Introduction to Near Surface Environmental Geophysics

Webinar

Region 5
Superfund
Chicago, Illinois

Jim Ursic
Field Services
Section

A Practical Guide for Commonly Used Methods & Applications

November 8, 2018
Ursic.James@EPA.GOV
Presentation Goals:

- Reveal options for several geophysical methods to characterize subsurface at hazardous waste sites
- Basic background how methods work
- How to plan/request subsurface surveys
- Avoiding interpretation pitfalls
What is “Near Surface” Geophysics

- A class of geophysical instruments, generally portable, capable of collecting data quickly within tens of feet below the ground surface.

- Investigation ranges vary dependent on type of tool used & site conditions.

- Deeper surveys require bulkier, more powerful equipment, some requiring acres of space.
Types of Near Surface Targets

- Buried metal (ferrous & non-ferrous)
  - Clues to burial depths, if known: type of backhoe, bulldozer, etc. used for burial

- Contaminant plumes
  - Plume conductivities greater or less than in situ background matrix most likely detectable
  - Generally several inches or more in thickness

- Characterization of geology
  - Soils, clay, sand, bedrock, major voids

- Characterization of hydrogeology
Physical Properties Measured

- **Velocity** (acoustic & EM)
  - Seismic (acoustic)
  - Radar (EM)

- **Electrical Impedance**
  - Electromagnetics
  - Resistivity

- **Magnetic**
  - Magnetics
    - Passive method

- **Density**
  - Gravity
    - Passive

- **Radioactive decay**
  - Natural gamma
    - Passive method
Geophysical Property Functions

- Passive methods
  - Magnetics
  - Gravity

- Electric* & Electromagnetic (EM)
  - Electrical resistivity*
  - EM Induction (EMI)
    - Frequency Domain
    - Time Domain
  - EM Radiation (EMR)

- Acoustic
  - Seismic
    - Refraction
    - Reflection

Associated Tools

- Magnetometer
- Gravimeter
- Resistivity meters
- Fixed & mixed EM freq’s
- Time Domain EM tools
- Ground penetrating radar
- Seismic system tools
Common Geophysical Tools/Targets
Rapid Near Surface Data Collection

- Magnetometer
  - Detects Ferrous metals

- Electromagnetics
  - Measures Ground Conductivity
  - Metal Detection (Ferrous & Non Ferrous)

- Ground Penetrating Radar
  - EM microwave pulses to image subsurface
  - Measures changes in material properties

- Tanks, Drums, Wells, Foundations, Landfills
  - Stratigraphy changes
  - Soil moisture changes
  - Contaminate plumes
  - Distinguish metal types, shapes

- Stratigraphy changes, Contaminate plumes, Burial pits, tanks, drums
  - Approximate depths to anomalies
Common Geophysical Tools
Deeper - More Expansive – Time Intensive Data Collection

- **Seismic**
  - Stratigraphy changes due to reflecting/refracting sound waves

- **Electrical Resistivity**
  - Stratigraphy changes due to ground conductivity changes

- **Gravity**
  - Measures gravitational acceleration

- **Stratigraphy**
  - Stratigraphy, contaminant plumes

- **Void detection**
## Detection Limits* for Geophysical Tools

<table>
<thead>
<tr>
<th>METHOD</th>
<th>DETECTION LIMIT*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetometer</td>
<td>Based on ferrous mass 40’</td>
</tr>
<tr>
<td>Gravimeter</td>
<td>Based on size of void 40’</td>
</tr>
<tr>
<td>Electrical Resistivity</td>
<td>Line length, power source 100’+</td>
</tr>
<tr>
<td>Electromagnetic (EM)</td>
<td></td>
</tr>
<tr>
<td>Fixed Freq. Domain</td>
<td>EM 31 15’</td>
</tr>
<tr>
<td>Variable Freq. Domain</td>
<td>GEM 2 surface to 30’</td>
</tr>
<tr>
<td>Time Domain</td>
<td>EM 61 15’</td>
</tr>
<tr>
<td>GPR</td>
<td></td>
</tr>
<tr>
<td>Seismic</td>
<td></td>
</tr>
<tr>
<td>Refraction</td>
<td>Line length, power source 50’+</td>
</tr>
<tr>
<td>Reflection</td>
<td>Line length, power source 50’+</td>
</tr>
</tbody>
</table>

* Variable limits dependent on site conditions & equipment capabilities
Common Environmental Geophysical Survey Tools
Gradient Magnetometer

- Detects Ferrous Metal (minor response from some fired clays)
- Data logger stores data
- Real time on-screen output
- GPS (optional)
- 2 sensors define gradient mag
- Hand carried / vehicle mount
- 0-40’ BGS dependent on mass
- Passive sensors no Tx /Rx
- Report out: contour, quasi 3D
- Fanny-pack batteries
- Brass counter-weight
- Above ground area / influence

Above ground area / influence

Steel Building

Ground Surface

Subsurface

Steel Cyclone Fence

Subsurface

Ground Surface
Metal Detector ≠ Magnetic Method

METAL DETECTORS use internal power to create an electromagnetic field to locate metal.

MAGNETOMETERS are passive instruments and only sense ambient magnetic fields.

Typical GPR: Cart Platform

Images of Subsurface

Estimates Depth to Targets

Confirm Buried Tanks - Shapes

- Must have contact w/ ground
- Hand pushed / vehicle towed
- GPS (optional)
- Data logger stores data
- Real time on-screen output
- Uses EM energy, batt. power
- Antenna contains Rx & Tx
- Antenna size shows frequency
- Freq’s: high/shallow, low/deep
- Cart adjusts to antenna size
- Above ground area / influence
- 0-30’ BGS depends on freq’s
- Report out: single x-sec or 3D
EM31
Fixed Freq. Domain
Conductivity & Metal Detection
(Ferrous & Non Ferrous Metal)

- Hand carried / vehicle towed
- GPS (optional)
- Uses EM energy, batt. power
- Rx & Tx antenna at each end
- Two readings taken @ once
- Gnd. cond. = Quad. phase
- Metal detection = In-phase
- Fixed frequency = fixed depth
- Data logger stores data
- Real time on-screen output
- Coil angle sets depth limit
- Vertical angle ≈ 12’ depth
- Horizontal angle ≈ 8’ depth
- Report out: contour maps
GEM2 – Multi Frequency Domain
Conductivity & Metal Detection
(Ferrous & Non Ferrous Metal)

- Hand carried / vehicle towed
- Data logger stores data
- Multiple simultaneous readings
- Multi frequency / multi depths
- GPS (optional)
- Gnd. cond. = Quad. phase
- Metal detection = In-phase
- No horizontal angle like EM31
- On-screen data view allowed - not practical (older units only)
- Antenna: Tx & Rx at each end
- Antenna: bucking amid Tx-Rx
- Uses EM energy, batt. power
- Typically 5-6 frequencies used
- Report out: contour maps, 3D
- Surface area interference 15’
EM 61 High Sensitivity Metal Detector
Detects Any Metal

- Hand push/pull - vehicle tow
- GPS (optional)
- Backpack: batt. & controller
- Data logger stores data
- Real time on-screen output
- Uses EM energy
- 3 antennas (coils): 2 Tx & Rx
- Coils allow shallow/deep data
- Detection depths 0-15’ BGS
- Report out: contour map
- Above ground area / influence

Above Ground Detection Limit to 15’ AGL
Direct Current Resistivity

Detects Changes in Subsurface Conductivities by measuring voltages from currents applied

- Resistivity array batt. powered
- Programmed internal switching
- Often duplicated for more detail
- 100’ bgs pending cable length, DC power, opposing transmission materials
- Elevation tool for electrodes
- Tape measures
- Electrodes
- Sting* controller / processor
- Cabling for electrodes
- Not optimal congested areas
- Report out: pseudo-sections

*Sting is a trademark of AGI
Seismic Refraction
Commonly Used Environmental Surveys
Records 1st Arrivals of P-Wave

- P-wave: pressure or primary wave, rest of wave ignored
- Records first refracted energy
- Finds depth to GW, bedrock, weathering zone
- Close-up of geophone
- Sound source: plate & hammer
- Geophones and cabling
- Sensitive to external noise
- Geophones in ground
- Seismograph linked to laptop
- Not optimal congested areas
- Report out: seismic record
Micro Gravimeter

Measures Material Density
Maps Voids and Intrusions

- Must have contact w/ ground
- Time intensive data collection
- Susceptible to vibration / wind
- Unit stores data, batt pwr’ed
- Real time on-screen output
- Passive sensor - no Rx & Tx
- Report out: contour map
- Corrects tides by unit location
- DoI* depends on mass
- Non unique measurements

DoI* = Depth of Investigation
Borehole Geophysical Methods for Existing 2” Monitoring Wells

- When are existing 2” wells a focus for borehole geophysics?
  - Legacy wells prior to federal intervention
  - Five year reviews

- Common available options
  - Optical camera (sidewall/downhole views)
  - Natural gamma
  - Ground conductivity (non-metal casing)
Modeling for Interpretation

- Two kinds of simple models
  - Forward
  - Inverse

- Models depend on input conditions and data

- Models can be very helpful in visualizing the site

- Models are not reality
Geophysical Methods

Advantages

- Non-intrusive
- Rapid data collection
- Detects a variety of targets
- Screens large areas
- Fills in data gaps
Geophysical Methods

Limitations

- Methods require a specialist
- Physical contrasts must exist
- Resolution varies by method & depth of target
- May be expensive
- Interpretations are non-unique
Correct Interpretation
Problematic Interpretation
Real Life Situation

Reality:
Buried Seat Belt Buckles
GEOPHYSICAL SURVEY DESIGN

Jim Ursic - U.S. Environmental Protection Agency - Chicago, Illinois

Planning – Reviewing Geophysical Surveys

30 Acre IEL Superfund Site Uniontown, Ohio
Survey Design Rationale

- Establishes a plan
- Find potential pitfalls
- Maximize benefit
- Minimize surprises
  - Property line issues
  - Archeological sites
  - Utility lines
- Customize requests
Pre-survey Planning: Garbage IN – Garbage OUT

- Inadequate background information & planning dooms a survey before it starts:
  - Requires more time in the field
  - Increases costs
  - Missed targets
  - Questionable data
Define Problem

- List issues of concern
- Can geophysics help?
- Data confirmable?
- How will results benefit your plan?
Background Paperwork Review

- Site history
- Previous studies
- Geology
- Geohydrology
- Geographic issues
- Health, safety & QAPP issues
Background Maps/Image Review

- Sanborn or other Public Maps
  - Historical site records & buildings
- Topographic Maps
  - Terrain conditions
- Geologic Maps
  - Indirect conditions
- Aerial Images - internet
  - Indirect conditions
Sanborn Map Example: Anacortes, Washington State

Nov. 1907
Topographic & Geologic Maps
Example of Aerial Photo Details
Following up from previous slide’s topographic map
Background Photo Review

Circa 1990 Aerial Photo

Circa 1960 Aerial Photo

Recent Site Photo

Historical Site Photo

1990 Aerial Photo Area

Circa 1990 Aerial Photo

Circa 1960 Aerial Photo

Same Building
Photo Interpretation

Sept 25, 1936: B & W

May 7, 1981: Color Infrared

Lammers Barrel
Beaver Creek, Ohio

Remote Sensing & Imagery Analysis Services (RSIAS)
Office of Environmental Information (OEI), RTP North Carolina

April 5, 1988: Color

Formerly Environmental Photographic Interpretation Center

http://intranet.epa.gov/gis/remotesensing.html
Other Issues To Consider

- Property boundaries
- Consent for access
- Traffic & pedestrians
- Vegetation status
- "Noise" issues
- Utility location
- Archeological sites
National Historic Preservation Act

Why should we care?

- It’s the law
- It’s EPA’s policy
- It’s a good idea

Public Law 89-665; 16 U.S.C 470 & Subsequent Amendments
Code of Federal Regulations (CFR)  
(for Hazardous Waste Sites)  

“Handling Drums & Containers”

- 1910.120 (j) (1) (x) “A ground-penetrating system or other type of detection system or device shall be used to estimate the location and depth of buried drums or containers”
Analyze Background Information to Determine..

- Area to be surveyed
- Size - number of suspect targets
- Potential problems
- Site reconnaissance needed?
Match Most Favorable Geophysical Techniques to Problem

- What method(s) contrast most from background?
- Can instrument operate over site terrain?
- Know depth confines
- “Noise” issues
Dealing With Noise Issues

- Accounting for unwanted Interferences
  - Power lines, fences, cars
- Apply a “walk-away” test
  - Start at source
  - Walk-away until readings normalize – note distance
Target Contrasts & Background

- What physical properties are associated with:
  - Target elements
  - Natural background elements surrounding target
  - Is there enough physical contrast between both?

- What is the extent of the problem:
  - Lateral limits & vertical depths
Matching Methods to Target Elements

- Determine what physical property is associated with target element
- Is metal part of target element?
  - Metal ferrous or non-ferrous
- Is geologic structure critical to target element?
  - Location of bedrock, clays, permeable formations
- Contaminate plume present?
  - Low or high plume conductivity
- Groundwater location
- Landfill boundaries
- Voids
Further Defining Methods

Once physical method is selected:
- What are the limitations of the selected method?
- Is method easily operated in the site environment?
- Are there nearby objects that cause interference?
- How to document results for replicating survey, if necessary?
Optimize Data Collection Routine

- Establish how data will be collected
  - Traverse pattern
  - Grid spacing
  - Axis labeling
  - Data Location ID (ft/M)
Key Issues For Collecting Data

- Systematic collection (grid or lines)
- Spacing dependent on target size
- Accurate grid or line establishment
- Method to ensure location accuracy
- Maintain good field notes
- Take plenty of photographs!
Data Collection Grids

Continuous or Rapid Succession Measurements

Station Measurements

“Data Grid” Recent Instrument Technology

Data Grid for 1970’s 80’s Instrument Technology

(modified from Benson et al., 1988)
Consider Analogy Between Data Density & Photographic Pixels
Detection Probability
(Using Individual Station Measurements)

At = Area ft² of Target (Circle)

As = Site Area
ft² is 1 Acre

○ At = Area of Target
43

As = Area of Site
43,560

<table>
<thead>
<tr>
<th>Probability of Detection</th>
<th>As/At = 10</th>
<th>As/At = 100</th>
<th>As/At = 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>16</td>
<td>160</td>
<td>1600</td>
</tr>
<tr>
<td>98</td>
<td>13</td>
<td>130</td>
<td>1300</td>
</tr>
<tr>
<td>90</td>
<td>10</td>
<td>100</td>
<td>1000</td>
</tr>
<tr>
<td>75</td>
<td>8</td>
<td>80</td>
<td>800</td>
</tr>
<tr>
<td>50</td>
<td>5</td>
<td>50</td>
<td>500</td>
</tr>
</tbody>
</table>

(modified from Benson et al., 1988)
Determining Grid Spacing

\[
\frac{\text{Area of Site in ft}^2}{\text{Area of Target in ft}^2} = a \text{ in ft}^2
\]

\[a \times \text{Probability Factor} = \text{Sampling Points (Approx.)}\]

\[
\frac{\text{Area of Site in ft}^2}{\text{Sampling Points}} = b
\]

\[\sqrt{b} = \text{Grid Spacing in Feet}\]

<table>
<thead>
<tr>
<th>Probability Factors</th>
<th>100% = 1.625</th>
<th>75% = 0.8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>98% = 1.3</td>
<td>50% = 0.5</td>
</tr>
<tr>
<td></td>
<td>90% = 1.0</td>
<td></td>
</tr>
</tbody>
</table>
## Typical Acquisition Traverses

<table>
<thead>
<tr>
<th>Modes</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternating mode</td>
<td>Areas broken into rectangular shapes</td>
</tr>
<tr>
<td>Most often used</td>
<td>Irregular boundaries</td>
</tr>
<tr>
<td>Random mode</td>
<td>Use multiple base lines</td>
</tr>
<tr>
<td>Used for small or</td>
<td>Positioning methods</td>
</tr>
<tr>
<td>large areas</td>
<td>Station to Station</td>
</tr>
<tr>
<td>Parallel mode</td>
<td>Timed – collection</td>
</tr>
<tr>
<td>Irregular shaped</td>
<td>Wheel encoder</td>
</tr>
<tr>
<td>sites</td>
<td>GPS</td>
</tr>
<tr>
<td>Work from one base</td>
<td></td>
</tr>
<tr>
<td>line</td>
<td></td>
</tr>
</tbody>
</table>
Random Survey Pattern

Small Back Yard Example
Alternating Traverses
Parallel Traverse – No GPS

Solid Line: Recording
Dash: Not Recording

Obstruction

Start
Base Line
End
Alternating Traverse Grid Setup
No GPS Guidance

- Layout grid markers at desired spacing
  - Flagging (plastic)
  - Spray chalk or paint
  - Ropes
  - Wooden stakes
- Large sites require multiple marker lines
Data Recorder Types/Methods

- Station distance position
  - X, Y, set by distance
- Time
  - X, Y, distance set by a time unit
- Encoder wheel
  - X, Y, distance - a unit of wheel revolution
- GPS
  - X, Y set by longitude and latitude
Data Recorders: Correction Issues for Positioning

- Timed devices: - spacing issues
  - Corrections for pace (use pause key)
- GPS devices
  - Use proper datum, projections, units
  - Correct for errors
- Wheel encoder devices
  - Resolve distance errors (calibrate)
Time - Continuous Data Acquisition
Issues for Y Axis Example

- Operator inputs start & end points per line
- Unit auto “fits” data to input distance
  - Assumes same pace
- Obstacles usually slows pace
- Use data pause features as needed

<table>
<thead>
<tr>
<th>Line 1</th>
<th>Line 2</th>
<th>Line 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Even pace: Real &amp; posted</td>
<td>Off pace: real</td>
<td>Posted</td>
</tr>
<tr>
<td>12 pts</td>
<td>9 pts</td>
<td>9 pts</td>
</tr>
<tr>
<td>12</td>
<td>9</td>
<td>9</td>
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<td>11</td>
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<td>10</td>
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<td>5</td>
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<td>2</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Reality Vs Processed
Global Positioning Systems

- Accuracies vary by method & equip. used
- Here are 2 analogous examples:
  - Some on a scale to be within 120’ of an airport threshold, as an example
  - Others on a scale to be within centimeters from the center of runway
- Use proper datums, projections & units
Several GPS Methods

- Stand alone GPS receiver
- Differential correction (DGPS)
  - Real time using beacons, base stations
- Post processing GPS values
- RTK Survey Grade
  - Tx base station, Rx at rover, satellites
- 3 Grades of GPS accuracy & cell phone
  - Recreational, mapping, survey, Cell Phone,
  - 25’ 3’ cm 80’
How a Differential GPS Service Works

Fixed Bases

Rover

Drawing modified from Omnistar corp. graphic
Integrating GPS to Other Systems

- Most geophysical instruments will connect and integrate GPS systems
  - Will record & tie all data to lat-long

- What if you want to traverse specific routes? Two possible options:
  - Trimble AgGPS 132 parallel swathing
  - Field Analysis & Sampling Tool (FAST)
FAST
Field Analysis & Sampling Tool

- System integrates a field laptop to GPS and instrumentation
- Free downloadable program for EPA staff
- OS limited to Windows XP
- Requires non-EPA imaged field laptop
- Operator traces their traverses over pre-loaded grid using laptop screen
- System can be programmed for XRF, various radiation tools and other tools
Trimble Parallel Swathing Lightbar Guidance

- Center: on line
- Left: move left
- Right: move right
- Outer edges yellow: nearing line end
- Outer edges red: at line end
- Advances to next spacing
Geophysical Tool Options
Which Method is Applied First?

- Dependent on site goals
- Generally........First
  - Methods having larger sensing areas
  - Rapid data collection times
- Generally........Second
  - Methods with more definitive sensing capabilities
Check List For Considering Geophysical Survey

- Define problem
- Research history
- Find area of concern
- Note site conditions
- Describe target(s)
- Estimate depth

- Will geophysics help?
- List methods that will show most contrast
- How will you use this information?
A Note About Contracting Geophysical Jobs

- Use source that is knowledgeable about all geophysical methods
- Write contract to assume several “what if” scenarios to deal with special issues
- Obtain copies of raw data & notebooks
- Be aware that interpretation & reports may be optional
Geophysical Data Examples
Mag Data
Example of Rubble Landfill

Waukesha, WI

Aerial View
Example of Rubble Landfill Mag Data

Waukesha, WI

Black=traverse lines; Red=neg. contours; Blue=pos. contours
More Rubble Landfill Mag Data

Waukesha, WI

Aerial View

Black=traverse lines; Red=neg. contours; Blue=pos. contours
Vacant lot in Toronto, Ontario, Canada

EM 31 Data - Example
Apparent Conductivity Data – Quad Phase
Shaded Relief Map – In Phase
Lot During Excavation
Direct Push Soil Conductivity

Source: USGS Keyesport, Illinois 7.5 Minute Topographic Map
Contour Interval = 5 feet

GeoProbe® Electrical Conductivity
Direct Push

Wenner Array Sensor

Direct Push Unit Powered by Skid Steer
Direct Push Conductivity Data

Depth in Feet

mS/m

#14

#13

#12

#11

#10
EM-61 Data Closed USCG Station

N. of Hancock, MI
GPR Data - Buried Storage Tanks

1 Cross-Section Slice

Post Processed Plan View Time Slices
3-D GPR

Marquette, MI
30 m by 6 m area
6 - 8 m depth

Ground Surface
Sand and Gravel
Water Table
Sand and Gravel
Gravel lenses
Bedrock

Source: Grumman Exploration
GPR Leaking Tank - Upper Michigan

Carpet Shop
(former metal working shop)

204 W. Lincoln

Traverse Index Map
Plan View

Lines Start at Center Line of Road

Tank
Backyard in Michigan – Stressed Vegetation Area

Default “Bone” GPR Image

“Prism” Option GPR Image

weak reflections
Seismic Refraction Example

Fast Layer

1st Layer

2nd Layer

3rd Layer

The first arrival time for P wave for 1st geophone

Time after offset (s)

Geophone offset (m)
2 dimensional measurement configuration for a resistivity profile

Source: AGIUSA, agiusa.com
One Example for Confirmatory Methods

- **Magnetics**
  - Rapid Data Collection
  - Establish Amount of Mass
  - General Lateral Dimensions

- **Electromagnetics**
  - Detailed Lateral Dimensions
  - Generalized Depth Information (dependent on Tx & Rx range)

- **GPR**
  - Depth to Target
  - Top of Target Shape (dependent on soil conditions)
Requesting A Survey
(Questions Provider Should Ask You)

- How big is the site?
- Composition of targets?
- Orientation & size of targets, if known
- Depth or burial method of targets, if known
- Describe terrain & site conditions
- Explain special circumstances
Provider Submits Plan

(Questions You Should Ask)

- Why are selected method(s) appropriate?
- What tool & configurations will be used?
- Method to ensure data location accuracy?
- What deliverables will be provided?
- Will data be presented for the layperson?
- How can I relocate area at a later date?
Limitations

- Subject to cultural noise
- Detection of small objects reduced with depth
- Depth estimates most difficult for non-homogenous masses
- Masses cannot be uniquely characterized
Brief Comments Concerning 2” Monitoring Wells
Monitoring Wells - Need for Doing the Job Efficiently

EPA Studied Wells At 22 Sites & Concluded:

Borehole Sensing Methods for Ground-Water Investigations at Hazardous Waste Sites

EPA/600/2-86/111 December 1986

- Screen Missed Plume: 50%
- Incorrectly Placed Wells: 30%
- Flow Direction Unknown: 10%
Summary Common Borehole Geophysical Topics

- Requires access by a pre-existing hole
- Tools capable of detecting
  - Stratigraphy changes
  - Porosity
  - Fluid flow
  - Casing/annulus integrity/hole diameter
- Limited by well construction method & presence - absence of fluids
  - Open hole, plastic or metal casing
  - Diameter of well may limit some tool use
  - Presence of fluids will limit what tools can be used
Natural Gamma

- Lithology
- Shale intervals
- Correlation
Video

- Wellbore/casing condition
- Investigate foreign objects in borehole
- Record stratigraphy

Operating Parameters

- Pore Space
  - Saturated and Unsaturated

- Detection Range
  - Casing Wall or Borehole Wall

- Environment
  - Metallic Casing
  - Plastic Casing
  - Uncased

- Data Value
  - Video Combined With Depth Value

- Detection Principle
  - Video Recorder

- Video recording borehole conditions

- Looking downhole vertically
- Looking horizontally at well screen

- Open hole well bore

- Holocene Dump
  - MW -2

- Pore Space
  - Saturated and Unsaturated

- Detection Range
  - Casing Wall or Borehole Wall

- Environment
  - Metallic Casing
  - Plastic Casing
  - Uncased

- Data Value
  - Video Combined With Depth Value

- Detection Principle
  - Video Recorder
Electro-Magnetic Induction

- Locate certain contaminant plumes
- Stratigraphy
- Ferrous/non-ferrous cultural objects
- Quality of borehole fluid

EM Induction Log
measurment conductivity of an in-situ volume

Pore Space
Saturated and Unsaturated

Detection Range
30 Inches

Environment
Plastic Casing Uncased

Data Value
Millimhos/Meter
Parts/Thousand

Detection Principle
Electromagnetics (Active)
Electromagnetic Induction Tool
Plan View

1,4-Dioxane Plume Tracking
Well Examples from the Field

Broken Inner Casing  Stable apron  Failed apron
Well Examples from the Field

Still locked
outer casing broken hinge

Nested wells
one missing cap
others not secured
Well Examples from the Field

Missing lock
bent from nearby traffic

Outer casing subsided
no cover, cap, faded ID
Well Examples from the Field

- Lock missing, faded ID
- Inner casing heaved
Well Examples from the Field

Inner casing heaved
can’t open

Outer/Inner casing sawed off,
no well ID, original reference point removed
Well Examples from the Field

Well in grade school playground
red circle shows items removed
from inner casing, no lock, well cap

Missing locks, fading IDs
Well Examples from the Field

6” well, no external ID or stick-up marker

No lock, ID fading
Well Examples from the Field

Six inch well, bent

Missing inner well cap
Well Examples from the Field

Broken lock

Broken lock
Well Examples from the Field

Wide photo shot
snow plow damage

Close up of snow plow damage
Well Examples from the Field

Lock missing, attempt made to secure cap with wire

Above ground

Below ground

Outer casing found lose enough to be lifted out of ground
Well Examples from the Field

No lock or inner cap.
Damage before or after guard posts?

No lock or inner well cap, wasp nest, subsiding of grouting materials
Well Examples from the Field

Annulus plug weathered & cracked

Security wire mesh fence pilfered
Common Problems from the Field

Locate well: GPS, metal detector, chisel, heat, hammer, socket & wrench

Where is that well?
Questions?