SUE PLUS: Geophysics Crossovers

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Premise or Fact?

- Geophysics are Improving
- The Use of New and Improved Tools for Utility Detection is Increasing
- The Overall Skill and Technical Level of Leading Subsurface Utility Engineering Firms is Improving
- Geophysics is used extensively for goals other than Utility Mapping
- Different DOT Departments may use the same geophysics but for different purposes and at different phases

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Recent Geophysics Research for Utility Mapping

- **UK's Mapping the Underworld**
- **EU's ORFEUS**
- **SHRP R-01 Project "Encouraging Innovation in Locating and Characterizing Utilities"**
  - ✓ **SHRP2 R-01A: Technologies to Support Storage, Retrieval, and Utilization of 3-D Utility Location Data**
  - ✓ **SHRP2 R-01B: Utility Locating Technology Development Utilizing Multi-Sensor Platforms**
  - ✓ **SHRP2 R-01C: Innovations in Expanding the Locatable Zone**

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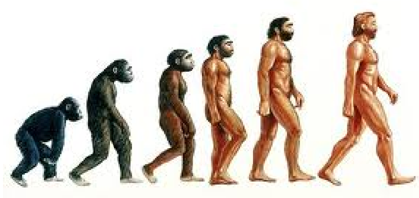

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◆ Traditional Designating Tools to Find Utilities

- ◆ Pipe “Witching”
  - ✓ This actually can work but is defeated by a weak and variable signal to noise ratio of the electro-static field

Traditional Designating Tools to Find Utilities

- EM Pipe & Cable Locators
  - Radio frequency
  - Direct connect or inductive
  - Works for metallic only
  - Defeated by complex networks

Traditional Designating Tools to Find Utilities

- Amplified Stethoscopes
  - Listening for fluid moving through pipes
  - Skill level of operator critical
  - Difficult to get precise location

Traditional Designating Tools to Find Utilities

- Magnetometers
  - Passive measurement of earth's magnetic field
  - Field changes due to local magnetic materials (ferrous pipes)
  - Very sensitive
  - Subject to interference

Traditional Designating Tools to Find Utilities

- Terrain Conductivity
  - Measures both in-phase and out-of-phase components of average electrical conductivity
  - Metallic utilities produce a signature
  - Poorer resolution

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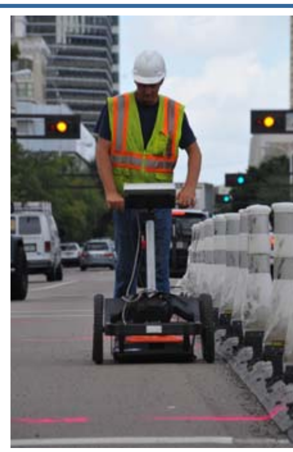
Traditional Designating Tools to Find Utilities



- GPR
  - Highly accurate in favorable soils
  - Requires expert to interpret
  - Often over-sold

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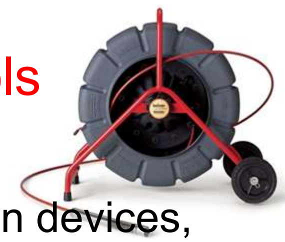
Traditional Designating Tools to Find Utilities



- Cameras, insertion devices, sondes, etc.
  - All very effective for the right situations
  - Limited to pipes that can be entered and pipes whose access is known

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Traditional Designating Tools to Find Utilities

Visible Spectrum

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New Tools to Find Utilities

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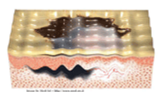
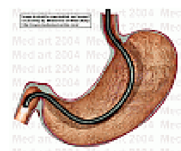
Sometimes we find what we are looking for….
Sometimes We Don't….Sometimes We find Something Else

Analogy – Medical Imaging

- Most studied object in history
- Consists of widely different materials
- Research into imaging in the billions of dollars for CAT, Ultrasound, MRI, etc.
- Highly controlled imaging environment
- Great records

- No one method works for everything
- Exploratory surgery still common
- Highly trained interpreters of data





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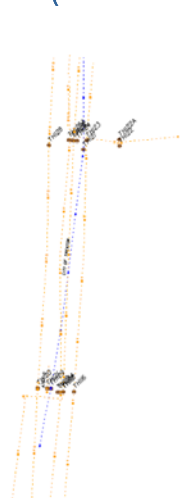
"Standard" SUE Mapping Deliverable 1986-2013 (2-D with Occasional Elevations at Test Holes)

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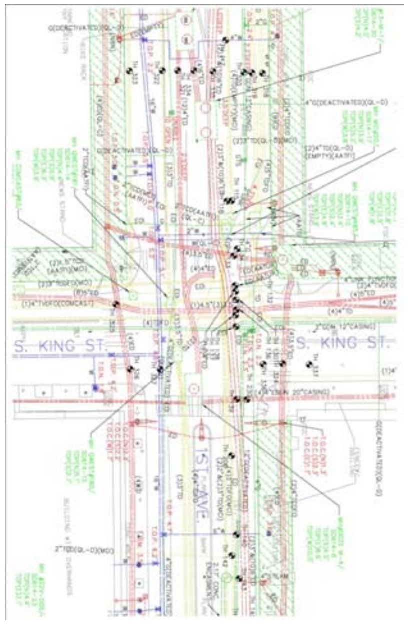


Another Example from WSDOT

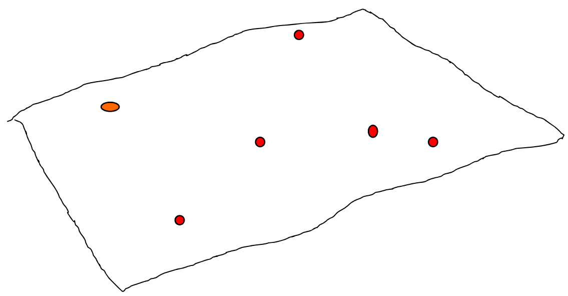
Advanced Geophysics Allow Us To "Do" The Following:

- A better assessment of where we need to excavate test holes, bore holes, drill holes
- Provide a continuous 3-D view of utilities where we get an adequate geophysical signal
- Find geotechnical features
  - ✓ Soil lenses
  - ✓ Pavement thickness /Voids
  - ✓ Depths to bedrock
  - ✓ Depths to water table
  - ✓ Sinkholes
- Find geo-cultural features
  - ✓ Cemetery details
  - ✓ Contaminant plumes
  - ✓ Septic fields / wells
  - ✓ Construction rubble
  - ✓ Foundations
  - ✓ USTs
- Other features
  - ✓ Tree roots
- Depths to all these features (or elevations if DTM or other accurate and precise ground surface elevations are known)

LOVE CANAL

Geophysical Bore Hole Plan to determine contaminate problem and extent

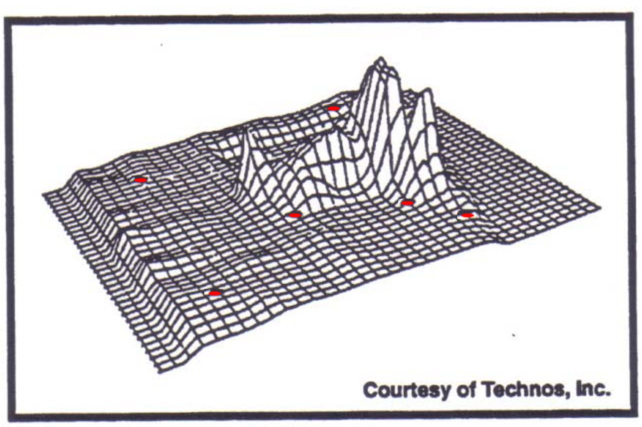
Six evenly-spaced bore holes



CONCLUSION: NO CONTAMINATION

Bring In the Geophysics:

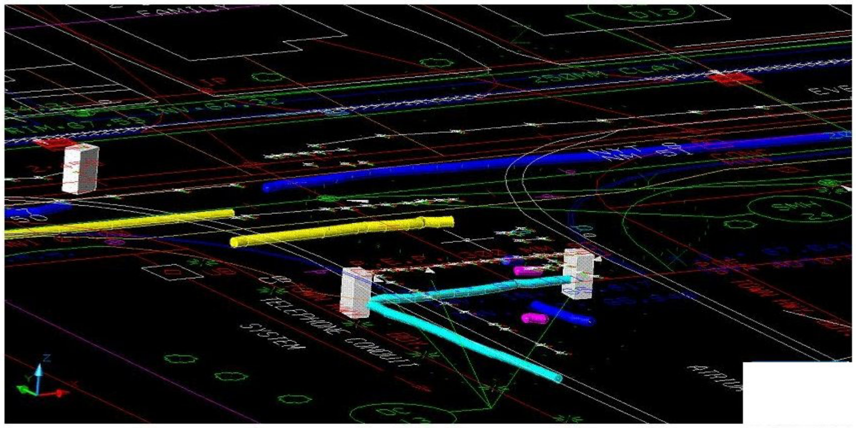
Launch the Superfund Program



Courtesy of Technos, Inc.

3-D view of “Imaged” Utilities
Cylinders indicate precise depth

(perhaps fewer test holes needed on these lines; note just a few utilities able to be imaged)



Without Method Differentiation, the Whole Purpose of ASCE 38 is Moot.
Decreased Ability to Manage Risk

DANGER
WILL ROBINSON

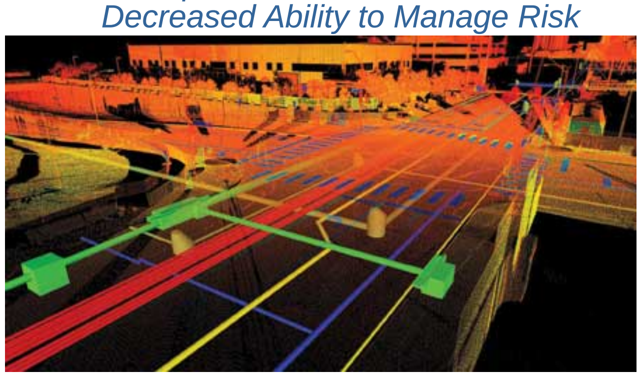


Image incorporates main street data point cloud, with a combination of various undifferentiated methods of populating the “z”

RECORDS / TEST HOLES / GEOPHYSICS / FILL IN THE GAPS

The "New" Geophysics still have Significant Limitations

- Field Trials from the SHRP2 R-01B and C projects

Field Test Results: Compare New Tools to Old

- SUE Firm Diligence for project mapping
  - ✓ Complete sweep of project limits with passive and active frequencies with PCL
  - ✓ Magnetic gradiometer to find buried valves
  - ✓ Insertions at all available empty pipes/conduits
  - ✓ Entry / direct coupling of all manholes
  - ✓ Tracing beyond project limits until appurtenance found for utility identification
  - ✓ Extensive utility records search and correlation

SUE Firm Results

- Virginia DOT, Stringfellow Road
  - ✓ typical commercial suburban widening and road realignment project.
  - ✓ private fenced areas, deep ditches, large numbers of utility poles, on-going parallel construction activities, heavy traffic, signalized intersections, and heavy tree and brush growth
  - ✓ natural gas, petroleum, water, electric, telephone, cable, storm, sanitary, and traffic control.
  - ✓ Depths 1-14 feet
  - ✓ Standard tools and techniques were capable of designating 93.5% of these utilities, including the 14 foot deep petroleum lines.

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SHRP B Tool Results (in areas of coincident coverage)

50% of project
would not be able to be covered by these tools
due to site topography restrictions

- GPR – soils not conducive to any results
- TEMS
  - ✓ Found 43% of utilities found by SUE Firm
    - 93% of metallic water
    - 33% of metallic gas lines
    - 10% of communications lines
    - 25% mis-identification

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SUE FIRM Results – Talbotton Road GDOT

- typical commercial urban and suburban widening and drainage project
- highly congested utility infrastructure
- poor records, heavy traffic, signalized intersections, limited line-of-sight due to road elevation changes, and some heavy tree and brush growth in a few places.
- natural gas, water, electric, telephone, cable, storm, sanitary, traffic control, and several with unknown function.
- 1 foot to 6 foot typical depths
- Drainage culverts, road and sidewalk under-drains, and residential services beyond their meters are not to be mapped under DOT scope.

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SHRP B Tool Results (in areas of coincident coverage)

- **Both GPR and TEMS gave good results**
  - **Both tools found a majority of the metallic water and metallic gas lines in the areas covered by it**
  - **Neither tool had great success on the communication systems**
  - **Overall, within the covered project areas the SHRP B tools found 52% of the QLB utilities in scope**

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- Perhaps the greatest advantage of the GPR tool is that of a continuous depth profile of an imaged utility.
- 13 test holes dug for correlation to GPR depth
- The results of the test hole excavation were:

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DEPTH GROUND TRUTHING VS GPR

Test Hole #	Sheet #	Expecting	Found	Actual	TerraVision II Depth	Differential*
2	24-14	10" water line 6-way tele duct	11" water line RPC tele duct	1.67	1.70	+.03'
150	24-05	12" water line unknown	12 ¾" water line 1" metallic	3.85 3.43	- 2.488	- +0.94'
151	24-05	unknown parallel unknown crossing	2 ¾" metallic 2" metallic	1.93 2.26	- 1.543	- +.0.72'
152	24-05	unknown parallel unknown crossing	2 ½" metallic 3 ½" metallic	1.92 3.12	2.13 to 3.971 1.569 to 1.367	-0.21 to -2.05 +1.55 to +1.75
153	24-05	unknown	14" clay pipe	2.22	-	-
154	24-09	unknown	1 ¼" metallic	2.62	1.947	+0.67'
155	24-11	8" water line	8 ¾" water line	2.83	2.331	+0.50'
156	24-31	unknown	2 ¾" metallic	2.66	1.996	+0.66'
157	24-10	unknown	1 ¼" copper water line	1.45	0.833	+0.61'
158	24-05	6" gas line	7" gas line	3.83	4.158	-0.33'
159	24-31	2" gas line unknown	4 ½" plastic gas line ¾" copper water line	4.24 .33	3.892 .537	+0.35' -0.21'
160	24-10	6-way MTD F.O. telephone	RPC Tele Duct	3.90	4.081	-0.18'
161	24-10	unknown	2 ½" metallic	3.29	2.891	+0.40'

% Δ

02% to 57%

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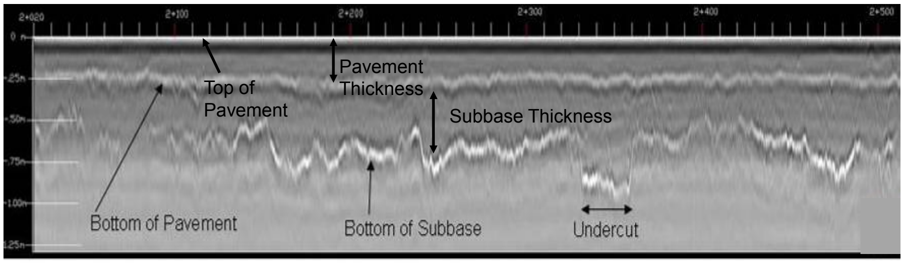
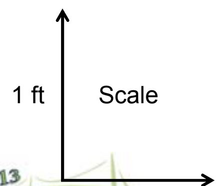
Pavement and Base Mapping





GPR on relatively thin pavement over base material

Quick and easy measurements

Pavement & Base Thickness

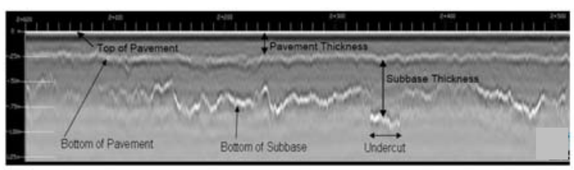


Figure 3: Example 400MHz data from the centerline of Janes Road with bottom of pavement & sub-base layers show. An undercut is visible as an area where the bottom of the subbase reflection layer drops below the surrounding layer. The jagged nature of the data is due to the data collection rate of one sample approximately every foot.

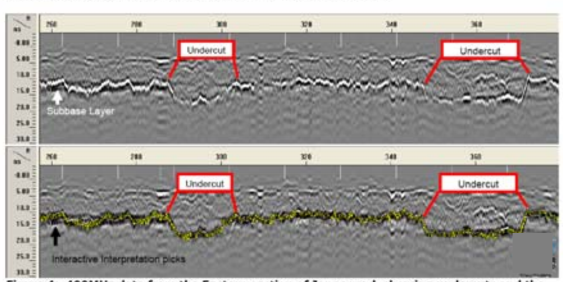
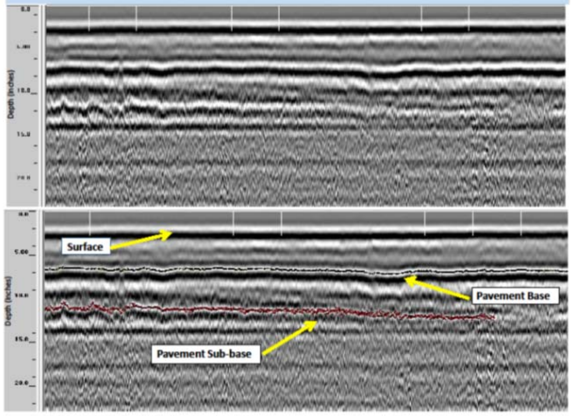


Figure 4: 400MHz data from the Eastern section of Janes road, showing undercuts and the sub-base layer. The lower portion of the figure shows the results of the semi-automated picks tracking the depth of the sub-base layer as the yellow dots.

900 MHz Data



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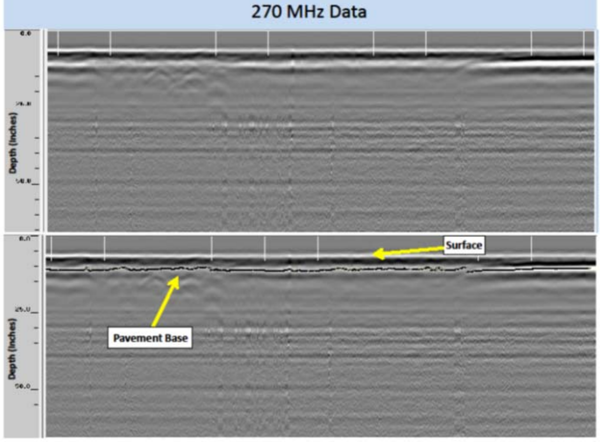
270 MHz Data



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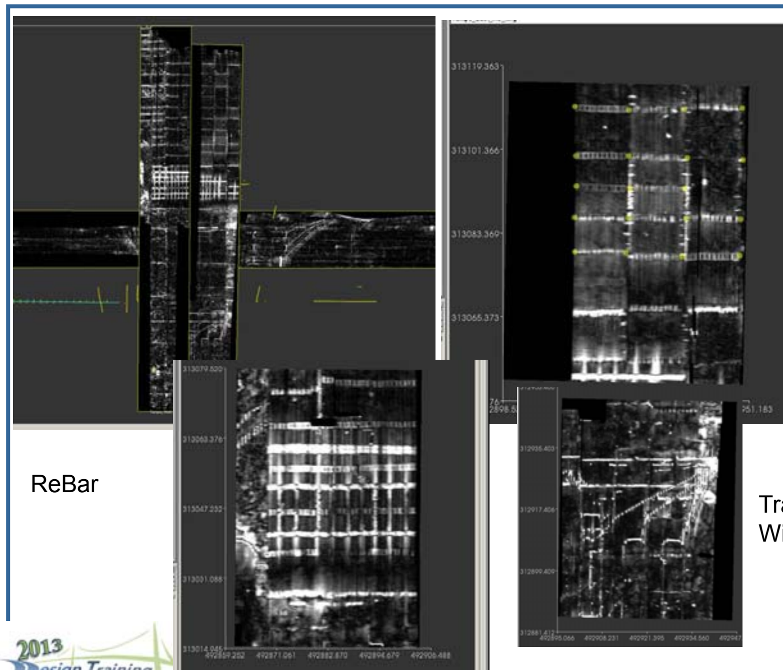
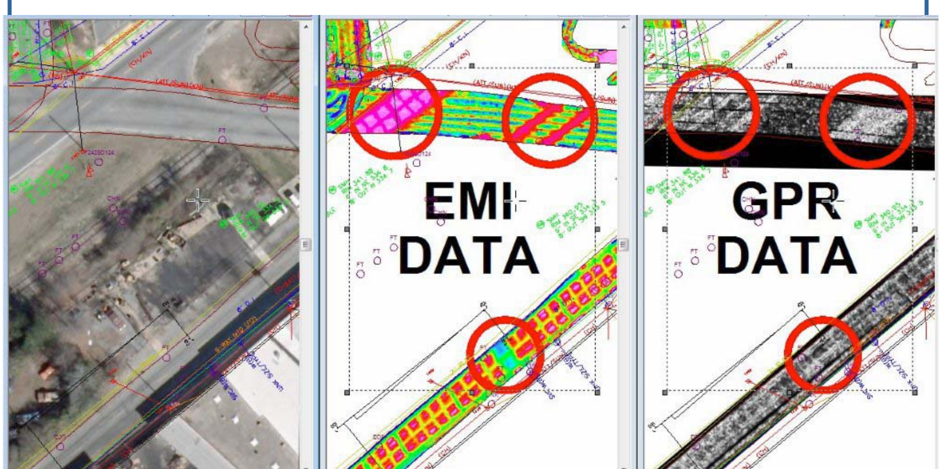
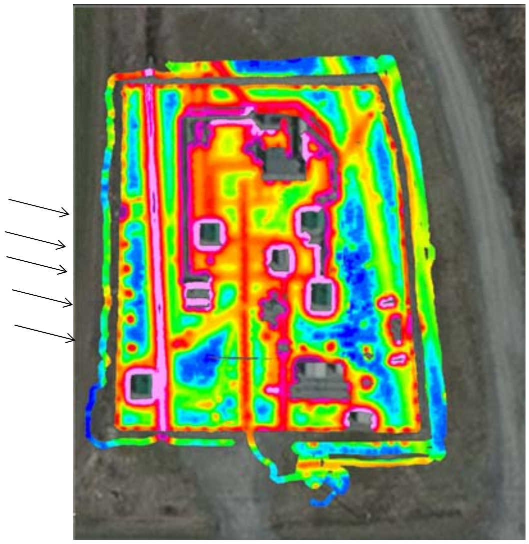


ReBar

Traffic Control Wires

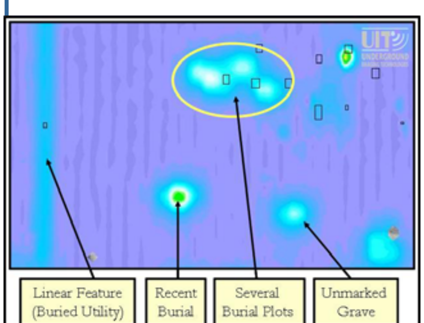


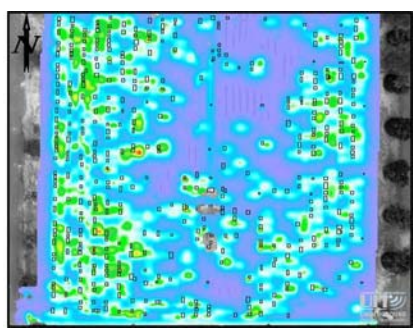
Remnant Foundation Supports at a Substation (Plus a variety of other linear targets)



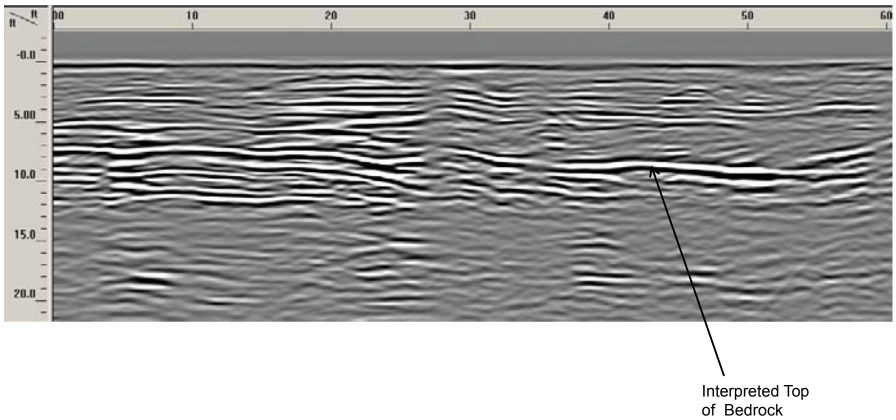
Cemetery Example GPR & EM Data

- The black rectangles represent grave stones surveyed from aerial photography.
- Green and white areas are TDEMI anomalies interpreted to be gravesites.





Bedrock



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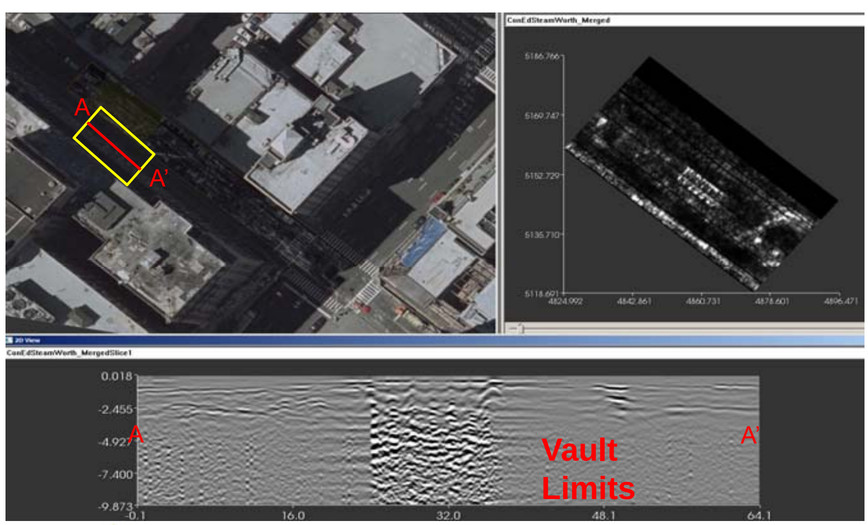
Vault Structure & Limits



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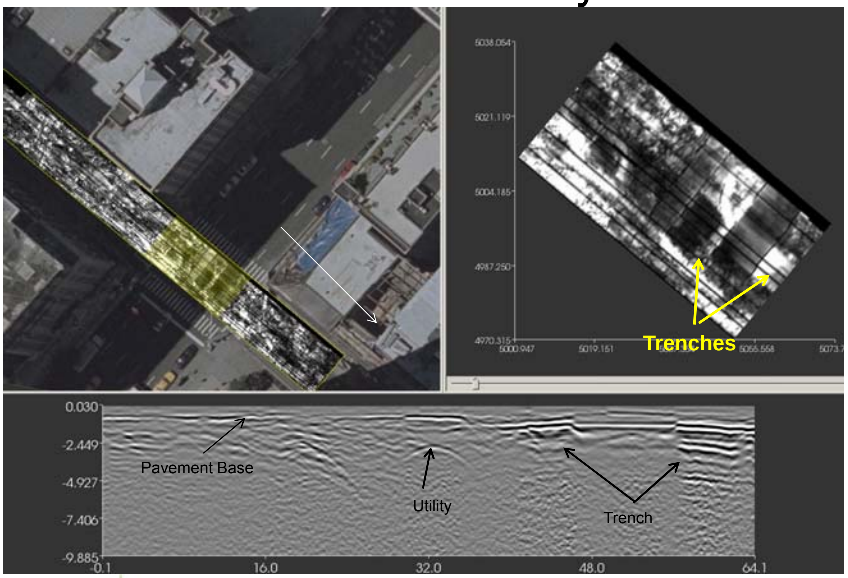
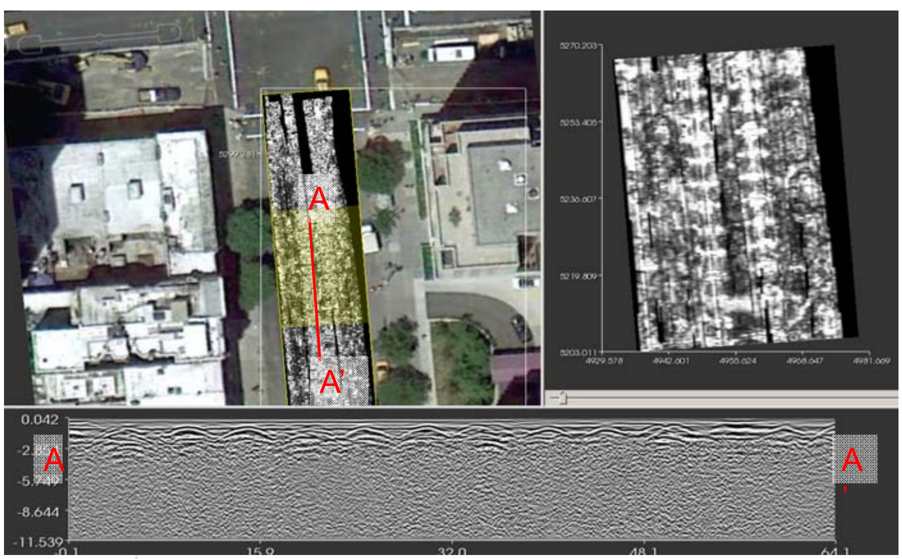
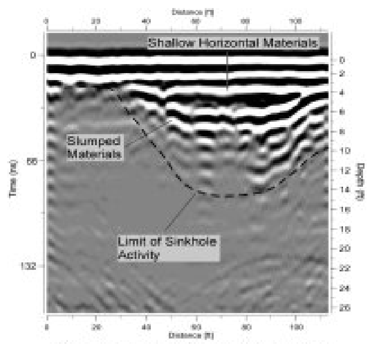
Trench and Pavement Layers in NYC



RR Tracks



Sinkhole



GPR Profile Showing Extent of Sinkhole Activity and Orientation of Subsurface Layers

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Taking Advantage of Advanced Geophysics: Project Procedures for Consideration

- In Planning Stage of Projects
  - ✓ Employ advanced geophysics to guide future investigations more intelligently within project limits

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Taking Advantage of Advanced Geophysics: Project Procedures for Consideration

- In Planning Stage of Projects
  - ✓ Employ advanced geophysics to guide future investigations more intelligently
  - ✓ Prepare QLD / QLC map in conjunction with standard topo development, or with new 3-D imaging technology
- In Design Stage of Projects
  - ✓ At 0-10% design, employ standard utility mapping tools
  - ✓ Merge data sets into 3-D

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Merge Geophysics and Other Data Sets into:

- Utility Maps and Reports (Traditional SUE)
  - ✓ Maps (2-D and 3-D)
  - ✓ Test Holes
  - ✓ Conflict Analysis
  - ✓ Utility Relocation Estimates
  - ✓ Condition Assessments
  - ✓ Special Provisions
  - ✓ Coordination
- Geotechnical/ Constructability Report
  - ✓ Pavements
  - ✓ Cultural
  - ✓ Geotechnical
  - ✓ Environmental
  - ✓ Structural

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Lots of Challenges

- Departmental Silos
  - ✓ Budgets
  - ✓ Project Timing
  - ✓ Value Sharing
- Capable Consultants
- Internal Champions
- Existing / Changing Technologies
- Inertia
- Fear of Change
- Standards Development
- Picking the Right Projects

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Utopia

- Accurate Comprehensive Underground BIM
- Phased for Maximum Value to Individual Projects
- No Underground Surprises during Construction
- Lower Construction Contingency Pricing

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FDOT is on the Way?

- 3-D Utility Mapping Program
- Great Soils for Advanced Geophysics
- Lots of CIP Needs
- Need a Great Trial / Research Project to evaluate Technology / Process Integration / Value

FDOT Statewide Consultant Support for Radar Tomography (RT), A Subsurface Utility Engineering (SUE) Mapping Technology

- To collect continuous and overlapping 3-Dimensional Ground Penetrating Radar (GPR) scans of underground from a synchronized array of multi-GPR antenna
- Post process raw data to produce 3-Dimensional Imagery
- Expectation for vertical infrastructure locations is to a maximum of 10 feet from the surface
- “Designate” and “Locate” services in support of RT and for utilities not images by RT.

FDOT Statewide Consultant Support for Radar Tomography (RT), A Subsurface Utility Engineering (SUE) Mapping Technology

Support with conventional Subsurface Utility Engineering, "Designate" and "Locate" for the following reasons:

- RT and 3D GPR do not provide accurate utility identification and depiction, but only position
- Confirm and assess horizontal and vertical information from 3D GPR

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3D Deliverables

Utility 3D deliverables are ***already available:***

- Gather depths from a multitude of options:
- Valves, Manholes and any measurable point
- Test holes
- Geophysics *(including RT 3D GPR)*
- Records
- Assess what is best and where
- Represent "Z" data referenced to DTM

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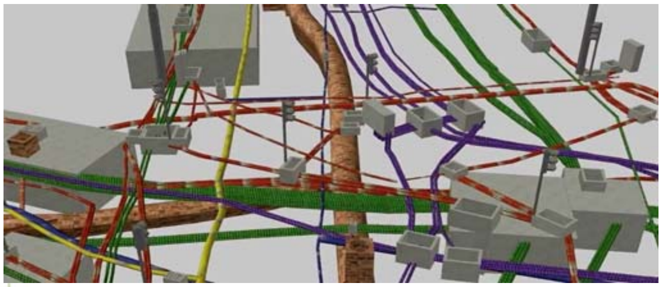
3D Deliverables

Utility 3D deliverables are ***already available:***

- Are we ready to use 3D utility drawings for design?
- Benefits
- Pro et Contra



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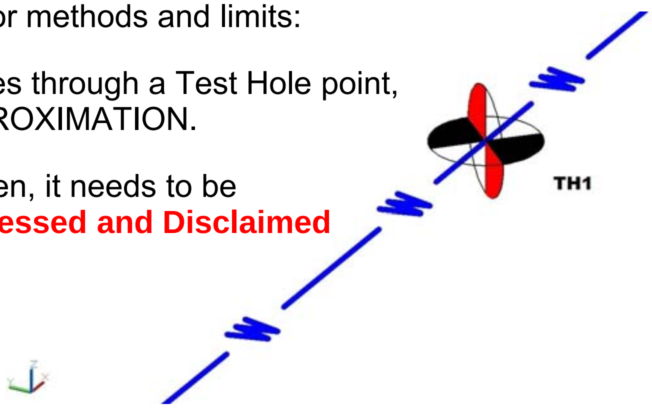
3D Deliverables: FDOT Standards

- Need to differentiate Utility Information Quality Levels
- Need to differentiate origin of 3D information
- Disclaimer for methods and limits:
  - Unless it goes through a Test Hole point, it is an APPROXIMATION.
  - If it is not seen, it needs to be **Quality Assessed and Disclaimed**



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QUESTIONS?

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Literature Resources

SHRP2 R-01, R-01-2 (SAULT), R-01A, R-01B, R-01C

SHRP2 R-15, R-15B, R-15C

Mapping the Underworld (UK)

ORFEUS (EU)