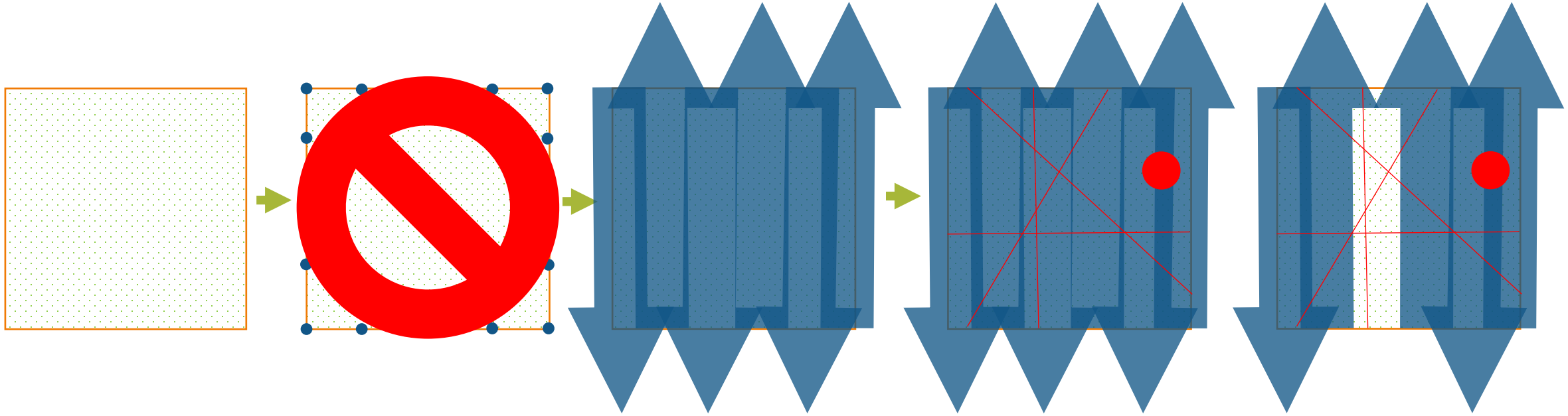
Data Density

- Grid Collection:
  - Single or dual frequency (multi-frequency)
  - High frequencies give better resolution but don't penetrate as deep, low frequencies inverse
- Collect (push, pull, or tow) in one or usually both directions of a grid using a set spacing
  - Can use GPS or staked points
  - Spacing represents 'smallest' object you want to find



Data Density

- ‘Full Coverage Collection’
  - Single or dual frequency (multi-frequency), multiple-channel with dual orientation (simulates running the antenna longitudinally and transversally at the same time)
  - Collect (push, pull, or tow) in one directions of an area with overlap for complete coverage using survey-grade GPS



Multi-Channel Methods

- GPR:
  - Multi-frequency (different frequencies for pulse vs continuous wave step frequency (CWSF))
  - Full coverage “mow the lawn” is possible
  - Air-launched for better coverage in difficult terrain
  - RTK GPS
  - Easy output to CAD
  - Towable: 3-5 mph (typical) but capable of highway speeds, smaller ones are still pushed.
  - Multi-method
- EM
  - Multi-channel EM61
  - Good metal detection, UXOs
  - Towable at slow speeds
  - RTK GPS

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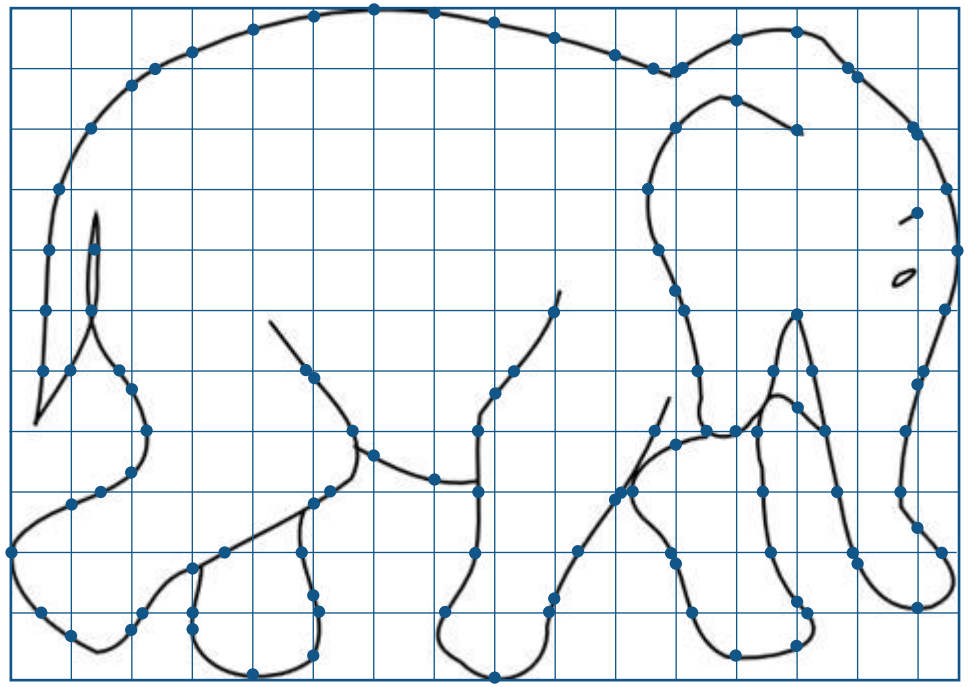
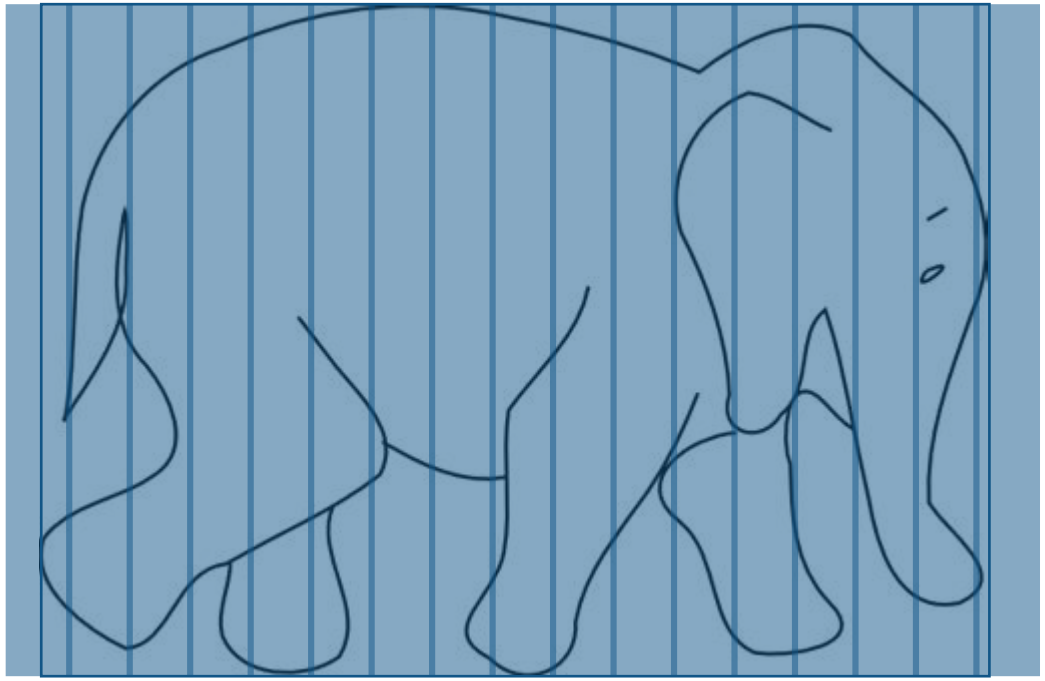
The Elephant in the Room





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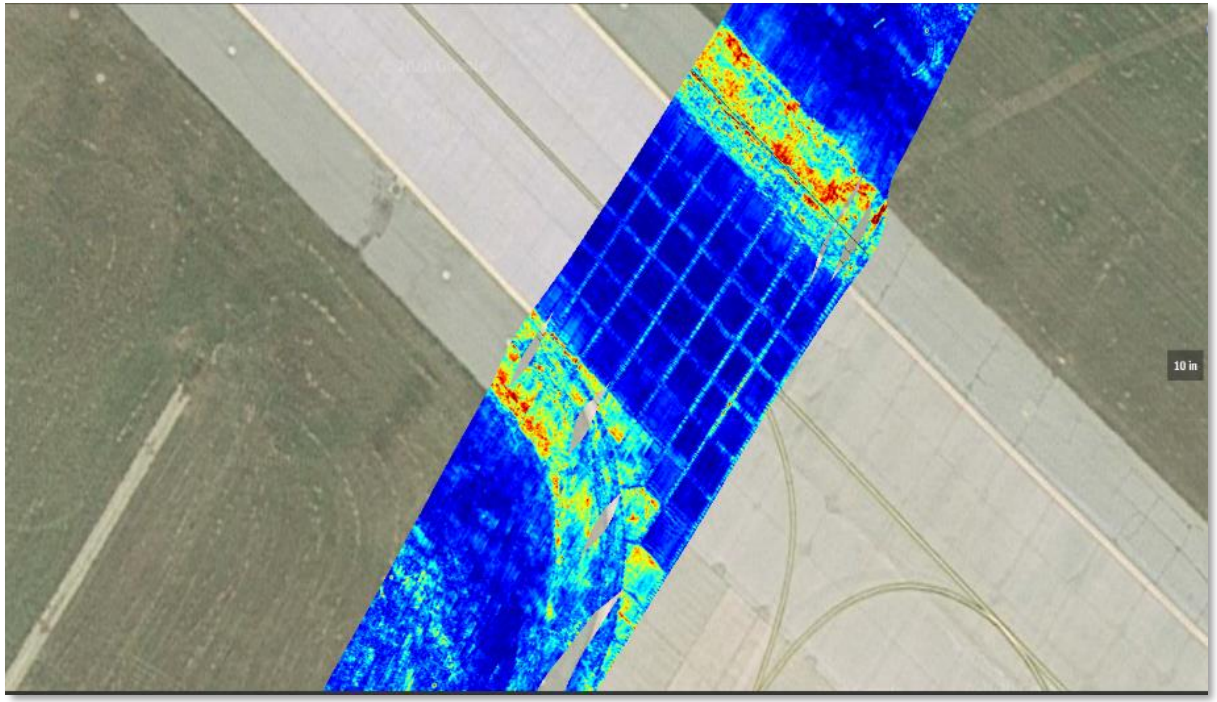
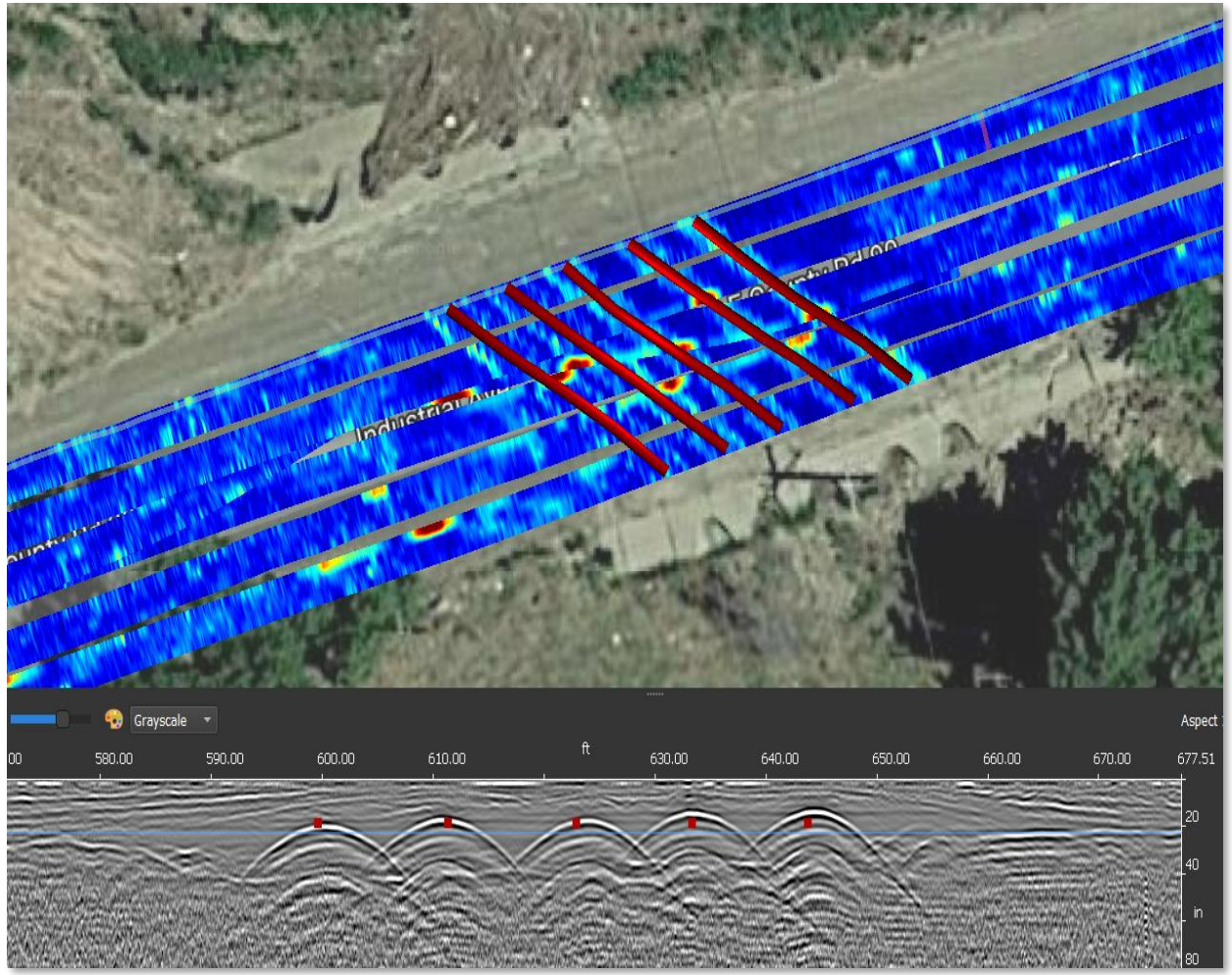
Constructability

- Geo-referenced collection
- MCGPR





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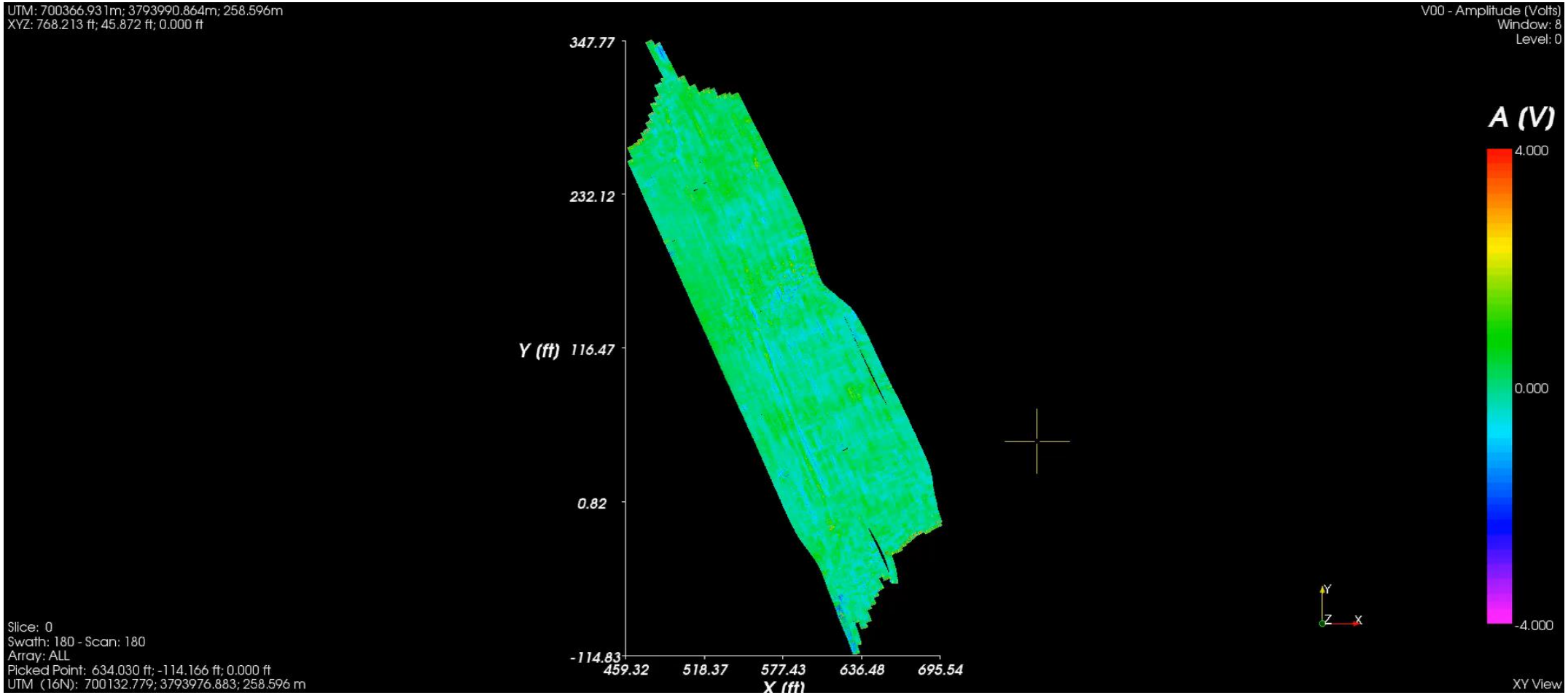
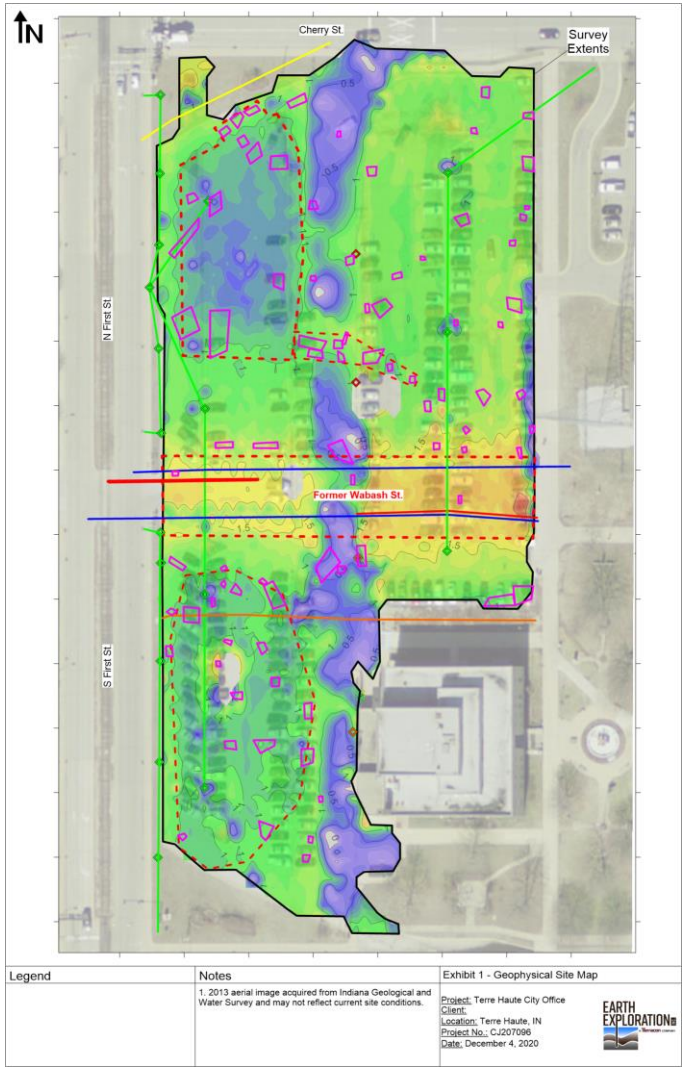
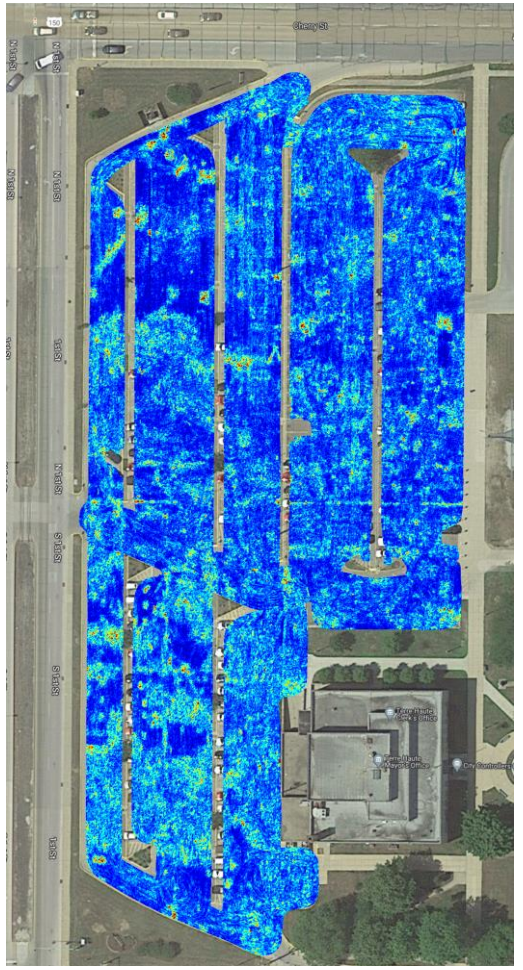
MCGPR


UTM: 700366.931m; 3793990.864m; 258.596m
XYZ: 768.213 ft; 45.872 ft; 0.000 ft
V00 - Amplitude (Volts)
Window: 8
Level: 0
A (V)
4.000
0.000
-4.000
347.77
232.12
116.47
0.82
-114.83
Y (ft)
459.32
518.37
577.43
636.48
695.54
X (ft)
Slice: 0
Swath: 180 - Scan: 180
Array: ALL
Picked Point: 634.030 ft; -114.166 ft; 0.000 ft
UTM (16N): 700132.779; 3793976.883; 258.596 m
XY View

MCGPR

- Geo-referenced collection
- Multiple methods
  - MCGPR
  - EMI





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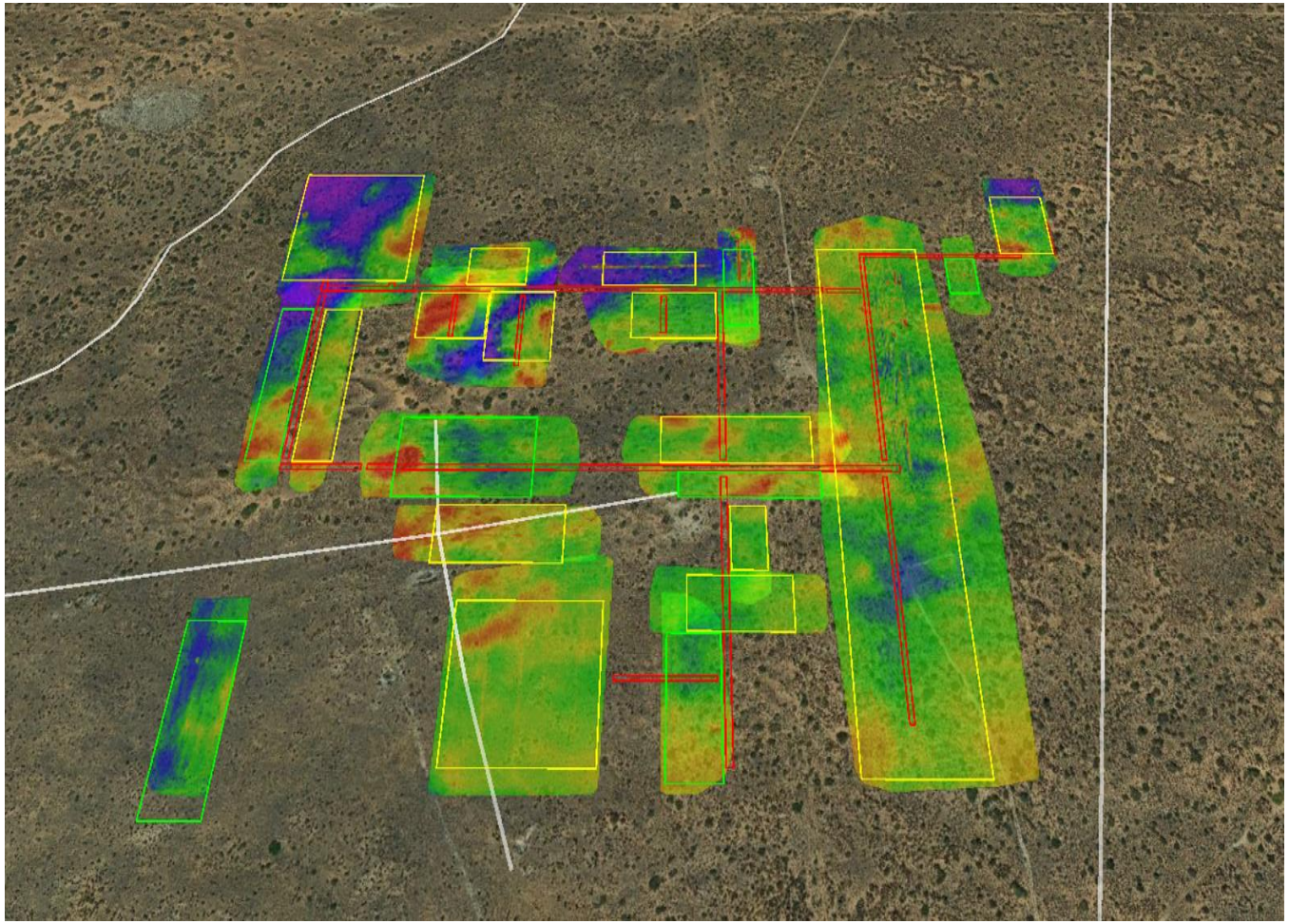
Geological Studies

- Geo-referenced collection
- Large areas
- EMI and GPR



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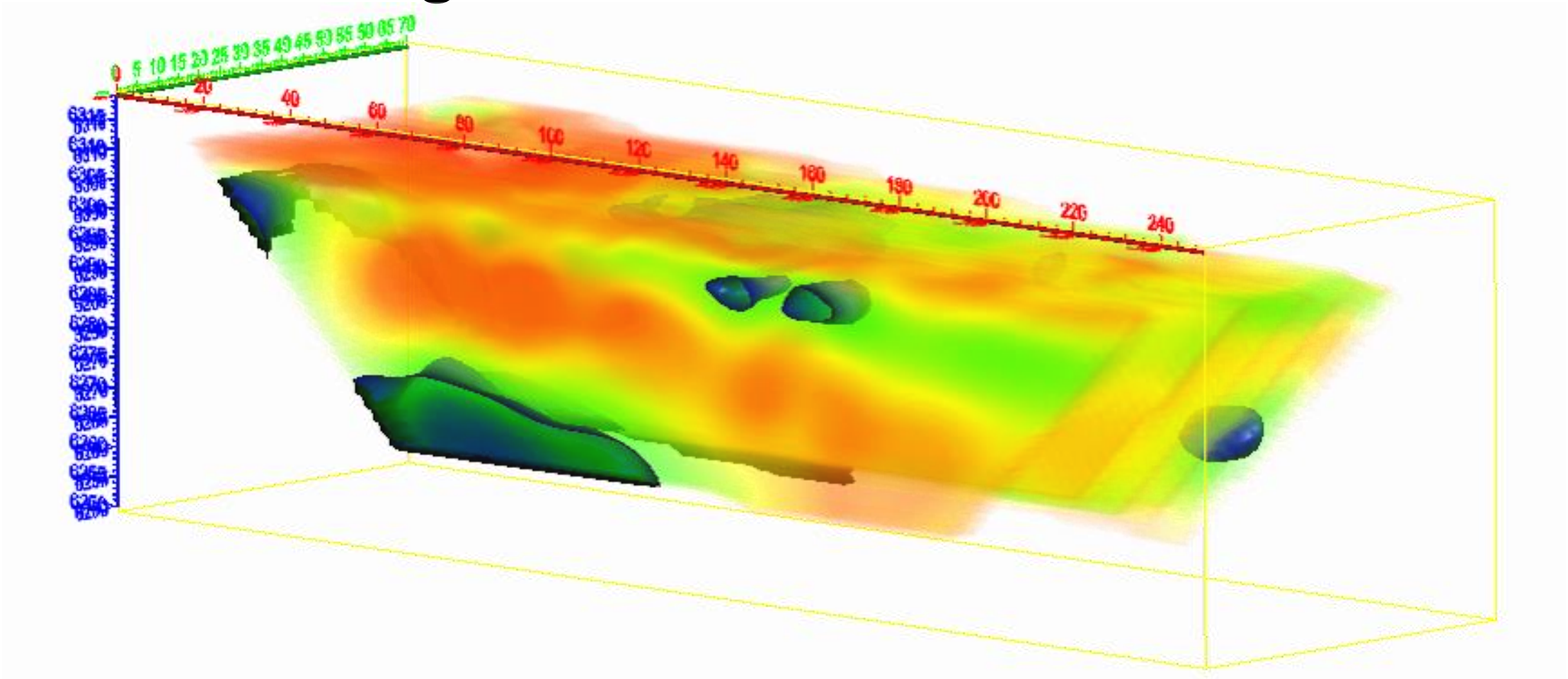
3D Modeling



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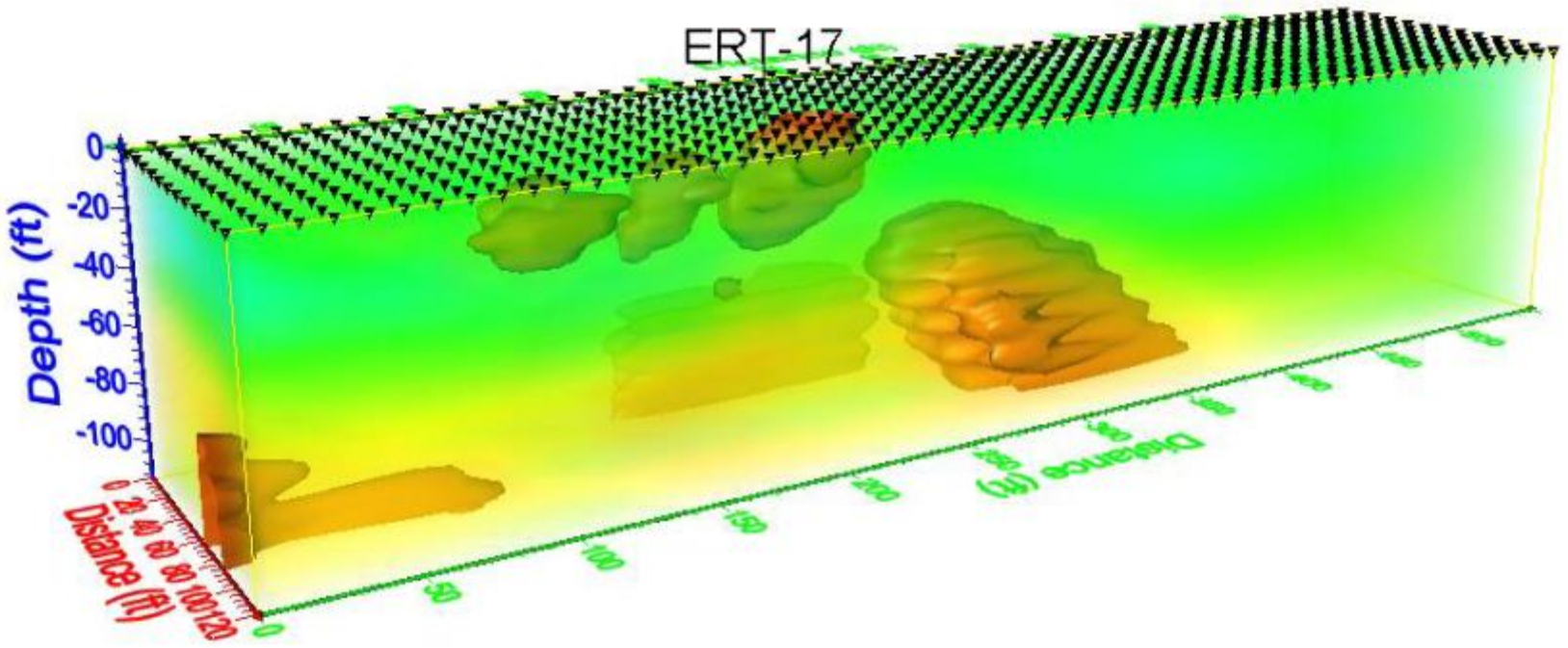
3D Modeling



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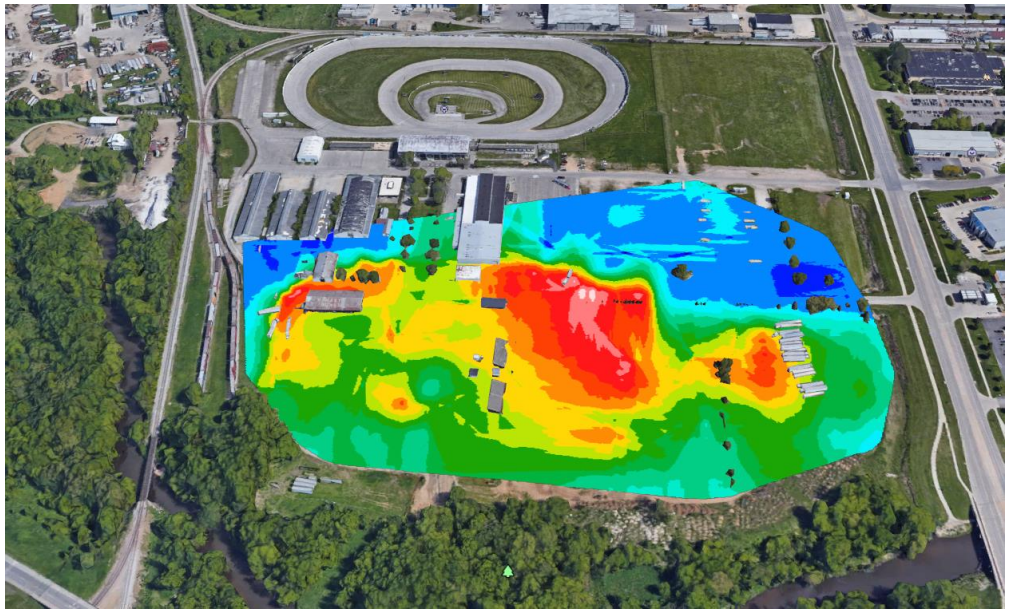
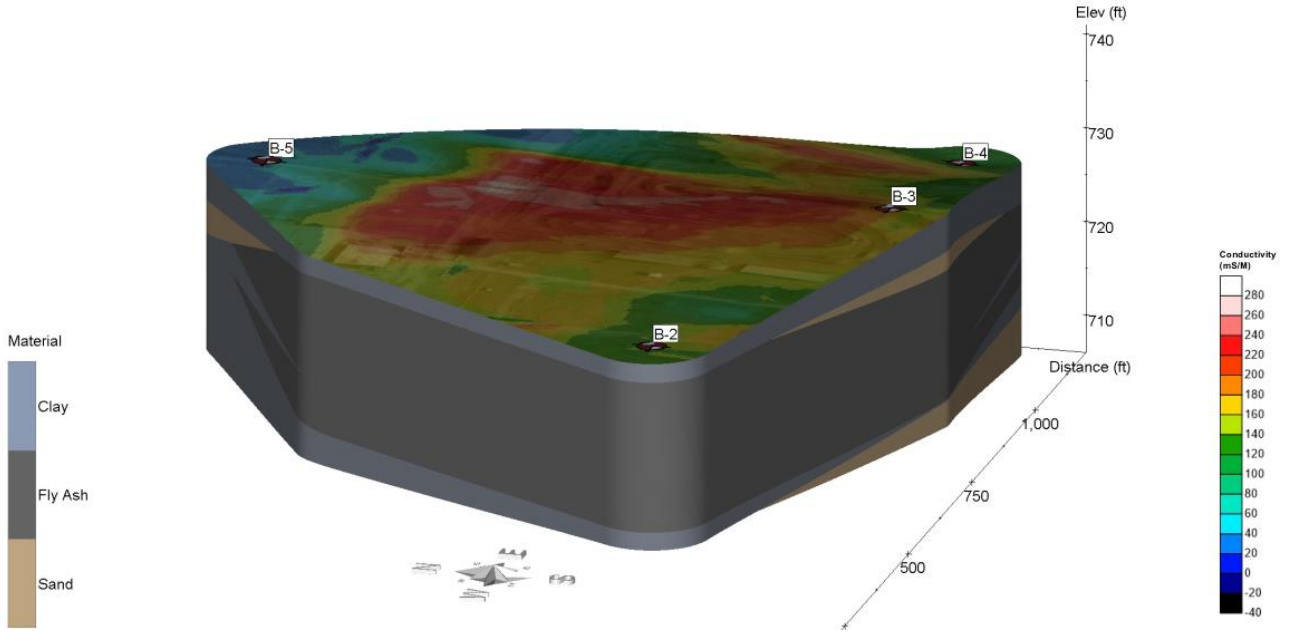
Extent of Waste Fill Material

- Geo-referenced collection
- 3D modeling
- EMI





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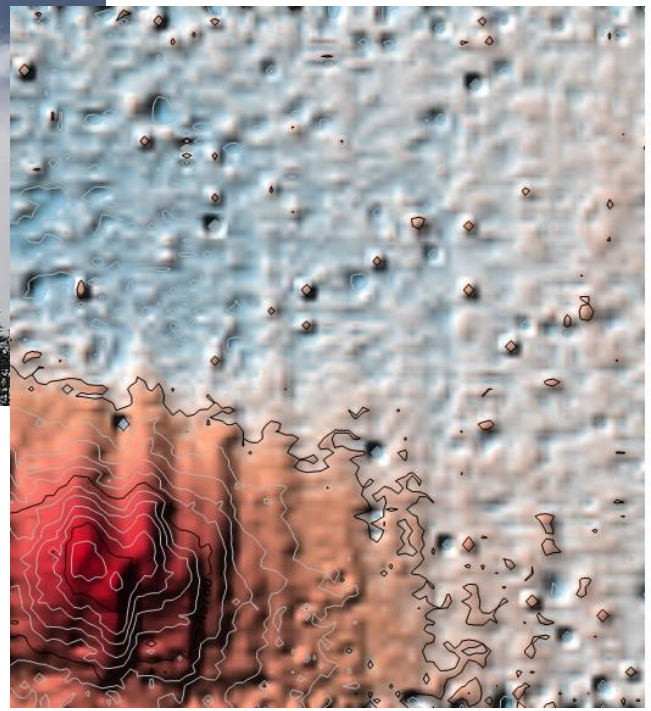
Aerial Surveys

- Magnetometry
- EM
- GPR
  - Reasonable resolution
  - Low-altitude



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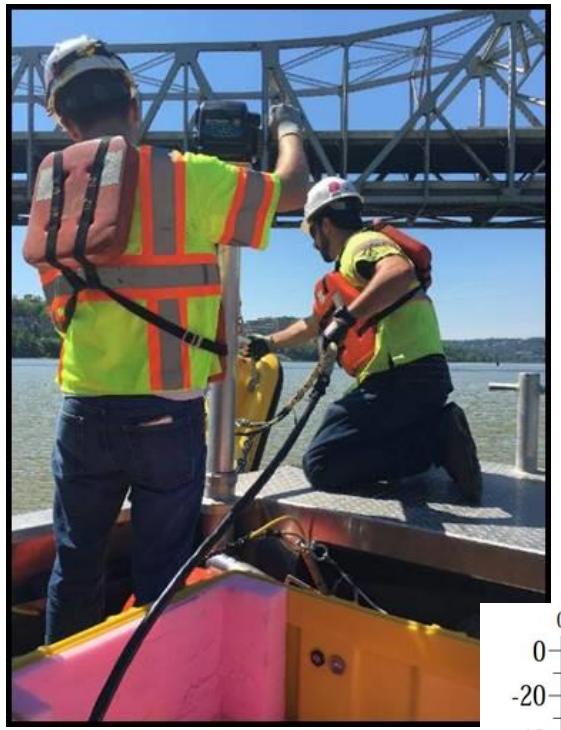
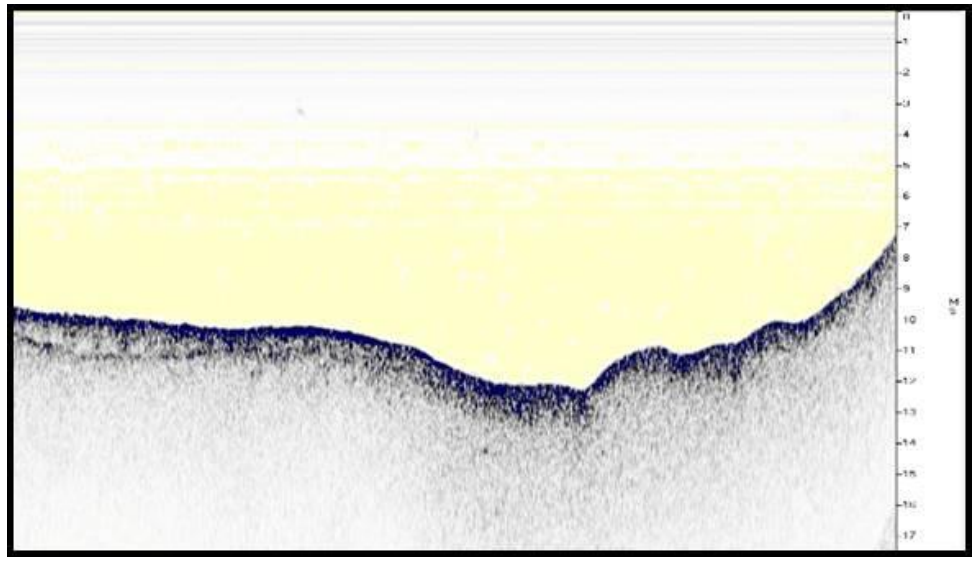
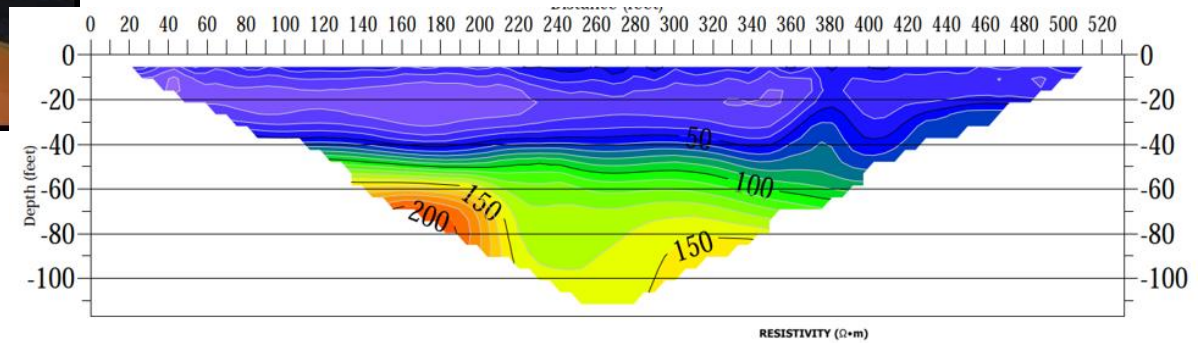
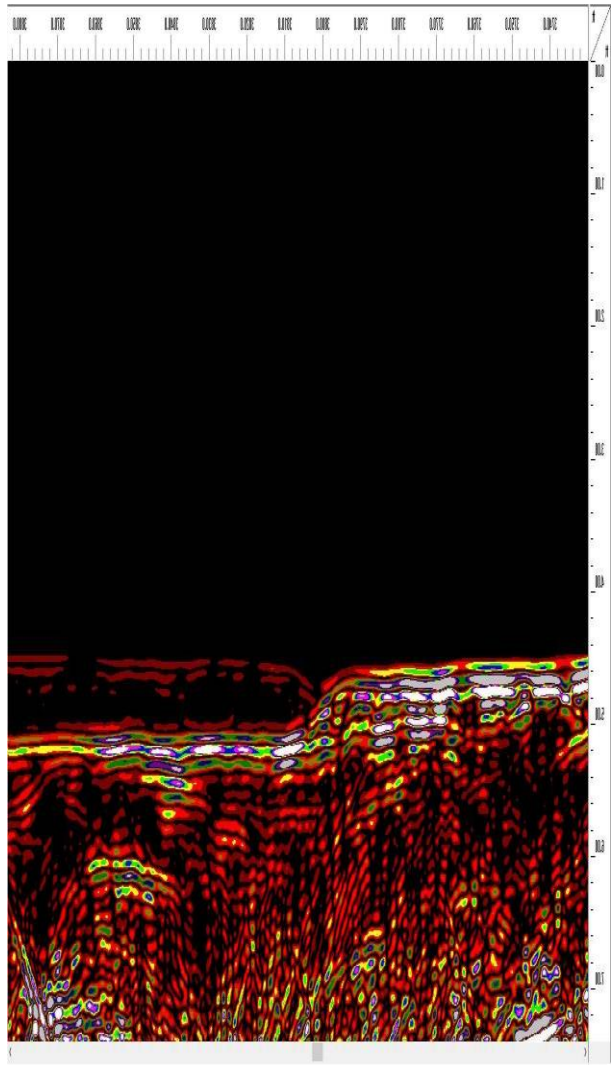
Marine Surveys









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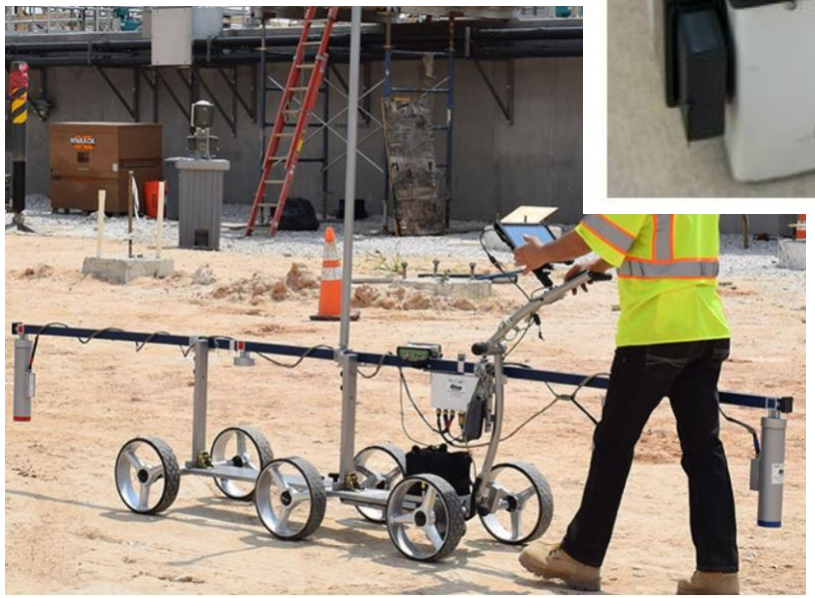
New/Updated Methods

- Microgravity
  - Instruments are smaller, more efficient, and more sensitive
  - Still a challenge to get the right conditions

- AM Gradiometer
  - Useful for long linear objects
  - Uses the AM signal to help locate linear objects such as utilities
  - Proprietary
  - Understand the claims being made



Source: KCI

Conclusion

- Normal limitations still apply
- Higher confidence in the final product
  - Multiple methods
  - Geo-referenced (easier to correlate)
  - More computational power able to collect and refine for better results
- Key: more data in less time, similar cost, higher confidence
- Still no ‘magic wand’