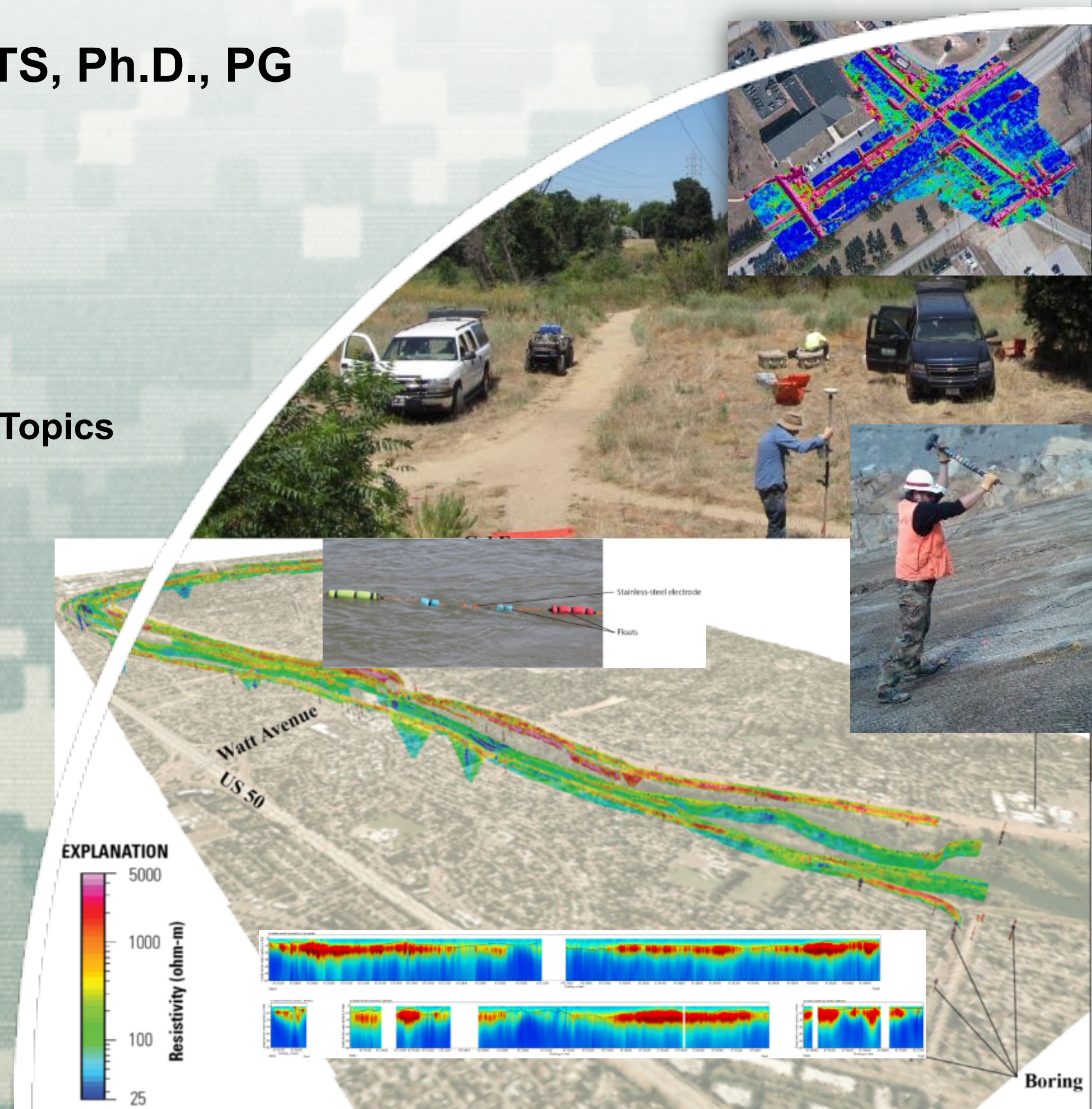
FORGOTTEN ENVIRONMENTAL GEOPHYSICAL TECHNIQUES

Lewis E. Hunter, Sr Geologist, RTS, Ph.D., PG
Geology Section, SPK

M2S2 Webinar Series – A Potpourri of RI/FS Topics

04 August 2016



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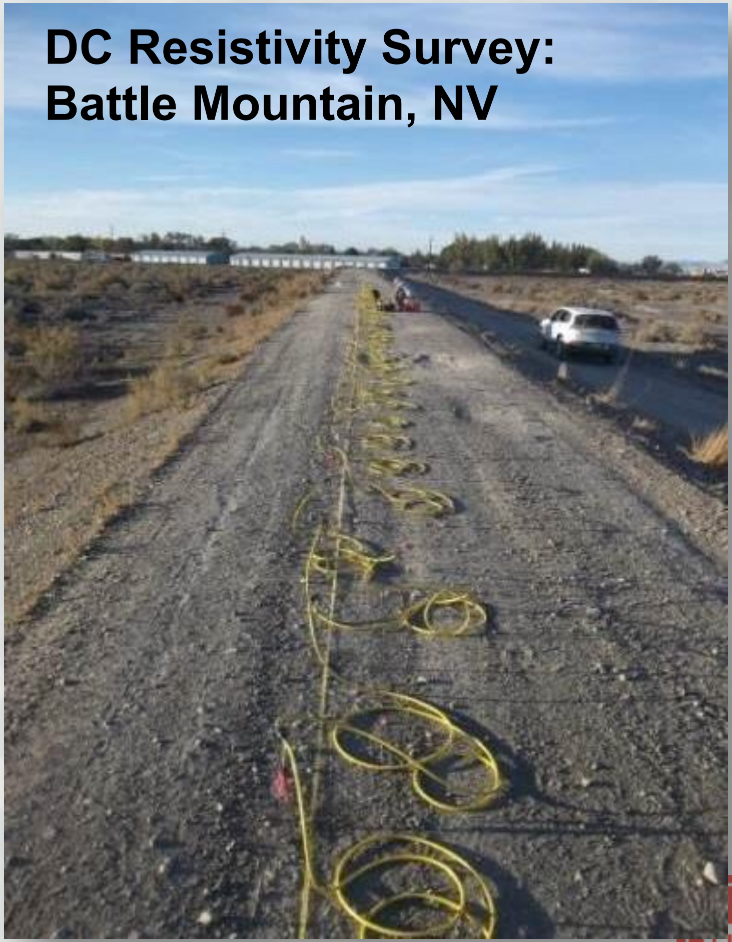
AGENDA

- **WHAT IS GEOPHYSICS**
- **TAKE-HOME**
- **QUESTIONS**
- **AVAILABLE METHODS**
  - Electromagnetics (TDEM & FDEM)
  - DC Resistivity
  - Magnetics
  - Ground-Penetrating Radar
  - Seismic
  - Others
- **PITFALLS AND ADVANTAGES**
- **GENERAL APPLICATIONS**
- **CASE STUDIES**



DEFINITION

What is Geophysics? – two answers from the Engineering and Environmental Geophysical Society

Geophysics (1): The subsurface site characterization of the geology, geological structure, groundwater, contamination, and human artifacts beneath the Earth's surface, based on the lateral and vertical mapping of physical property variations that are remotely sensed using non-invasive technologies. Many of these technologies are traditionally used for exploration of economic materials such as groundwater, metals, and hydrocarbons.

Geophysics (2): The non-invasive investigation of subsurface conditions in the Earth through measuring, analyzing and interpreting physical fields at the surface. Some studies are used to determine what is directly below the surface (the upper meter or so); other investigations extend to depths of 10's of meters or more

Non-invasive, remote sensing of subsurface conditions using variations in physical properties to make deductions on subsurface conditions:

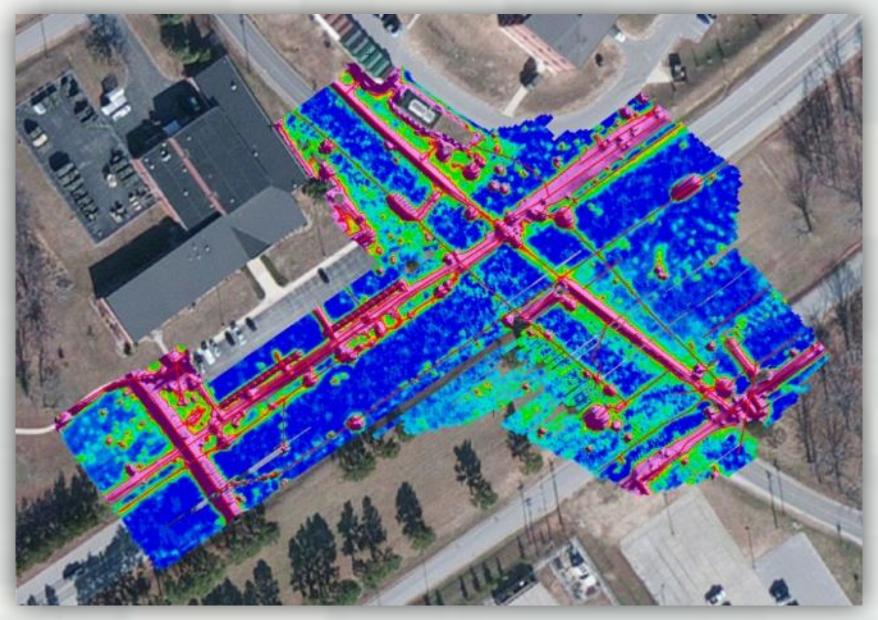
- **MMRP, environmental, archeological, engineering applications => same approach:** identify target, target properties & size, contrasts relative to background & ambient noise - - select method, tools & parameters

TAKE-HOME

Near-surface geophysics

- Few cm to 100's m
- Range of methods and applications
- Target properties dictate method/ approach
  - Size
  - Material properties
  - Contrast relative to background
- Intrinsic parts of successful survey

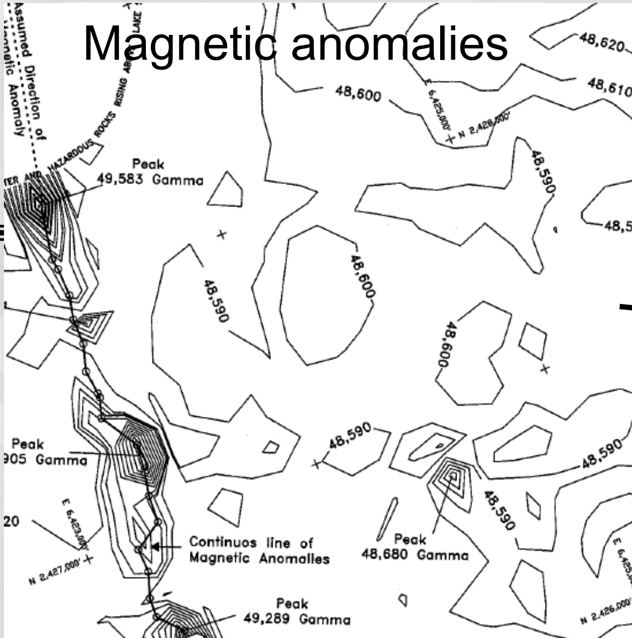
QC/QA

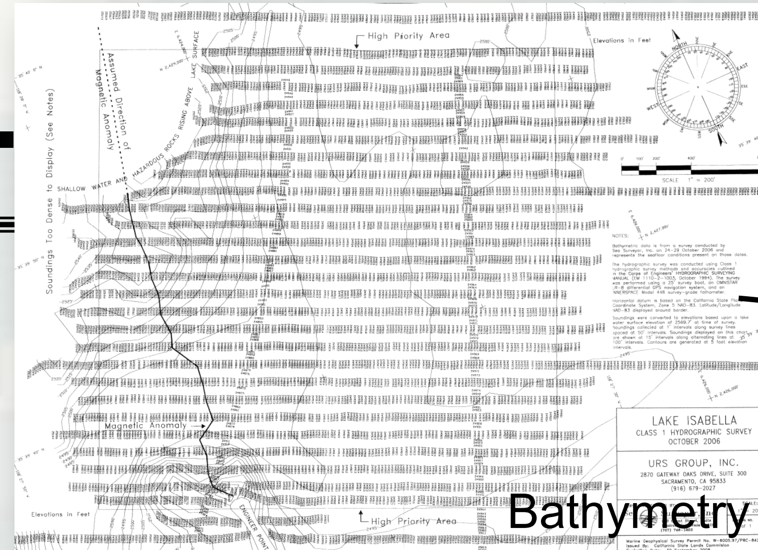


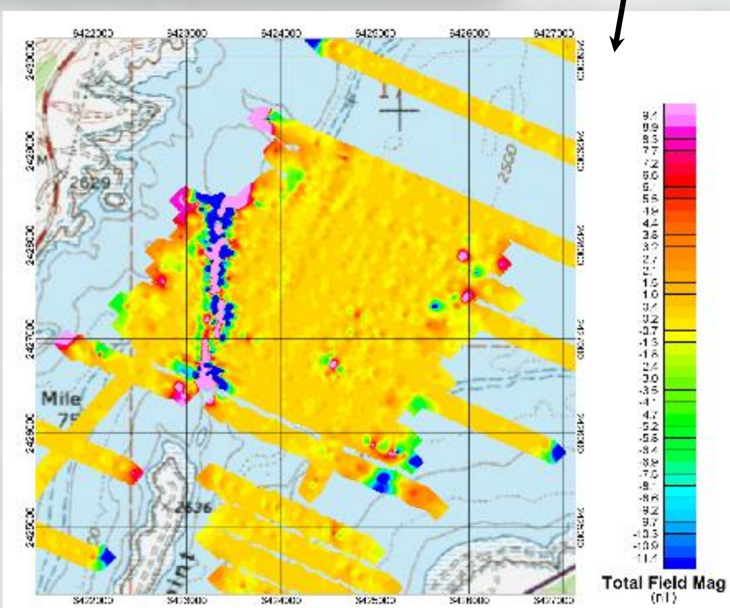
From M. Glover (NWO)

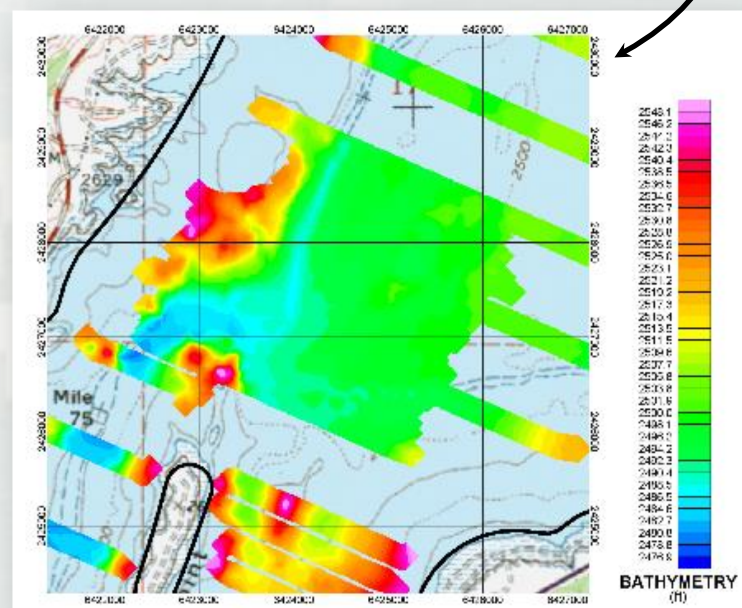
Note: outside of MMRP, no set standards for geophysics quality (Scary)

TAKE-





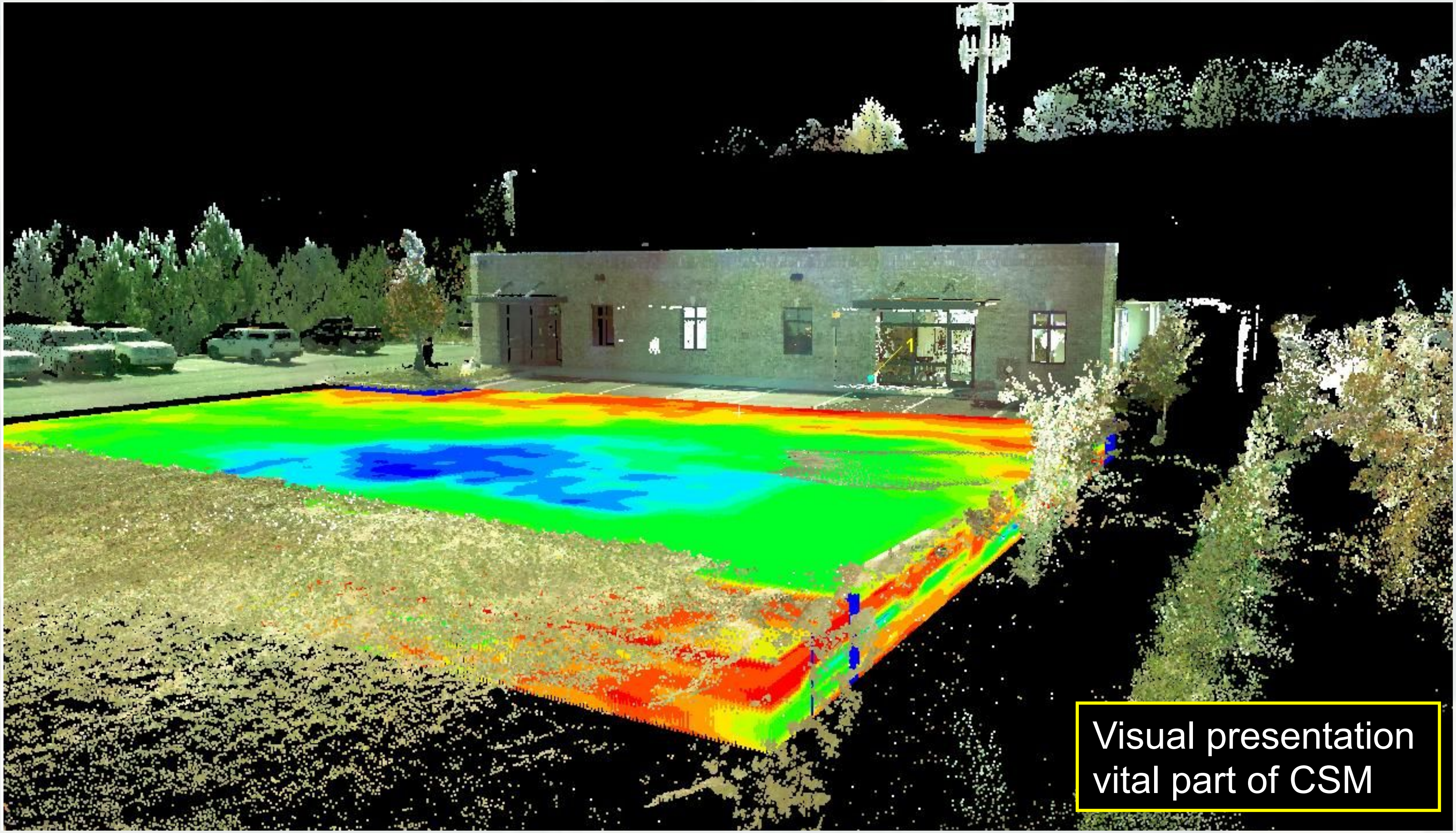




Which is more informative to you?

Utility survey:
3-D presentation of
gridded GPR data
with terrestrial LiDAR

PRESENTATION



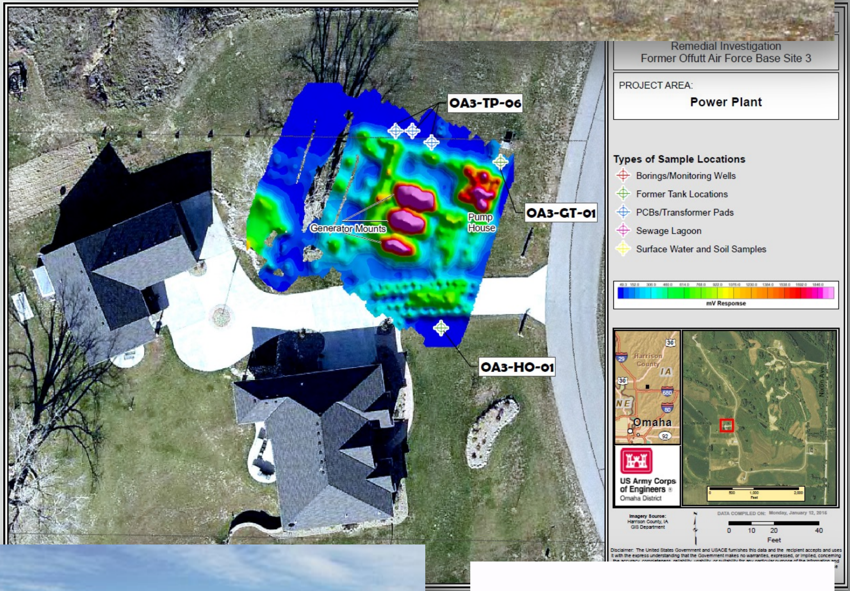
Images courtesy of D. Goodman

Merging/co-presentation of digital data

QUESTIONS

Basic questions:

- What is/are the target(s) of interest? (e.g., material composition, size)
- What are the geologic/ environmental conditions? (e.g., soil properties, clay content, saturation, etc.)
- What are the surrounding conditions? (e.g., buildings, power lines, transformers, metal fences, roads, metal plates in ground, etc.)
- What are the project constraints? (e.g., time schedule, funding limitations, reporting needs, and how the data will be used)



METHODS

METHOD	PROPERTY INVESTIGATED	TARGET
• Seismic refraction: P-wave	• Density & velocity contrasts	• Lithology variations
• Seismic refraction: S-wave	• Density & velocity contrasts	• Soft zones & bedrock
• Seismic reflection: P-wave	• Density contrasts	• Layer boundaries
• Seismic reflection: S-wave	• Density contrasts	• Layer boundaries
• Resistivity profiling (DC)	• Electrical resistivity (active)	• Fluid and/or lithologic variations
• Mis-a-la-masse electrical survey (Resistivity)	• Electrical resistivity (active)	• Extent of local conductor (metal, seepage, and/or clay content)
• Electromagnetic profiling (EM)	• Electrical resistivity (active)	• Property changes in shallow fluids or lithology; metal content
• Self-potential mapping (SP)	• Electrical resistivity (passive)	• Flowing water (streaming potential)
• Ground-penetrating radar (GPR)	• Electrical property interfaces (dielectric permittivity)	• Shallow interfaces (stratigraphy, anthropogenic modifications, infrastructure)
• Magnetics	• Magnetic field variations	• Geologic variations; metal; cultural features, burn pits, etc.
• Microgravity	• Mass variations	• Estimated location and shape of mass variations & structural geology
• Borehole geophysics	• Electrical resistivity, seismic velocity, gamma ray emission, etc.	• Stratigraphy, layer boundaries, water level, plume detection, etc.
• LiDAR	• Time & reflectance	• Surface morphology, change, and reflectance variations

METHODS

	Surface Methods															Down-Hole Methods							
	Seismic					Electrical																	
						Electromagnetic																	
						FDEM																	
APPLICATION / Tool/Method	Seismic Reflection	Seismic Refraction	Surface Wave	MASW	Magnetics	EM 31	EM 34	EM 61	TDEM	GPR	DC Resistivity	Self-Potential	Induced Polarization	Nuclear Magnetic Resonance	Gravity	Cross Hole	Borehole Laser	Borehole Sonar	Gamma	Nuclear	Induction/Conductivity	Televiewer	Nuclear Magnetic Resonance
Archeologic Site Characterization					X	X	X	X		X	X				X								
Void Detection	X	X	X	X	X	X	X			X	X				X	X	X	X					X
Levee & Dam Evaluation	X	X	X	X		X	X		X	X	X	X	X			X							
Groundwater Resources	X	X				X	X		X		X	X		X					X	X	X	X	x
Structure/Stratigraphy	X	X	X	X	X	X	X		X	X	X		X		X	X		X	X		X		
Saltwater Intrusion						X	X		X		X	X									X		X
Geotechnical Site Characterization	X	X	X	X	X	X	X		X	X	X				X	X	X	X	X	X	X	X	
Environmental Site Characterization		X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	
Seismic Engineering/Dynamic Properties	X	X	X	X																			
Pipeline Characterization/Detection	X	X			X	X		X		X	X												
Plume Characterization (landfill/UST/Acid Mine Drainage)					X	X	X	X	X	X	X	X				X			X	X	X	X	X
Energy Exploration - Geothermal	X				X				X		X											X	
Energy Exploration - Mining	X	X			X				X		X				X				X	X	X	X	
Energy Exploration - Oil & Gas	X				X										X	X		X	X	X	X		X

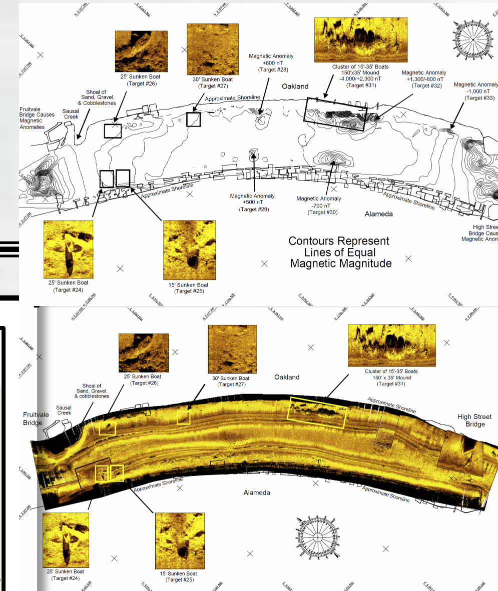

pulseEKKO 100 GPR

TOOLS


G-858 MAG
OhmMapper


EM61-MK2A
Noggin GPR
Control computer
GPS
Battery
Odemeter
Tx
Rx
EM38-MK2
SUPERSTING
SP
SP
EM31-MK2
G-858 MAG
OhmMapper
PROTEM
GSMP30
pulseEKKO 100 GPR
SMART SEIS
STRATAGEM
GEM2

METHODS



G-882 MAG

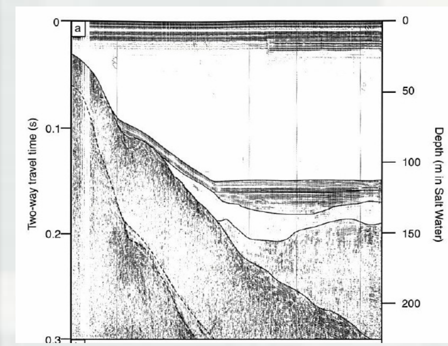
Side-scan sonar (600 kHz Marine Sonics)

Seismic reflection (Edgetech 424 CHIRP)

Marine Methods

Innerspace 448 Transducer (200-kHz, 3-degree)

APPLICATION \ Tool/Method	Echo-Sounding	Sub-bottom Profiling	Side-Scan Sonar	Magnetics	Resistivity
Bathymetry	X	X	X		
Depth to Bedrock		X			
Structure		X	X	X	X
Site Characterization		X	X	X	X
Mineral Resources				X	X



Applied Acoustic Engineering®
BU800-2,000 Hz GeoPulse® (acoustic source)

PITFALLS

Non-unique solutions

- Geophysics is non-bias in the sense that the techniques measure a response to physical properties
- But – a particular response can be the product of multiple causes
- Professional judgement, experience, geologically reasonable interpretations
- Multiple method approach to converge on interpretation

Noise: ~ any unwanted signal

•Natural

- Wind (seismic)
- Soil conditions (EM methods, DC & GPR)
- Saturation (GPR)

•Anthropogenic

- Traffic (air craft & vehicle) => seismic
- Metal fences => EM methods & GPR
- Stray electrical current => DC & EM methods
- Faulty electronics => all methods

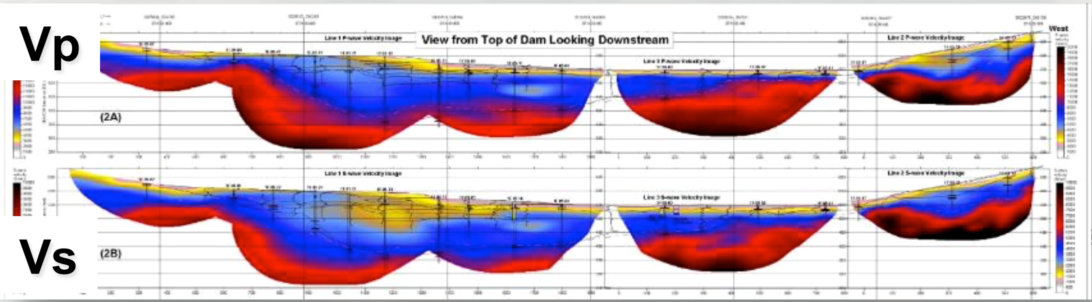
Prior to initiation

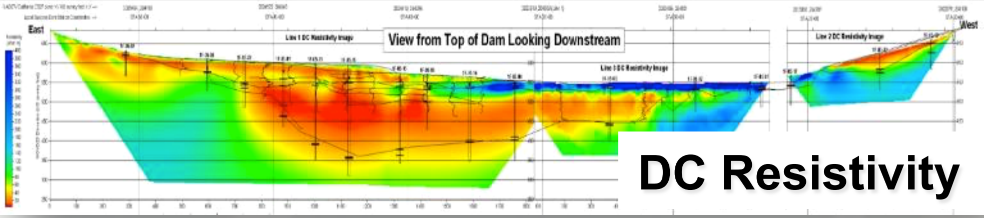
- Is target achievable?
- Often not proposed (preconceived bias)
- Often oversold

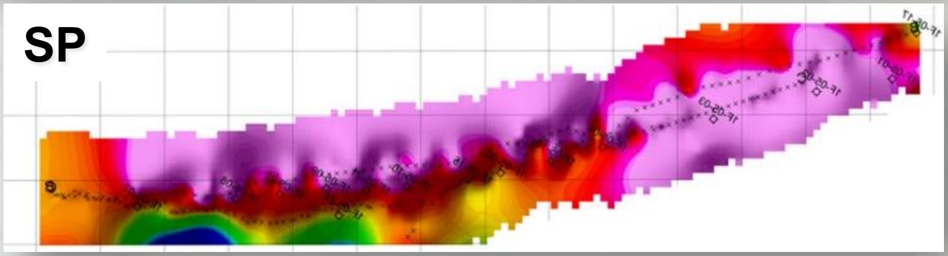
Communication

- Risk, deliverables, time, cost, …

ADVANTAGES







- Non-intrusive surface methods (except borehole methods)
- 2-D image
  - Vertical x-section
  - Planar map
- Hardware & software advances over last decade
  - making 3-D inversion and modeling more mainstream
  - Handling of extremely large data sets
- Respond to different properties in the subsurface
  - Electrical conductivity
  - Material density
  - Bulk/shear moduli
  - Dielectric permittivity
  - Water content
  - Density
  - Etc.
  - Property contrasts

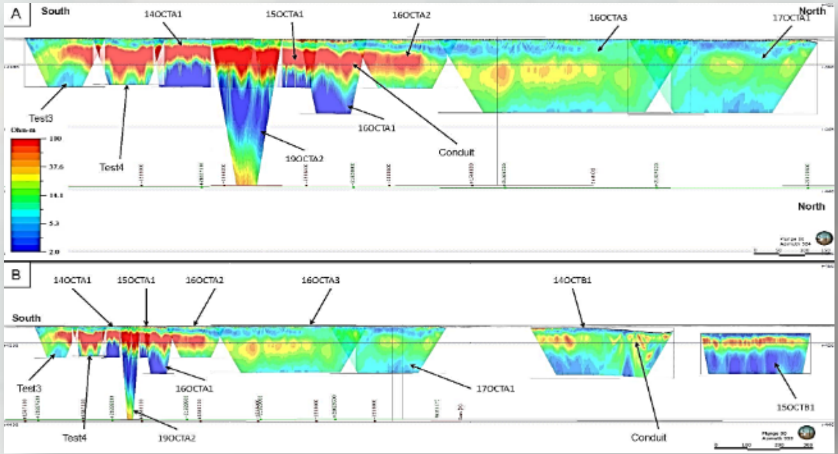
Carefully applied geophysical investigations can yield extremely valuable information

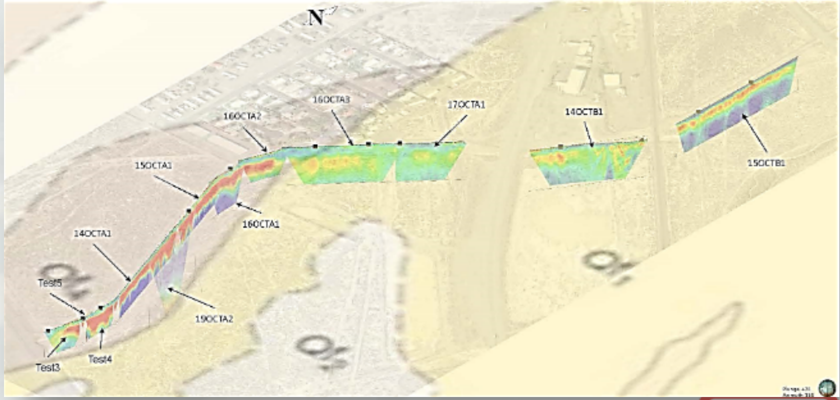
- Cost-effective component of the evaluation process.
- Modern digital equipment capable of collecting data over large arrays makes geophysical surveys increasingly useful and efficient
- New inversion and imaging software makes communicating results to non-geophysicists easier

APPLICATIONS

ENVIRONMENTAL

- **Geologic characterization**
  - **Aquifer/aquitard characterization**
  - **Stratigraphy**
- Plume mapping
- UST detection
- Utility detection
- Landfill delineation
- Trench delineation
- Infrastructure investigations
- Munitions detection and classification
  - Covered by EMCX-Huntsville, AL





DC Resistivity survey: Battle Mtn, NV

APPLICATIONS

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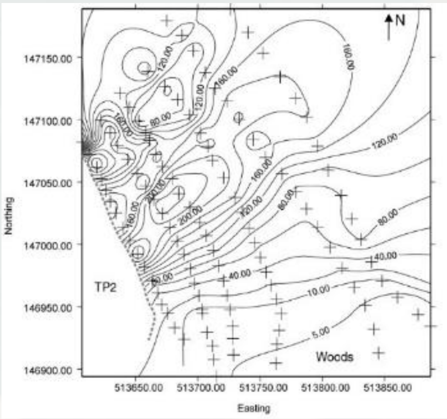
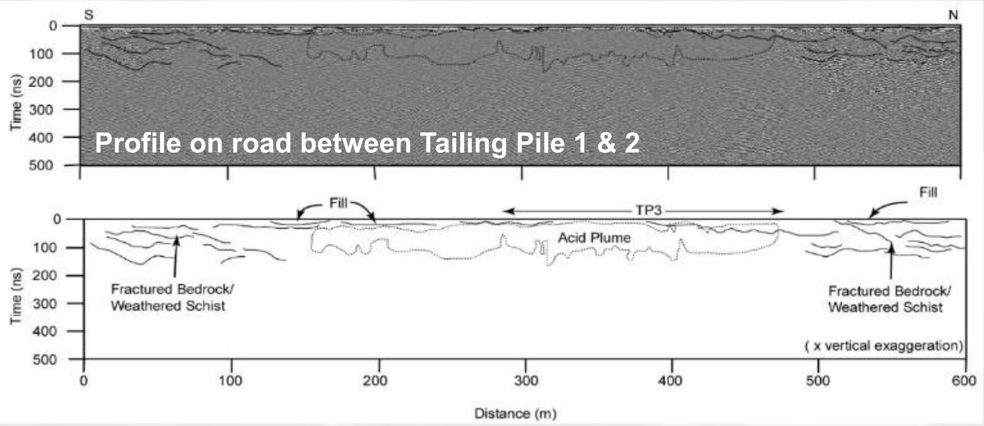
Acid Mine Drainage: Elizabeth Mine South Strafford, VT

EM 31

Conductivity

~100–240 mS/m





Results:

GPR penetration limited on tailings pile due to high conductivity of acid mine drainage (pH 2-4)

GPR technique able to define extent of acid plume

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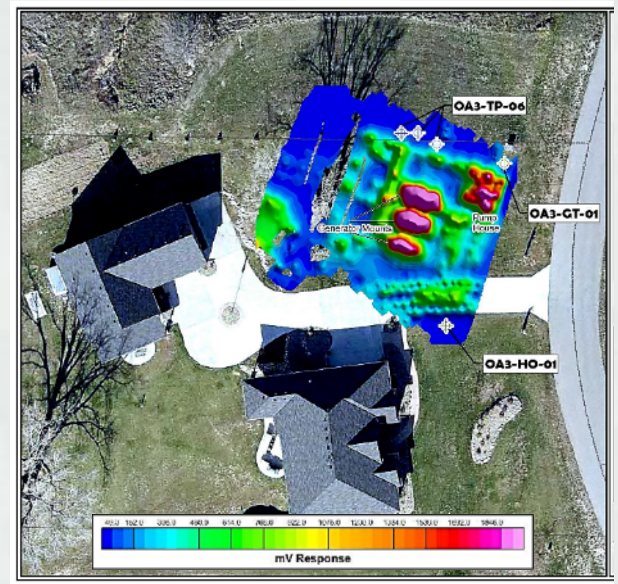
EM Resistivity survey: Former Offutt Air Base



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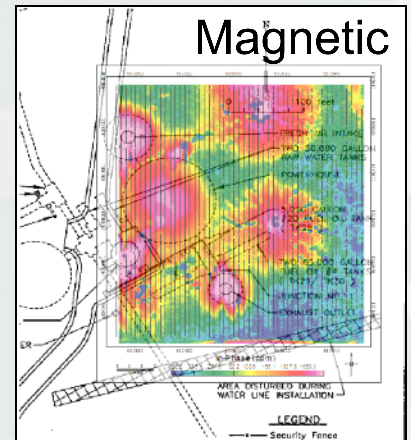
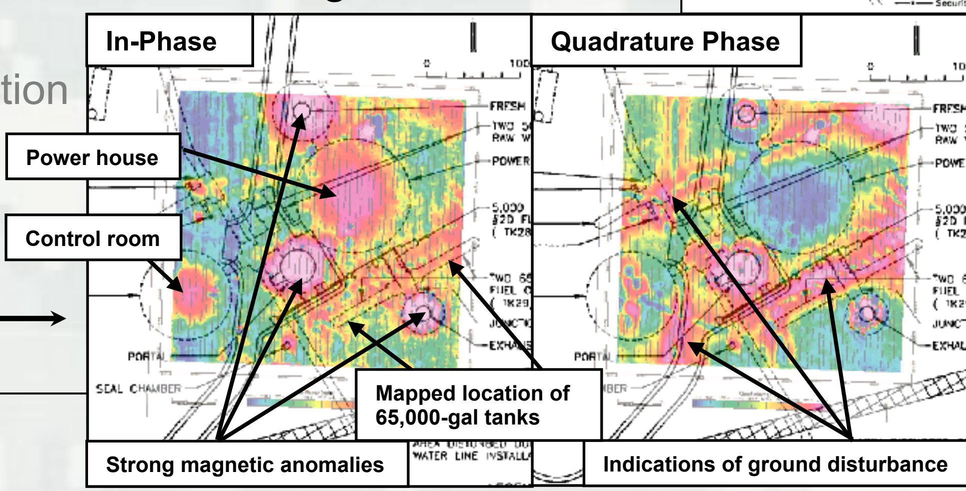


Electromagnetic

Magnetic and FDEM survey: Former Titan 1A Missile Site, Lincoln, CA



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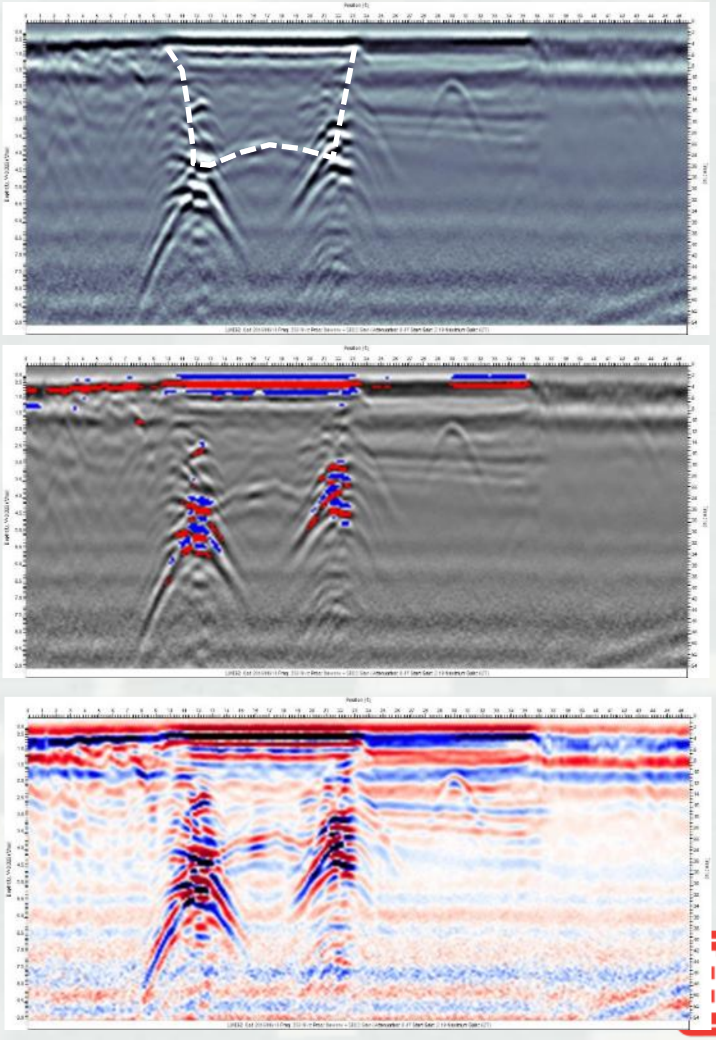

GPR – Utility detection survey at MOTCO, Concord, CA

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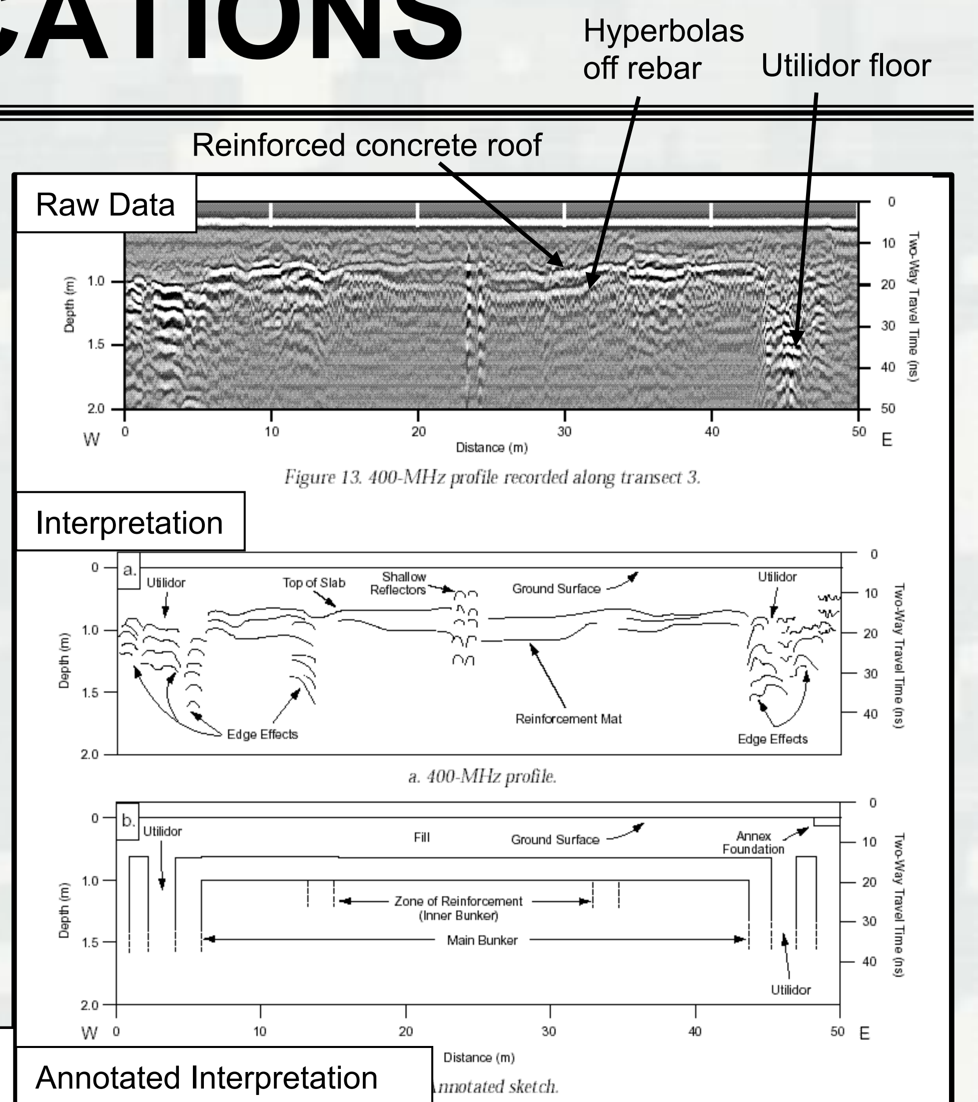

Results:

GPR provided quick cost effective method to locate abandoned bunker and associated utilidors

Roosevelt Rd Transmitter Site
Ft Richardson, AK

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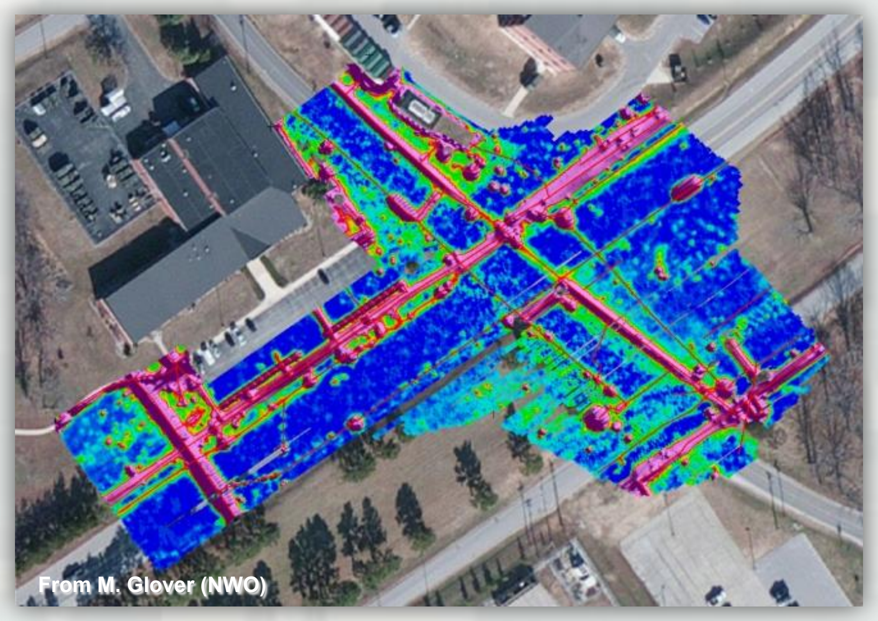
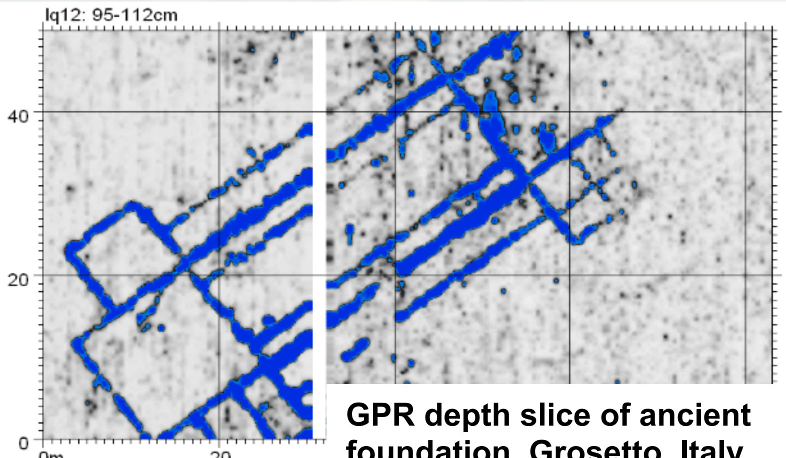


EM survey for utility detection: Ft Leonard Wood

APPLICATIONS

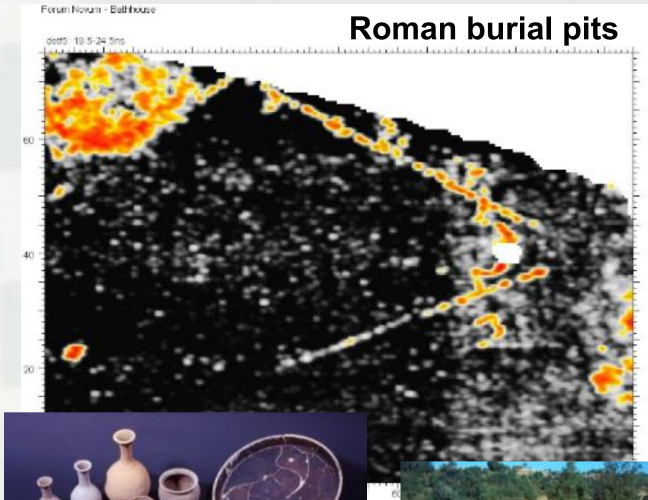
ARCHEOLOGIC STUDIES

- **Foundation footprints**
- Buried chambers
- Fire pits
- **Graves**

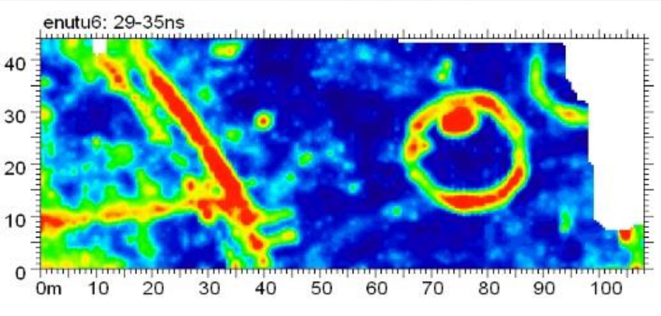


GPR depth slice of ancient foundation, Grosetto, Italy

Roman burial pits

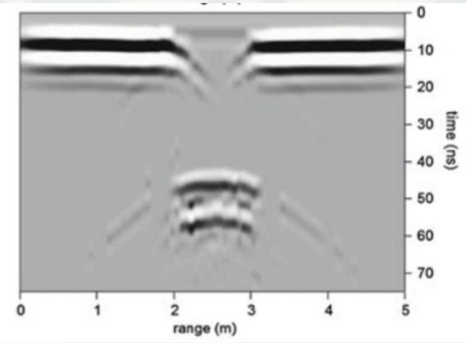


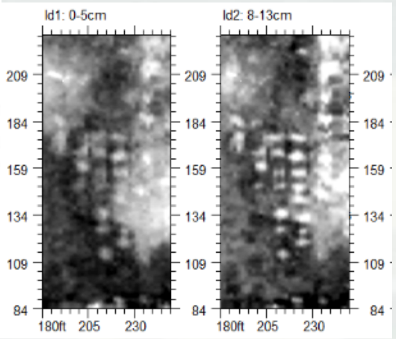
Images courtesy of D. Goodman



Burial chamber Miyazaki Prefecture, Japan

Graves/ cemetery



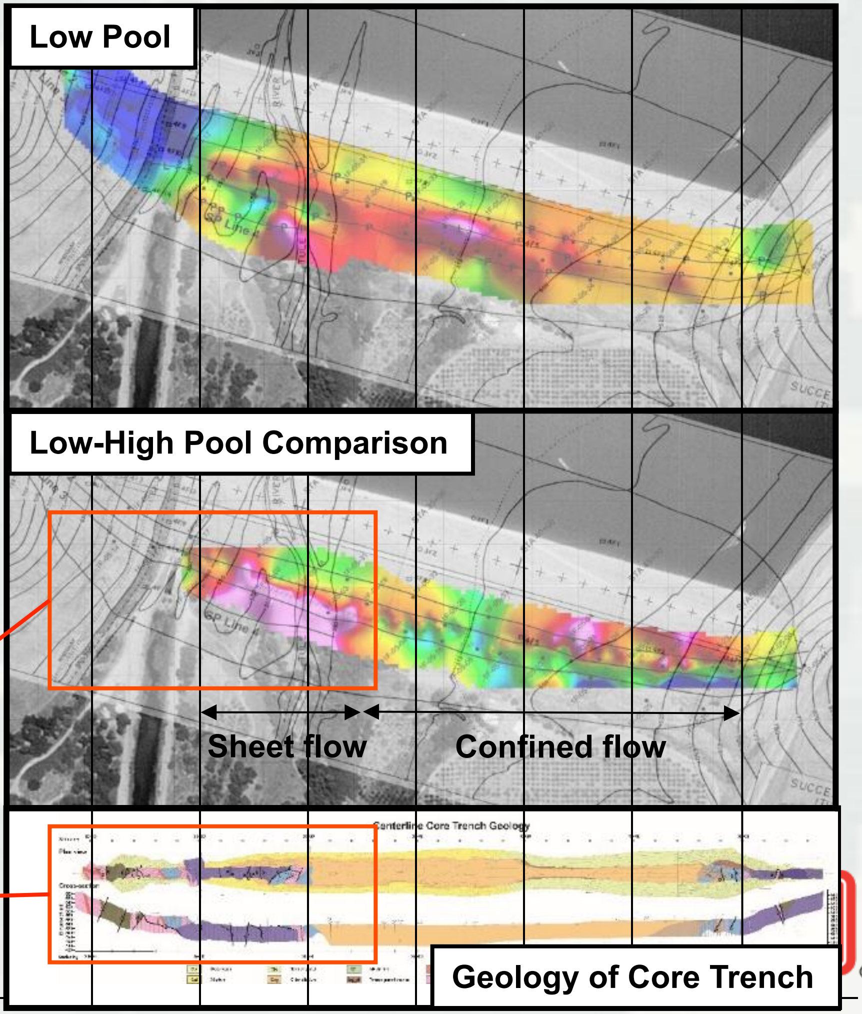


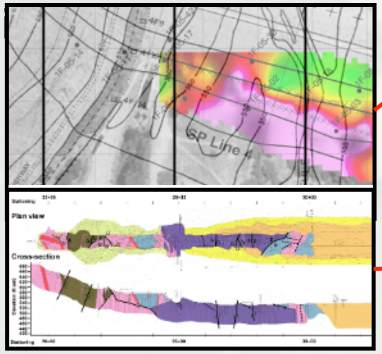
APPLICATIONS

Seepage analysis

GEOTECHNICAL STUDIES

- Dam & Levee foundation characterization
- Definition of geotechnical properties
- Geologic characterization
  - Stratigraphy
  - Fault/shear zone delineation
  - Depth to bedrock
  - Liquefaction potential
- **Groundwater & seepage studies**
- Infrastructure





Sheet flow anomaly

Pre-construction channel

Shallow bedrock

APPLICATIONS

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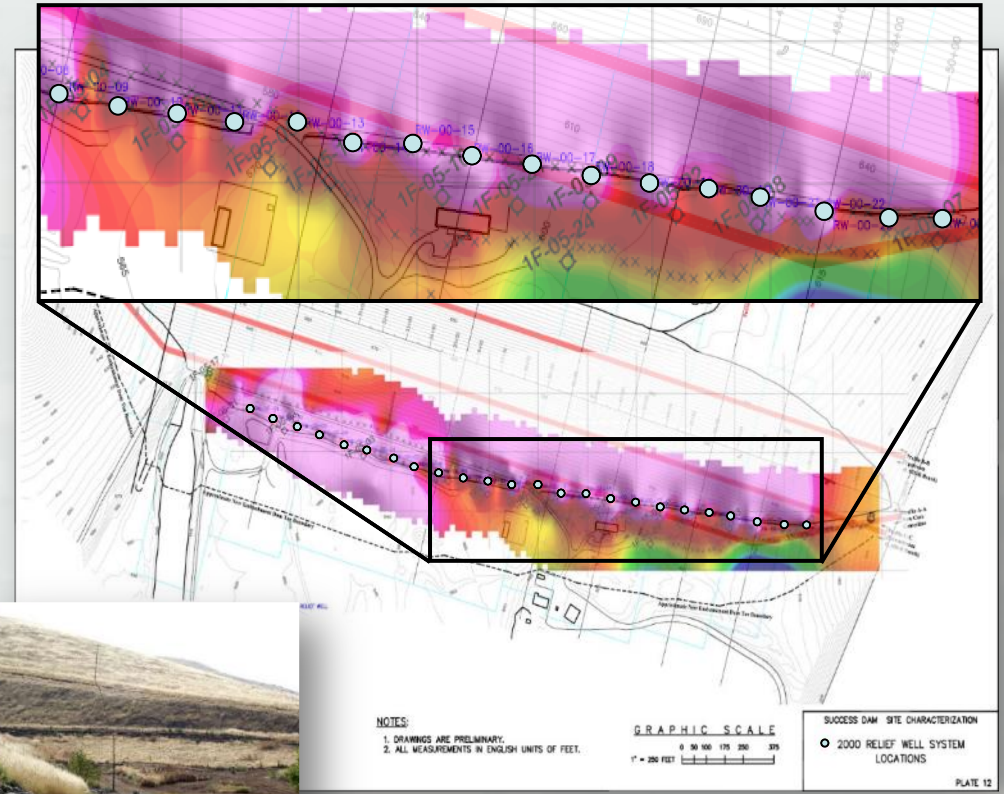
Seepage analysis



High pool SP data
- **Point anomalies**
- **Relief wells**
  - **Flowing at time of survey**

APPLICATIONS

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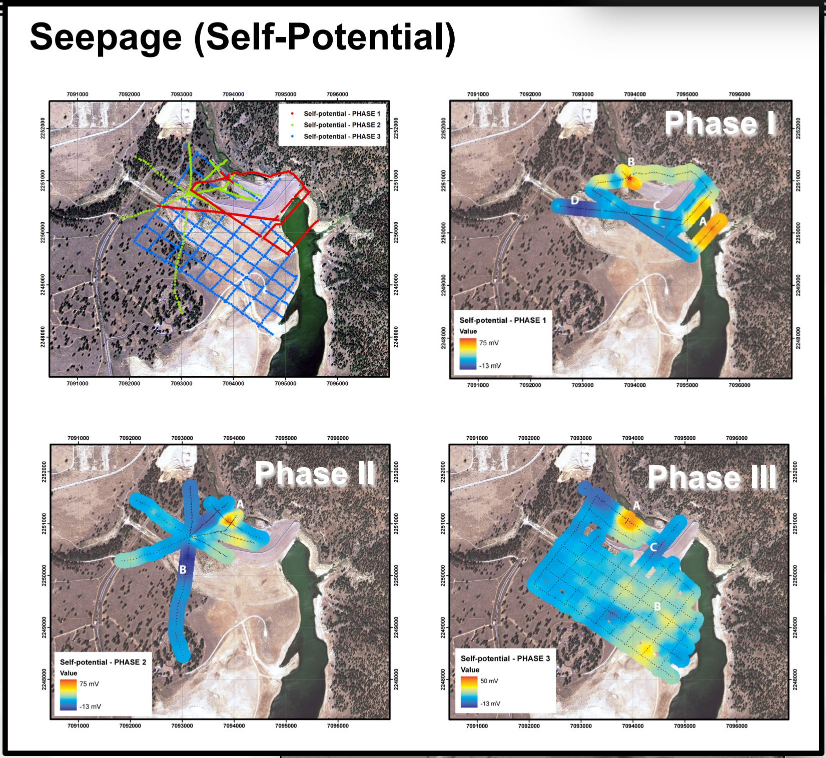

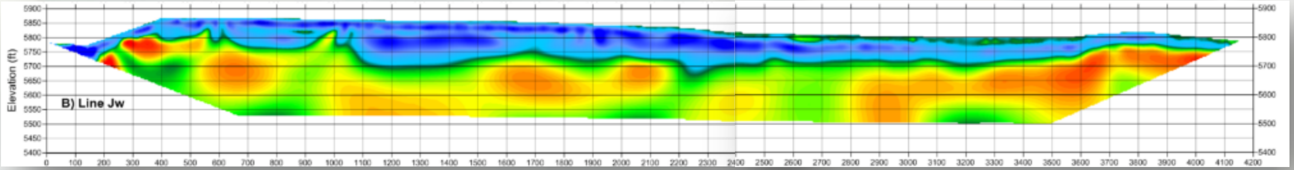

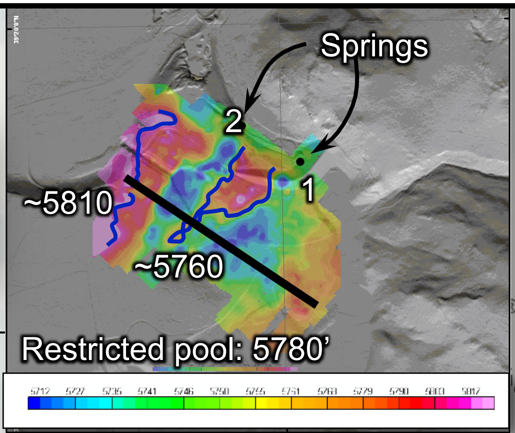

APPLICATIONS

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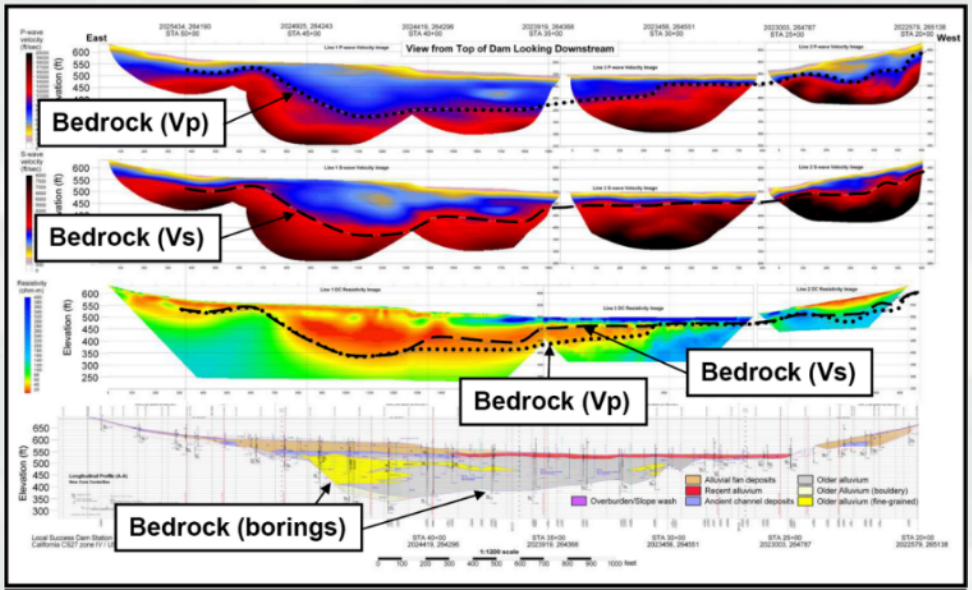
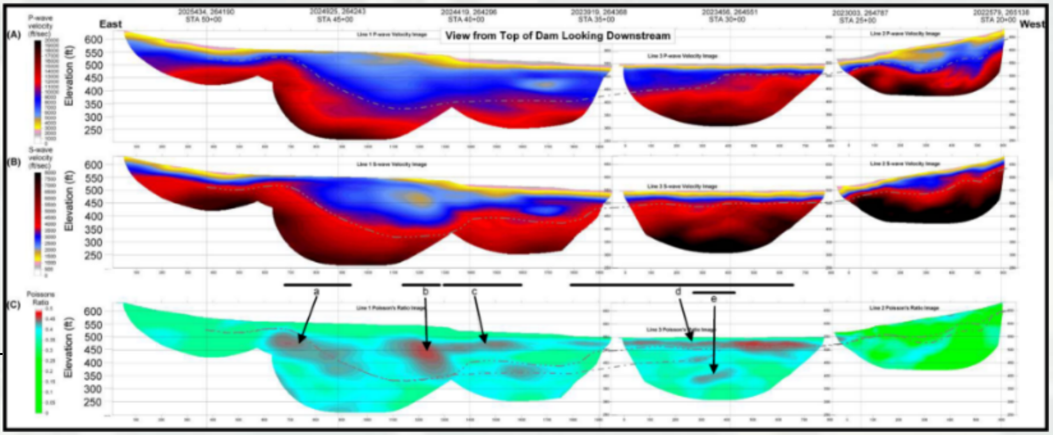


Different bedrock surface identified between Vp & Vs
- **Compaction, lithification, weathering**



APPLICATIONS

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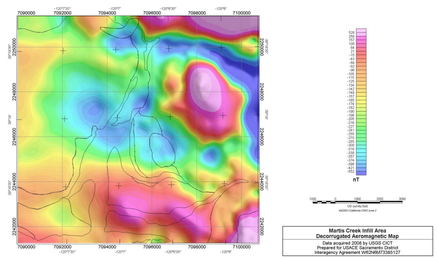
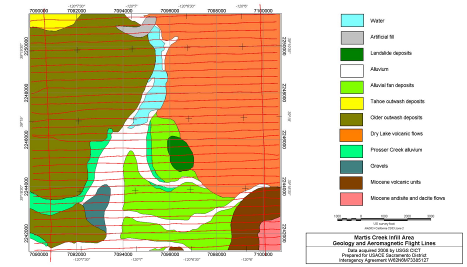
Depth to bedrock

Airborne magnetics

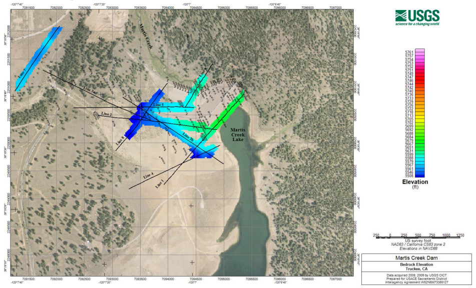


Mapped multiple lava flows

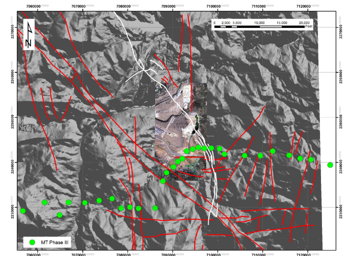


Bedrock Surface (Seismic)

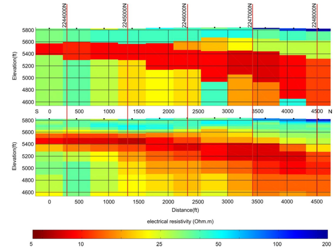
- Top of basalt flow



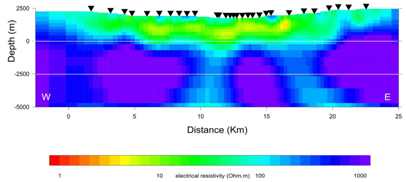
CS-AMT Transect (green dots)



TDEM (basalt flows/bedrock?)



CS-AMT Profile

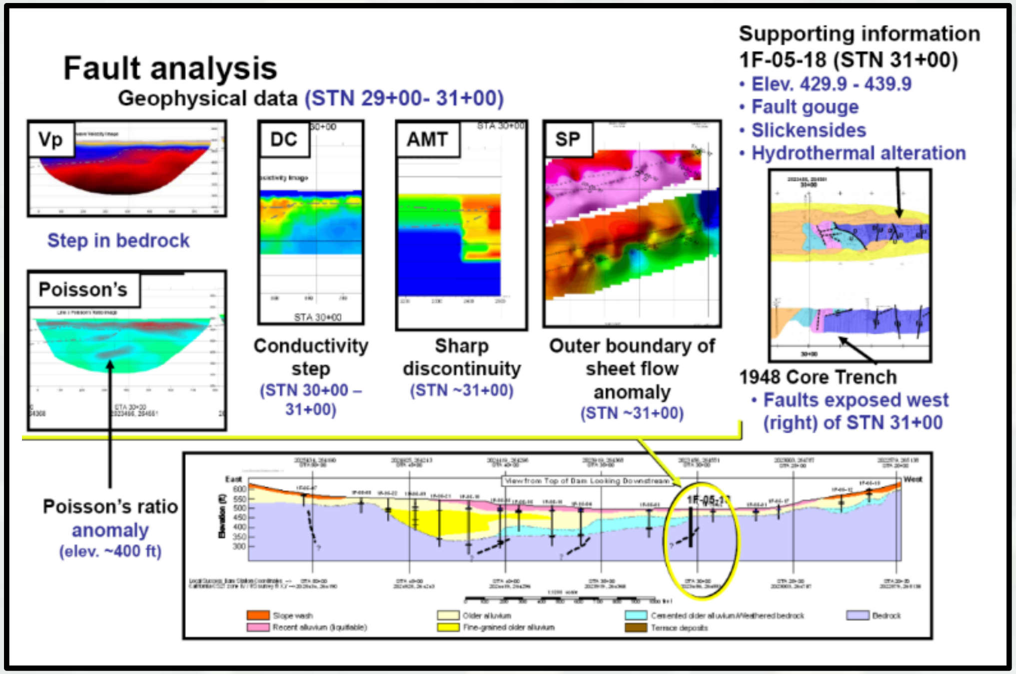


- 2 deep crustal faults
- Crystalline bedrock >2000 m

APPLICATIONS

GEOTECHNICAL STUDIES

- Dam & Levee foundation characterization
- Definition of geotechnical properties
- **Geologic characterization**
  - Stratigraphy
  - **Fault/shear zone delineation**
  - Depth to bedrock
  - Liquefaction potential
- Groundwater & seepage studies
- Infrastructure investigations



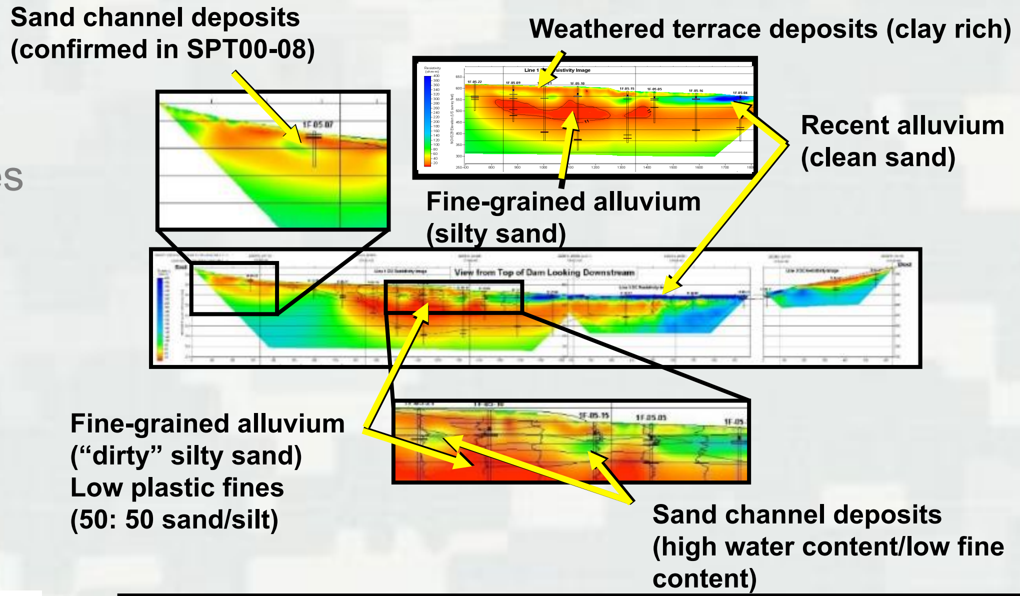
APPLICATIONS

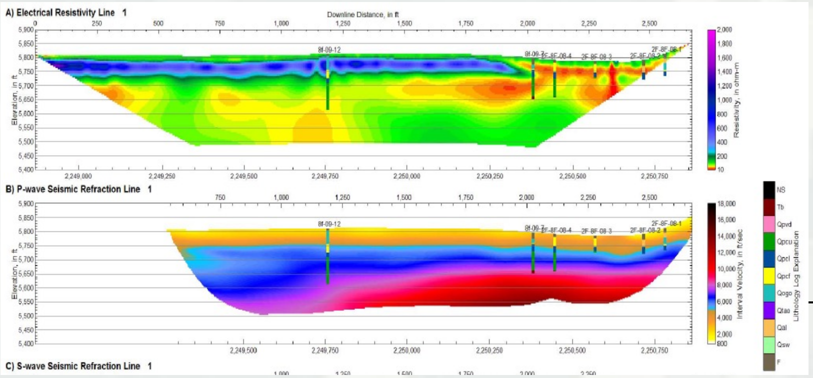
GEOTECHNICAL STUDIES

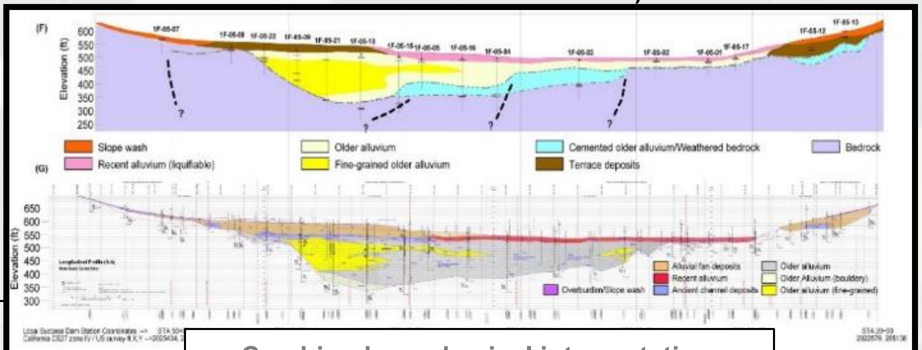
- Dam & Levee foundation characterization
- Definition of geotechnical properties
- **Geologic characterization**
  - **Stratigraphy**
  - Fault/shear zone delineation
  - Depth to bedrock
  - Liquefaction potential
- Groundwater & seepage studies
- Infrastructure investigations

Stratigraphic continuity

- **Correlate major stratigraphic units horizontally and vertically**
- **Improves confidence in lithologic correlations between boreholes**





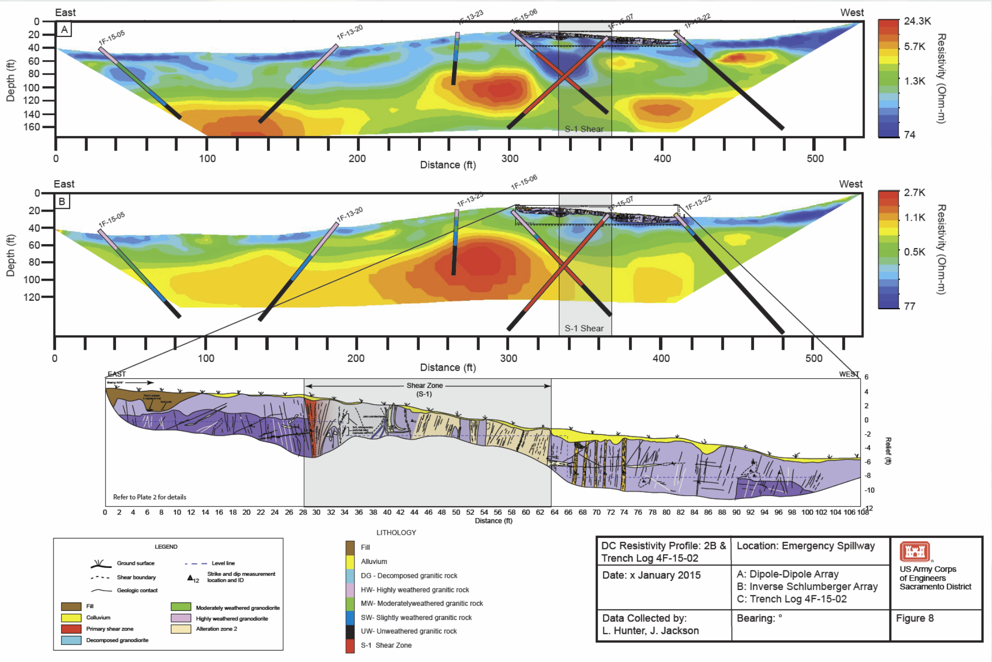


Combined geophysical interpretation yields generalized geologic cross section

APPLICATIONS

GEOTECHNICAL STUDIES

- Dam & Levee foundation characterization
- Definition of geotechnical properties
- **Geologic characterization**
  - Stratigraphy
  - **Fault/shear zone delineation**
  - **Depth to bedrock**
  - Liquefaction potential
- Groundwater & seepage studies
- Infrastructure investigations

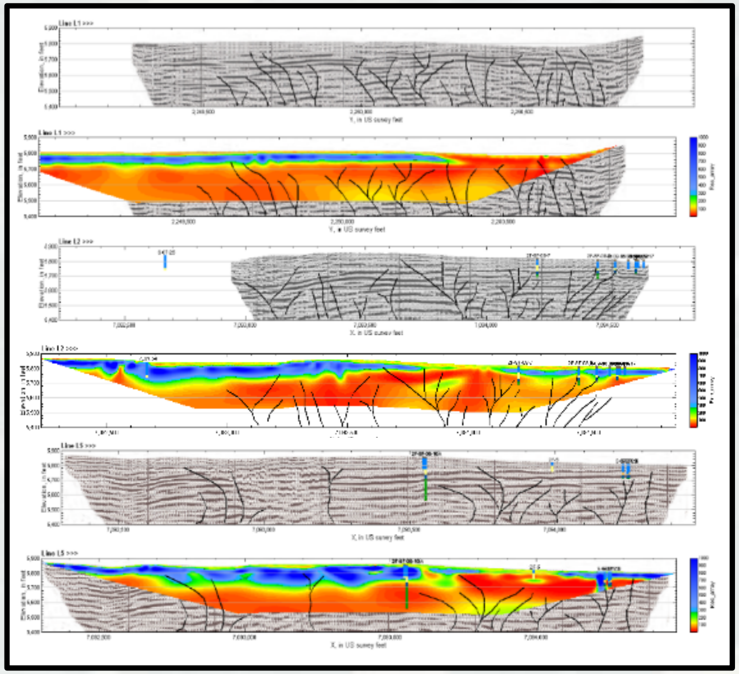


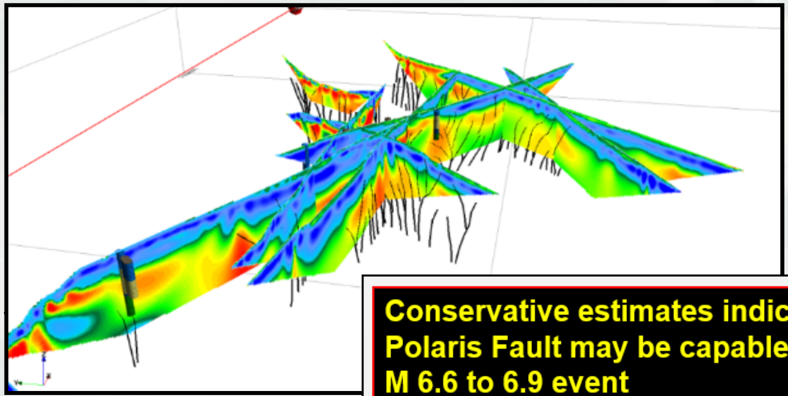
- **4 lines perpendicular to proposed spillway right cutwall**
- **Each collected with dipole-dipole and inverse-Schlumberger arrays**
- **Useful in defining shear zones along the proposed alignment of the new Emergency Spillway**
- **Each yielded anomalous responses reflecting discontinuities consistent with shear zones**
- **Trenching verified fractured and altered rocks associated with well-developed shears**
- **DG & HW granite near formed a nearly continuous low-resistivity layer**

APPLICATIONS

GEOTECHNICAL STUDIES

- Dam & Levee foundation characterization
- Definition of geotechnical properties
- **Geologic characterization**
  - **Stratigraphy**
  - **Fault/shear zone delineation**
  - Depth to bedrock
  - Liquefaction potential
- Groundwater & seepage studies
- Infrastructure investigations





Conservative estimates indicate Polaris Fault may be capable of a M 6.6 to 6.9 event

POLARIS FAULT, TRUCKEE, CA

Length (km)	Depth (km)	Area (km²)	Eq. 1 M	Eq. 2 M	Eq. 3 M
30	15	450	6.79	6.67	6.63
35	15	525	6.87	6.74	6.70
38	15	570	6.91	6.77	6.74

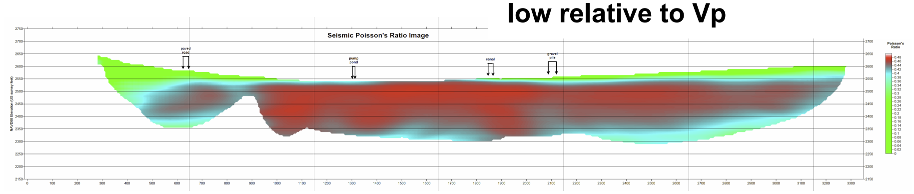
APPLICATIONS

GEOTECHNICAL STUDIES

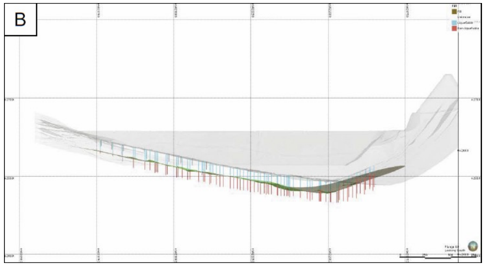
- Dam & Levee foundation characterization
- Definition of geotechnical properties
- **Geologic characterization**
  - Stratigraphy
  - Fault/shear zone delineation
  - Depth to bedrock
  - **Liquefaction potential**
- Groundwater & seepage studies
- Infrastructure investigations

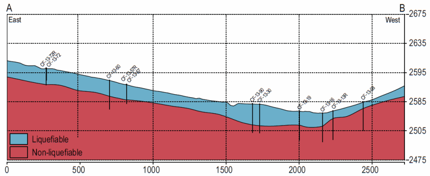
Liquefaction

Poisson's ration used to look for zones where Vs is proportionately low relative to Vp

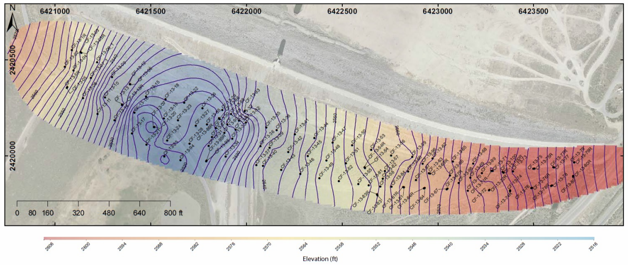


Factor of safety against liquefaction (FS_{liq}) calculated based on Youd et al. (2001) & Idriss & Boulanger (2008) to determine amount of material to remove to get below upper liquefiable layer



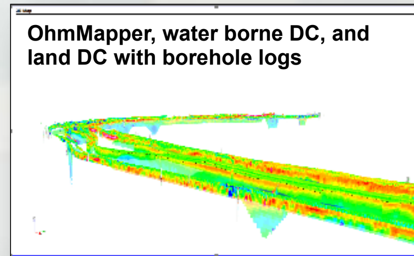


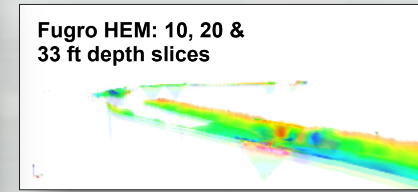
Isopach map showing material to be removed to base of liquefiable layer

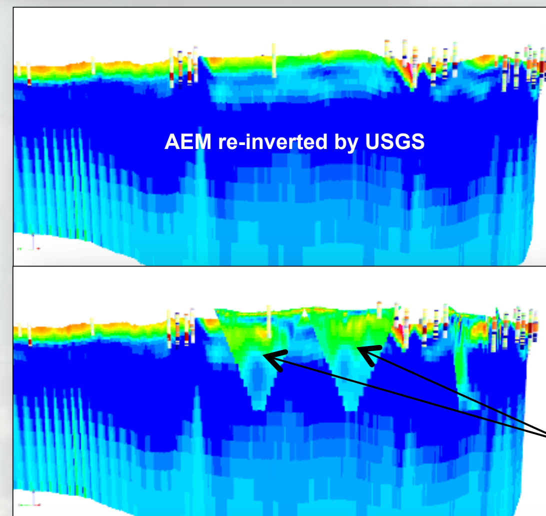


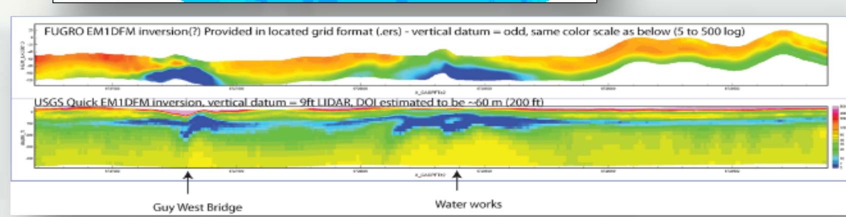
CONCLUSIONS

- Range of methods available in field of near-surface geophysics
  - Tailor to fit data needs based on series of site & project considerations
  - Methods well established (some used for over 100 yrs)
  - Software & computers enable processing on immense datasets and enhanced visualization (GIS)
- Geophysics often best applied early
  - Provided lateral/spatial continuity (vs Swiss cheese approach)
  - Cost effective
- “Unregulated”
- Often misused or not considered
  - Geophysics Cadre
    - Sacramento: *John Jackson & Lewis Hunter*
    - Omaha: *Erin Wallin & Matt Glover*
    - Huntsville: *Rick Grabowski & Bob Selfridge*



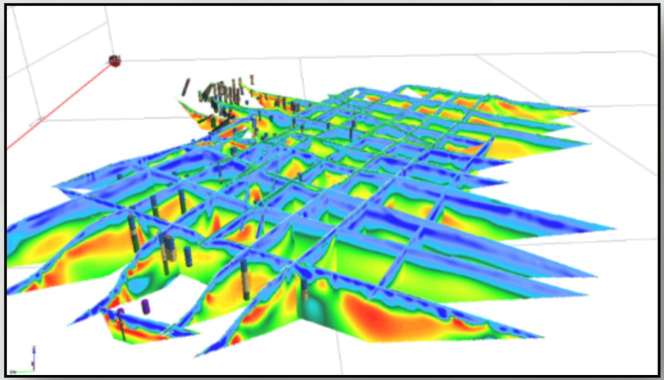


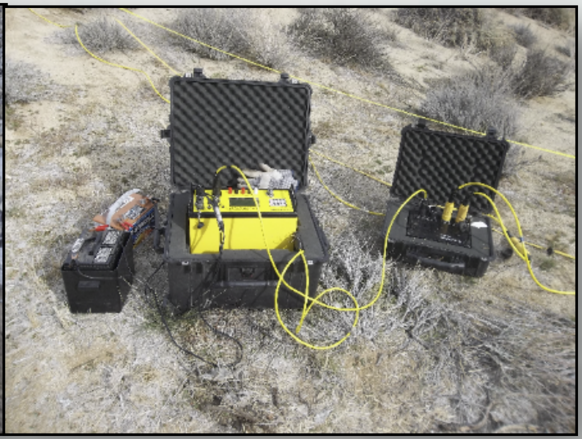




ADDENDUM

Select case studies at time allows

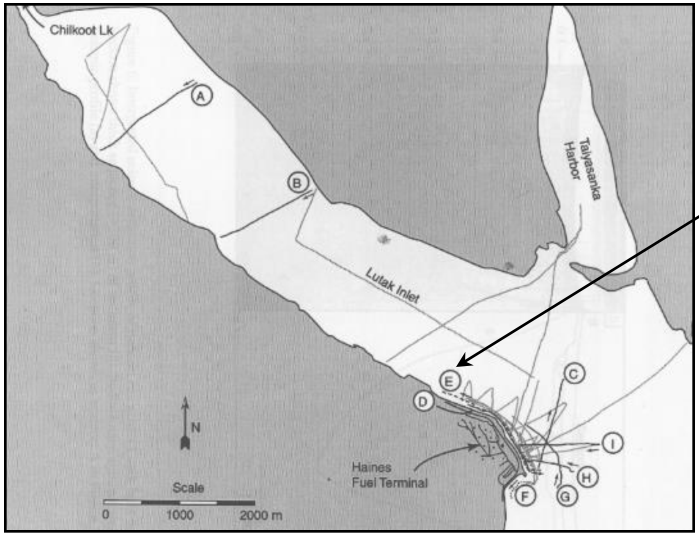




CASE STUDIES

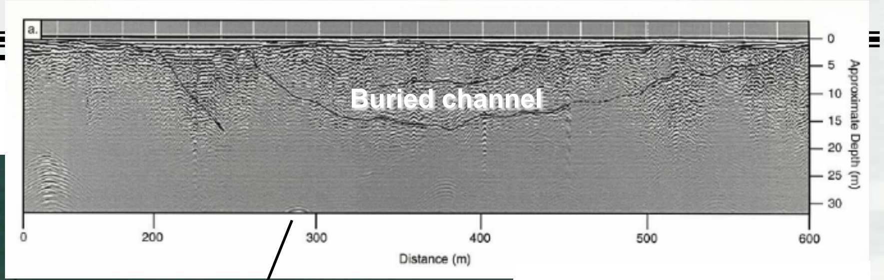
Target(s):
- Quaternary fjord infilling
- ID faults that could be pathways for hydrocarbon migration

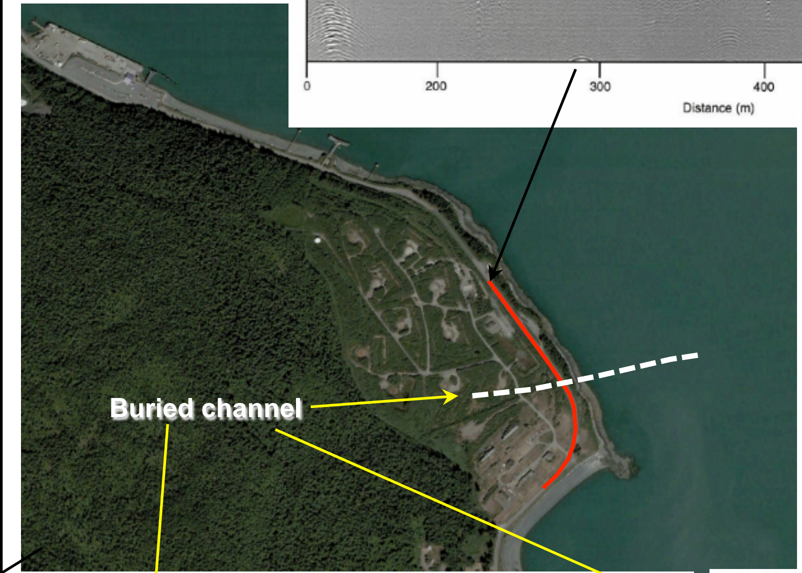
Method(s):
- GPR
- Marine seismic (DataSonics bubble pulser, 20 J, 350 Hz

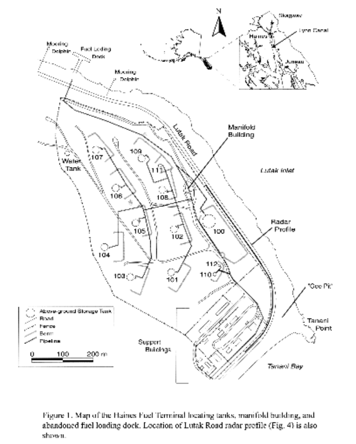


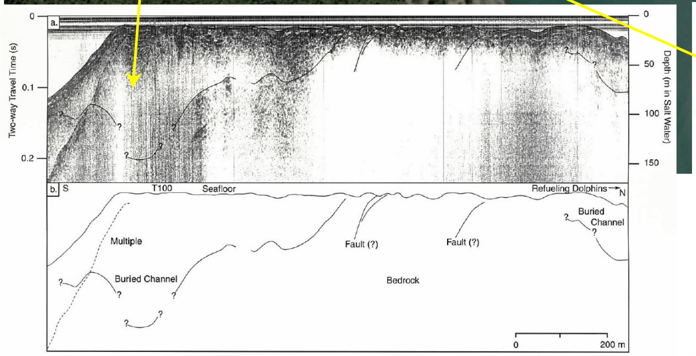
From ERDC/CRREL LR-00-04

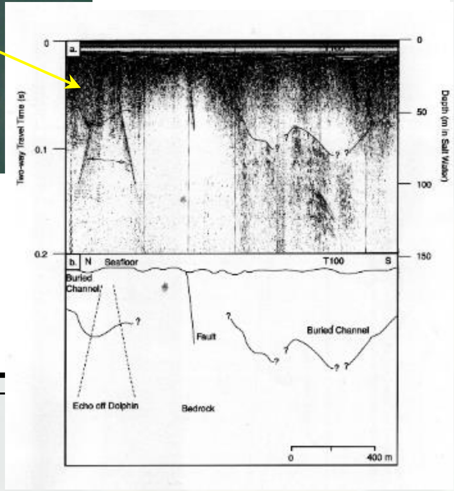
Results:









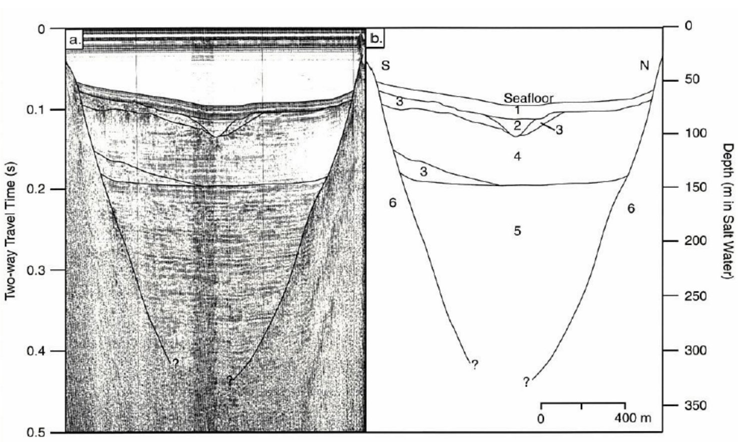


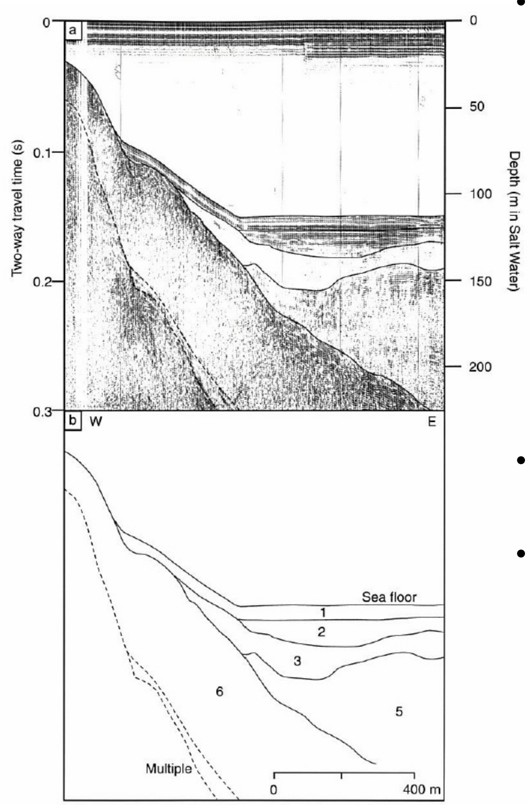
Project: Haines Fuel Terminal
Location: Haines, AK

Executing District: ERDC-CRREL
Responsibility: L. Hunter & A. Delaney

CASE STUDIES

Results:





- **Sediment infilling locally exceeded 500 m**
- **Identified 6 seismic facies:**
  1. **post-glacial mud**
  2. **incised channel deposits**
  3. **sediment gravity flow deposits**
  4. **distal glacimarine mud (silty mud)**
  5. **proximal glacimarine mud**
  6. **bedrock**
- **Offshore deposits capped my mud drape 10-20 m thick**
- **Identified 2-buried channels – correlated to inshore buried channels**
  - **Trough-like feature off Tank 100 extended at least 350 m offshore**
- **Several faults observed in nearshore profiles**

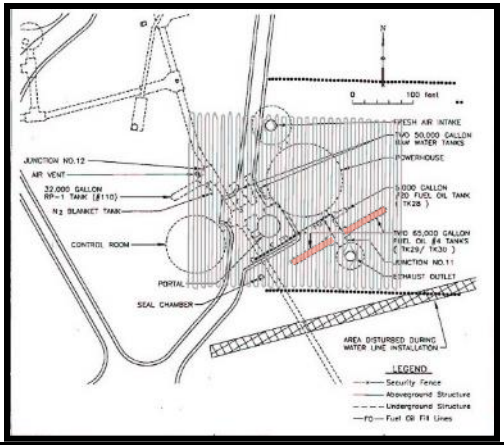
CASE STUDIES

Target(s):

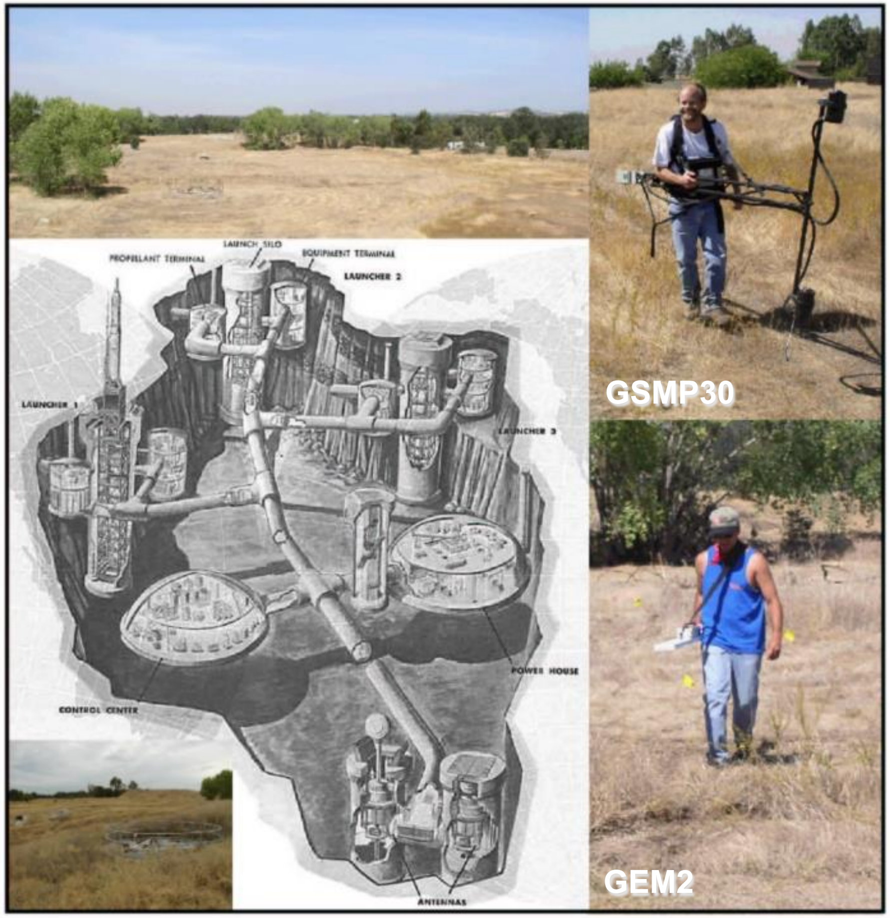
- Determine if we could detect two USTs (65,000-gal diesel storage tanks: TK29/ TK30)
- See if we could image other buried structures
- Evaluate soil conductivities to determine if GPR would be useful on site

Method(s):

- Magnetice (GSMP-30 K-vapor magnetometer)
- Electromagnetic Induction (FDEM using a Geophex GEM2)



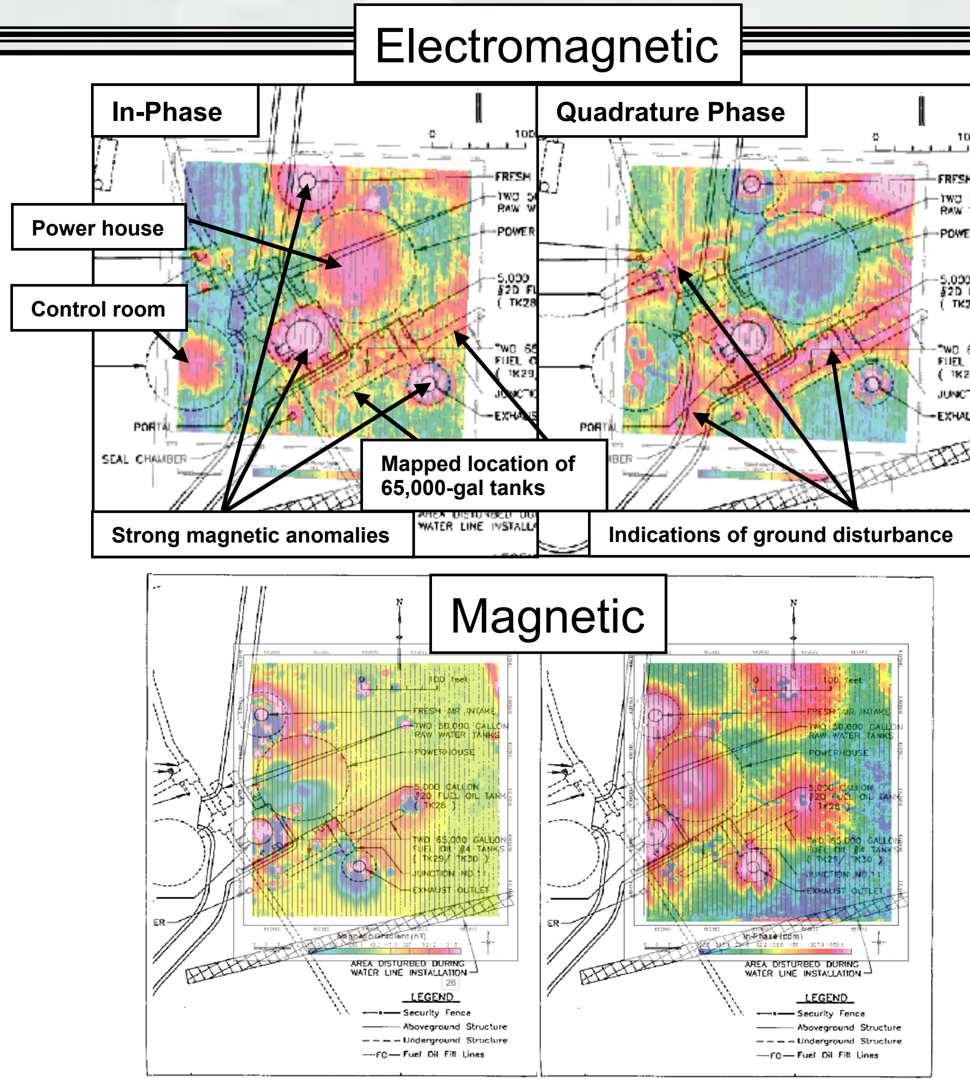
Results:



CASE STUDIES

Results:

- **Above ground structures**
  - ➢ **air intake, exhaust, entry portal, escape hatch produce strong anomalies w/both methods**
  - ➢ **locations agree w/site maps**
- **Both 65,000-gal tanks appear to have been removed**
  - ➢ **Quadrature phase data indicates ground disturbance**
  - ➢ **Magnetics lack strong anomaly**
- **Powerhouse appears intact; anomaly agrees closely with site map**
- **Tunnel locations apparent in EM data**



CASE STUDIES

Target(s):

- A series of reconnaissance geophysical surveys were performed to evaluate the performance of DC resistivity, electromagnetic induction and GPR on mine tailings.
- Elizabeth Mine is oldest copper mine in US and recently listed on Superfund NPL
- Funding: U.S. Army Applied Research Program, AT42

Method(s):

- DC Resistivity, TDEM & GPR

Results:

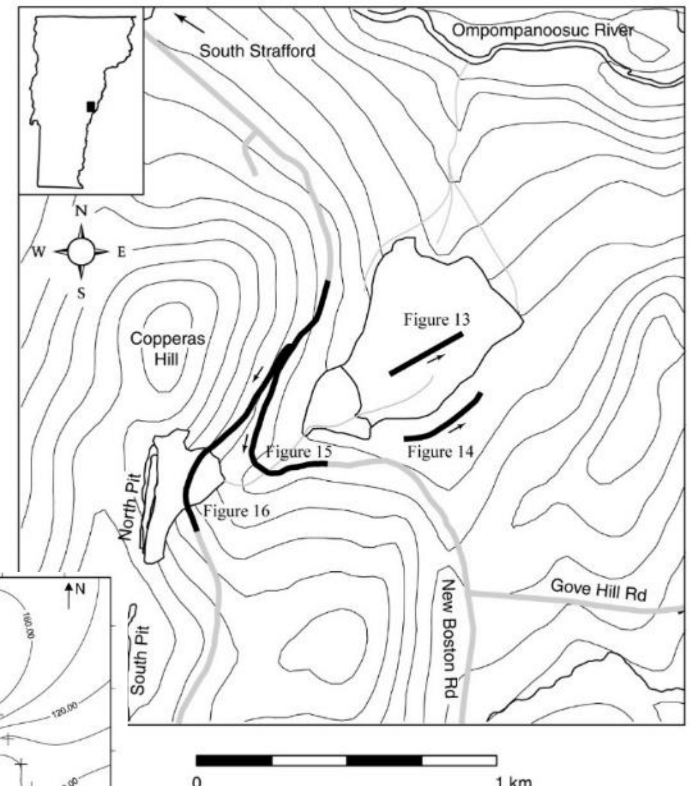
Elizabeth Mine

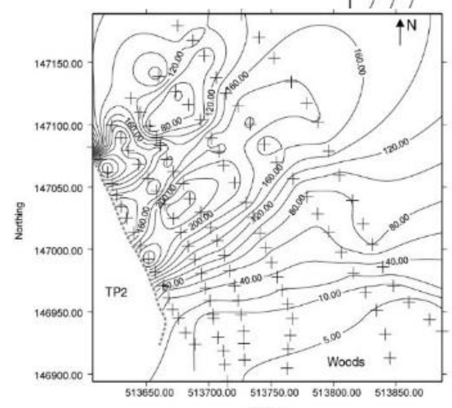
- **2 open pits & 3 tailing piles**
- **surface water (pH ~2.0)**
- **Discharges into Ompompanoosuc River then Connecticut River**

EM 31

Conductivity

~100–240 mS/m





Project: Elizabeth Mine
Location: South Strafford, VT

Executing District: ERDC-CRREL
Responsibility: L. Hunter (w/Arcone & Delaney)

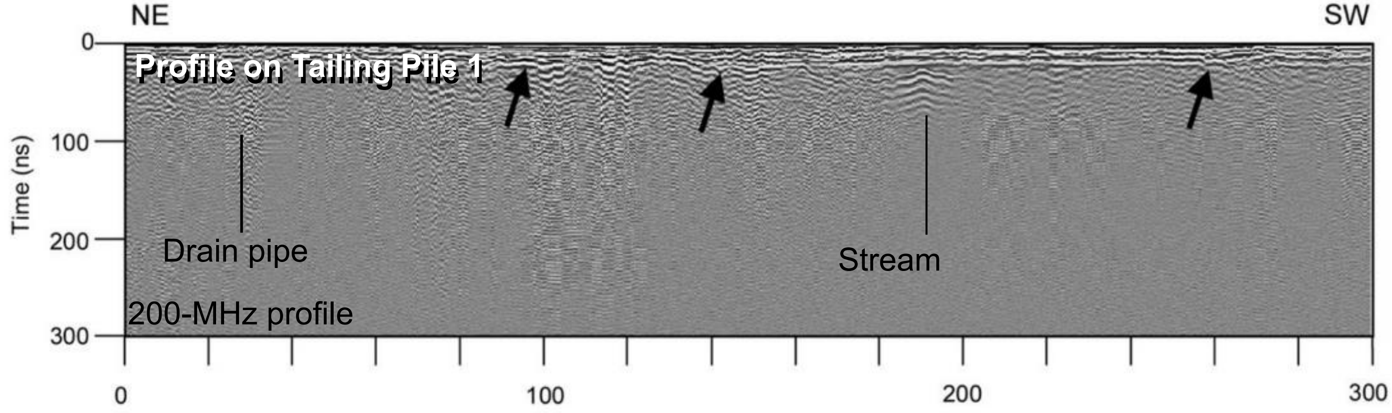
BUILDING STRONG®

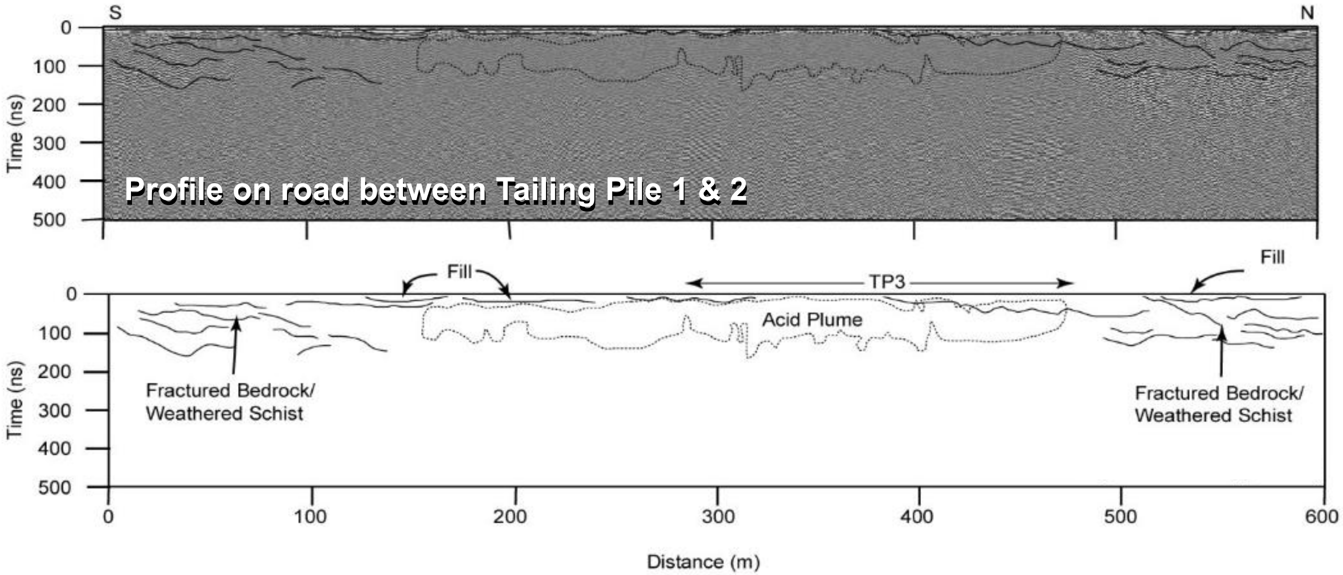
CASE STUDIES

Results:

Fractured/weathered schist
- reflectors visible to ~200 ns depth (8 m)
- velocity ~ 0.08 m/ns
- conductivity < 5 mS/m

Below acid mine drainage plume
- conductivity >200 mS/m
- radar penetration < ~20 ns (0.8 m)





Results:

GPR penetration limited on tailings pile due to high conductivity of acid mine drainage (pH 2-4)

GPR technique able to define extent of acid plume

Project: Elizabeth Mine
Location: South Strafford, VT

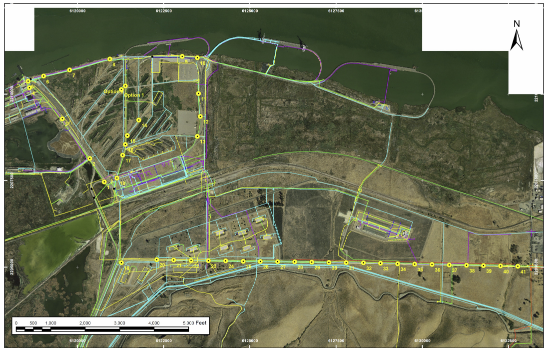
CASE STUDIES

Target(s):

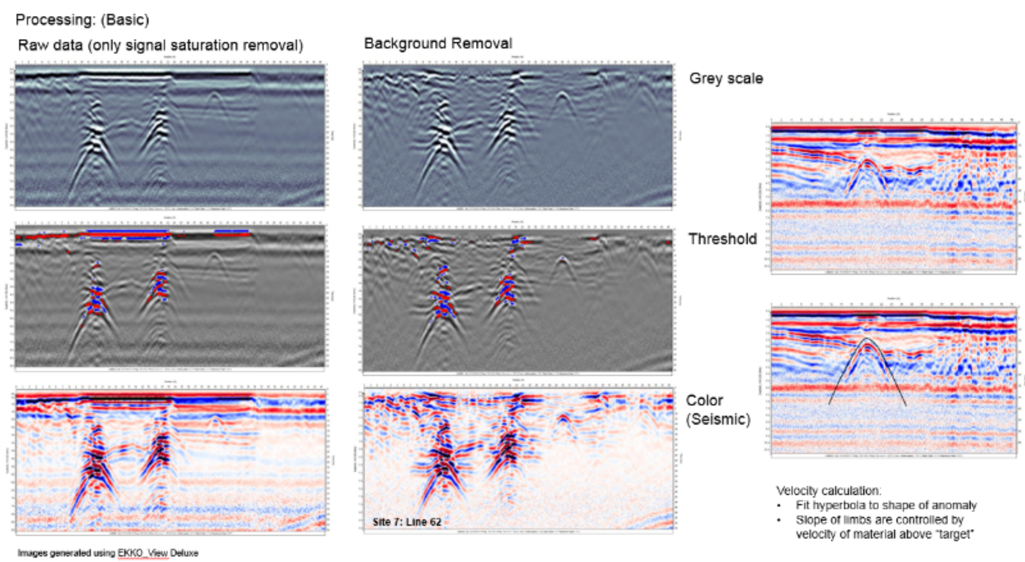
- Utilize GPR to identify utilities and estimate their depths

Method(s):

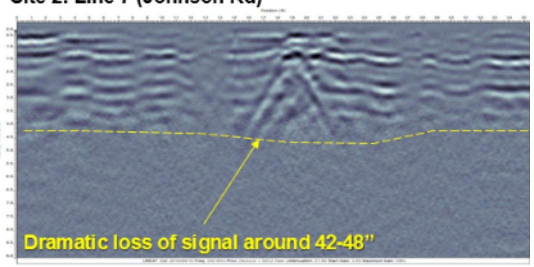
- 250-MHz Noggin
- 41 primary sites were investigated
- 2 optional sites were surveyed but preliminary results revealed nothing useful – so not processed
- 3 opportunity sites investigated – saw cuts in pavement surface so collected additional lines.
- 721 GPR lines collected over duration of project (includes 61 missing GPS data that were recollected)



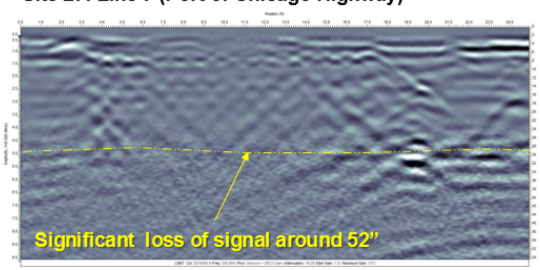
Results:



Site 2: Line 7 (Johnson Rd)



Site 27: Line 7 (Port of Chicago Highway)



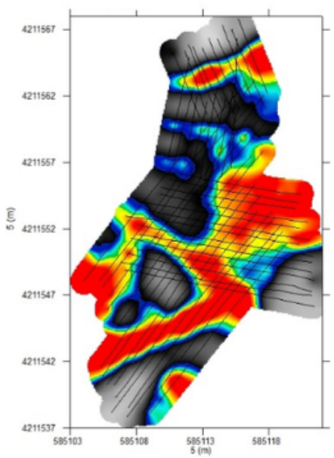
Project: MOTCO GPR Investigation
Location: Marine Ocean Terminal-Concord

Executing District: SPK
Responsibility: L. Hunter

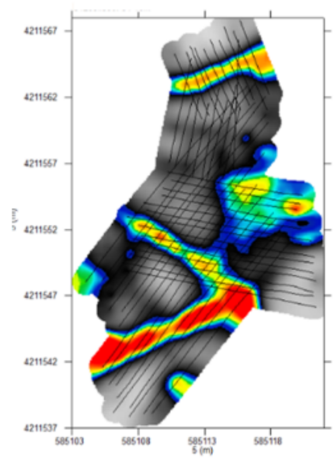
CASE STUDIES

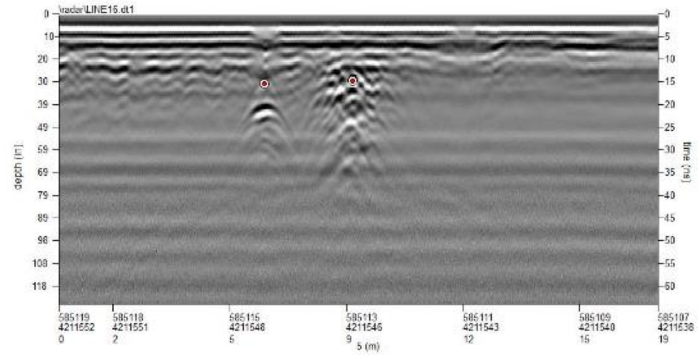
Results:

24-34 in

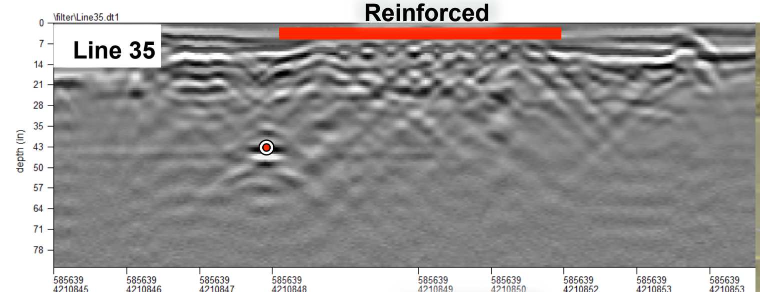


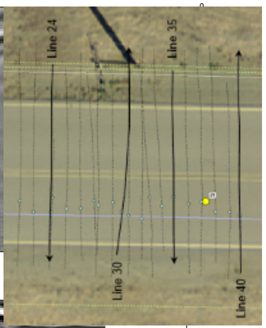
31-40 in

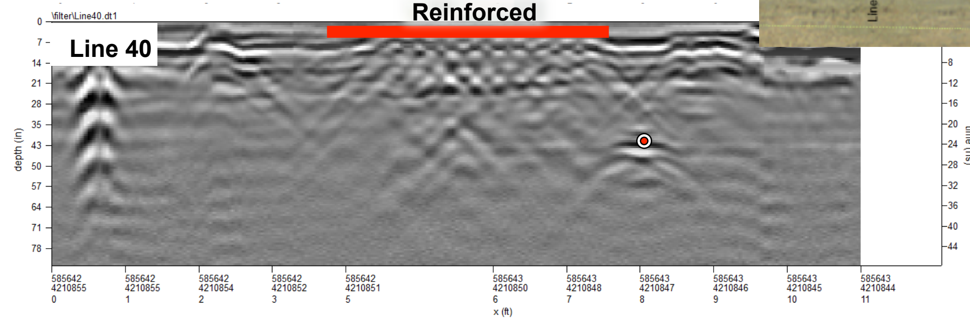




Site 18







UTM Coordinates (m)

Site 21

X (m)	Y (m)	Site	Line	Time (ns)	Depth (in)	comment
585632.4	4210847.8	21	22	23.57	42	WL
585633.3	4210847.1	21	23	21.95	39	WL
585633.2	4210847.7	21	24	22.22	39	WL
585634.0	4210846.6	21	25	21.27	38	WL
585634.7	4210848.0	21	26	22.22	39	WL
585635.4	4210847.1	21	27	22.22	39	WL
585635.6	4210848.0	21	28	22.08	39	WL
585636.3	4210846.5	21	29	21.13	37	WL
585636.8	4210847.8	21	30	20.18	36	WL
585637.1	4210846.3	21	31	20.73	37	WL
585637.8	4210847.6	21	32	21.27	38	WL
585638.2	4210847.1	21	33	21.27	38	WL
585638.7	4210848.1	21	34	21.54	38	WL
585639.3	4210847.1	21	35	20.59	36	WL
585640.0	4210848.3	21	36	20.46	36	WL
585640.7	4210846.7	21	37	20.73	37	WL
585641.4	4210848.0	21	38	21.27	38	WL
585642.2	4210846.4	21	39	21.54	38	WL
585642.6	4210848.0	21	40	22.22	39	WL

Project: MOTCO GPR Investigation
Location: Marine Ocean Terminal-Concord


CASE STUDIES

Objective(s):

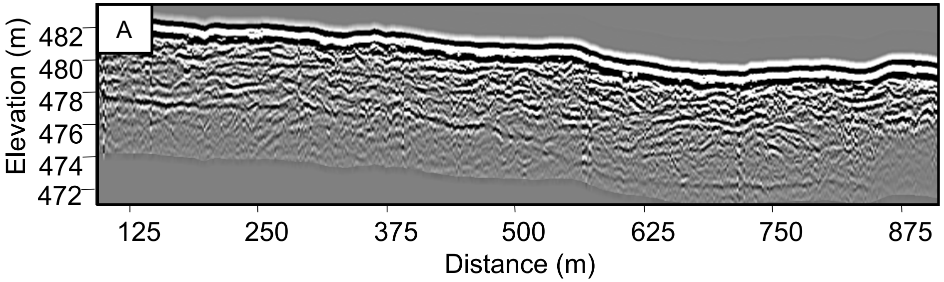
- Overall: To define processes affecting explosive contamination on firing ranges. Develop protocols for characterizing firing ranges.
- Specific: Evaluation of GPR performance in defining the hydrologic setting as part of site characterization phase.

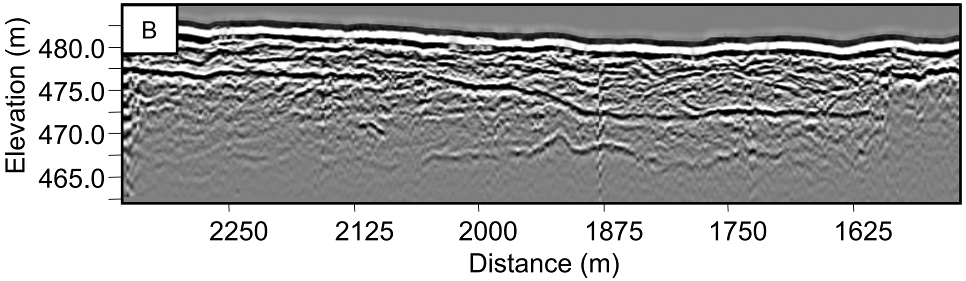
Method(s):

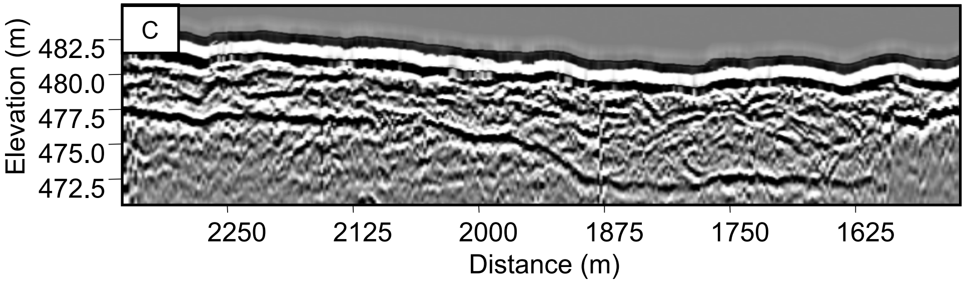
- GPR (S&S pulseEKKO 100 with 50- & 100-MHz antenna)



Results:







Project: GPR Groundwater Mapping
Location: Washington Range, Ft Greely, AK

Executing District: ERDC-CRREL
Responsibility: L. Hunter

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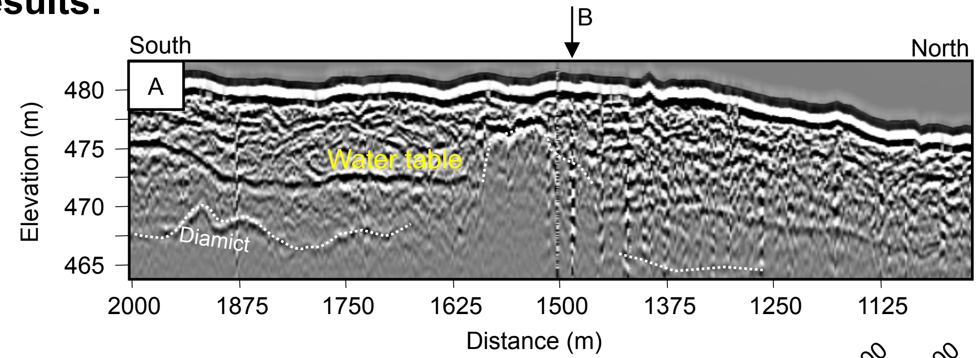
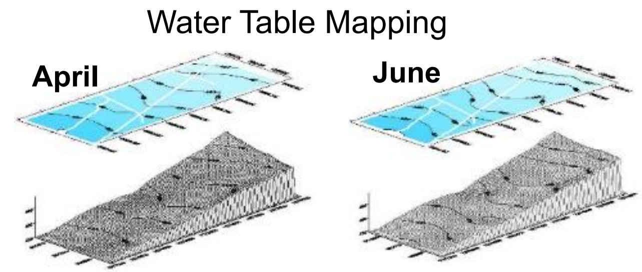
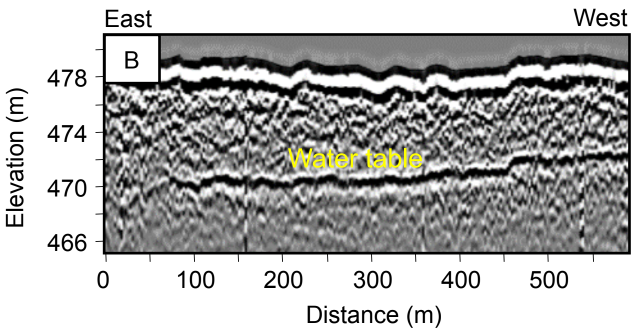
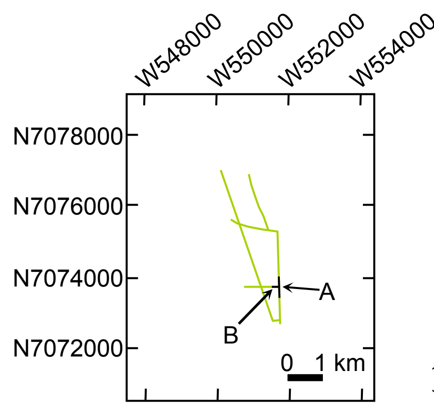
CASE STUDIES

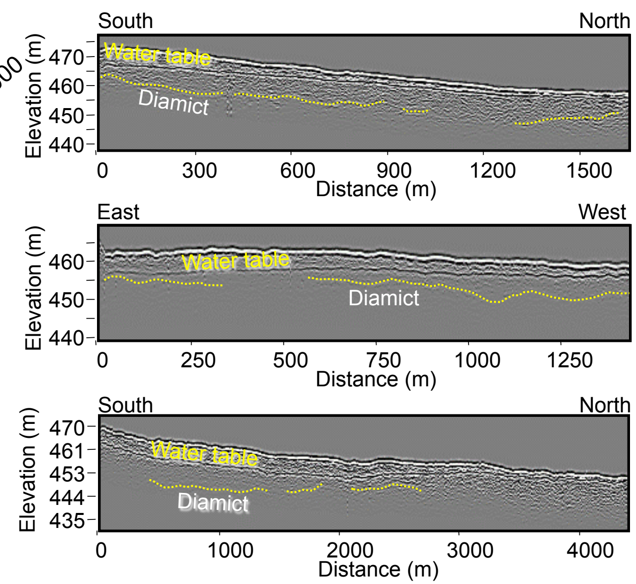
Results:











Results:

- **~20 km of gravel roads were surveyed in April & June**
- **Both 50 and 100 MHz detected water table in the coarse sandy gravels at depth up to 9 m**
- **Internal stratigraphy and depth to deep reflector (diamict) could often be observed**

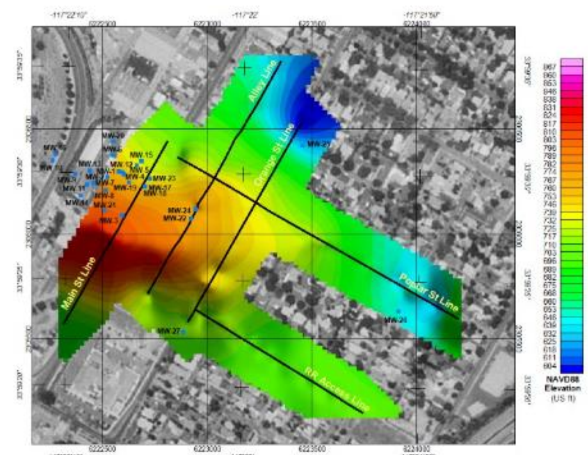
Project: GPR Groundwater Mapping
Location: Washington Range, Ft Greely, AK

CASE STUDIES

Target(s):
- Depth to bedrock in urban setting
- Chrome VI in fractured bedrock

Method(s):
- Seismic refraction
  - Vibroseis

Results:



CASE STUDIES

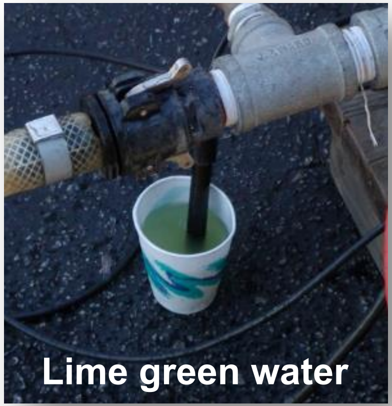
Target(s):

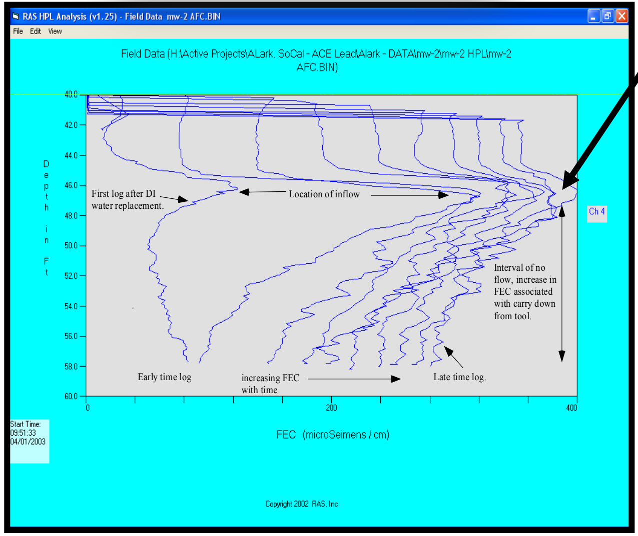
- Stratigraphic characterization
- Hydrostratigraphy

Method(s):

- Borehole Geophysics (induction, short-/long-normal resistivity, fluid resistivity, natural gamma, & optical.acoustic televiewer)
- Hydrophysics

Results:





Inflow zone:

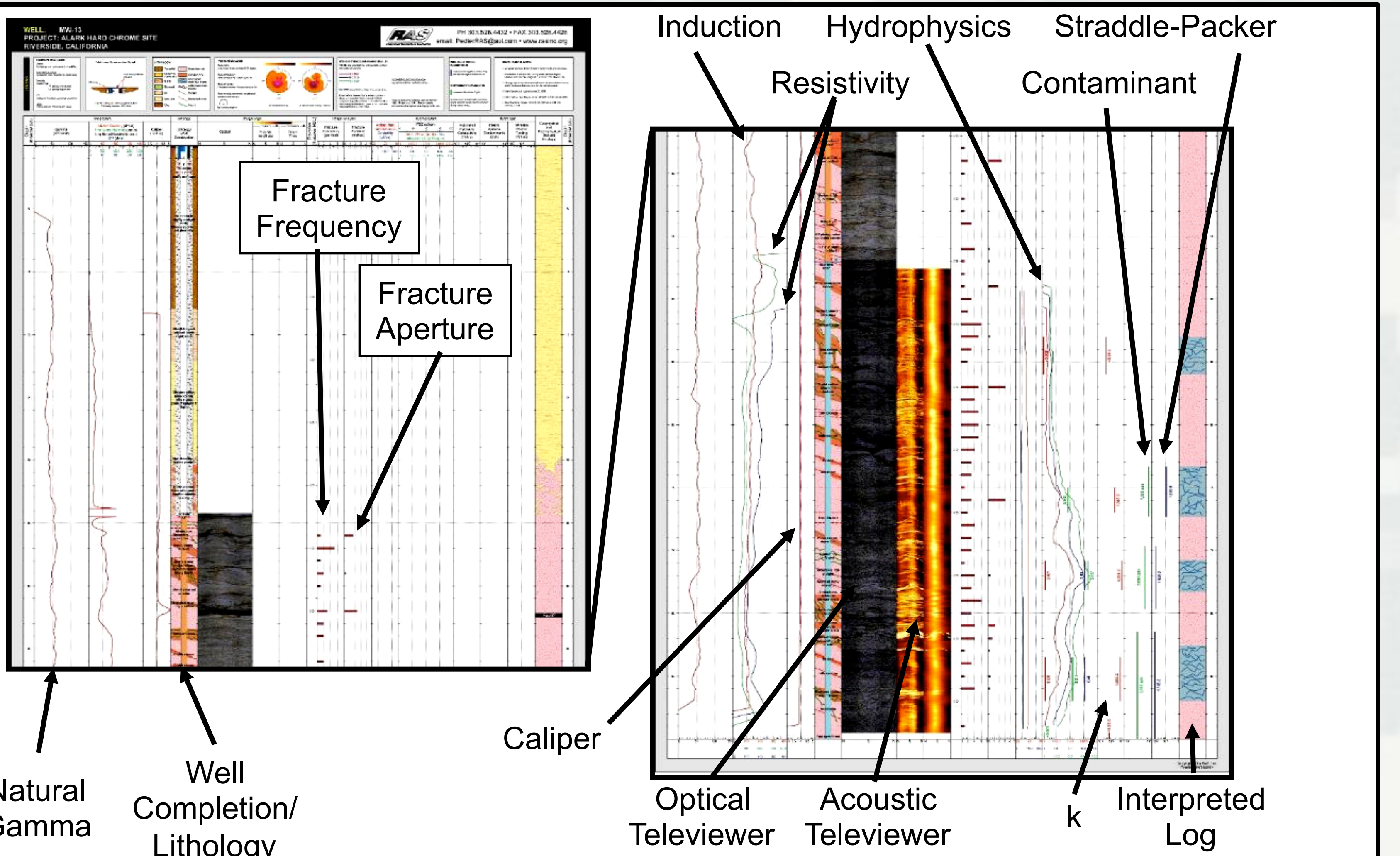
- Greater deflection of profile where DI is being replaced by ambient ground water
- Rate of deflection used to calculate mixing and hydraulic conductivity

Project: Alark Hard Chrome
Location: Riverside, CA

Executing District: SPK (w/B. Pedler) for EPA
Responsibility: L. Hunter & D. Henry

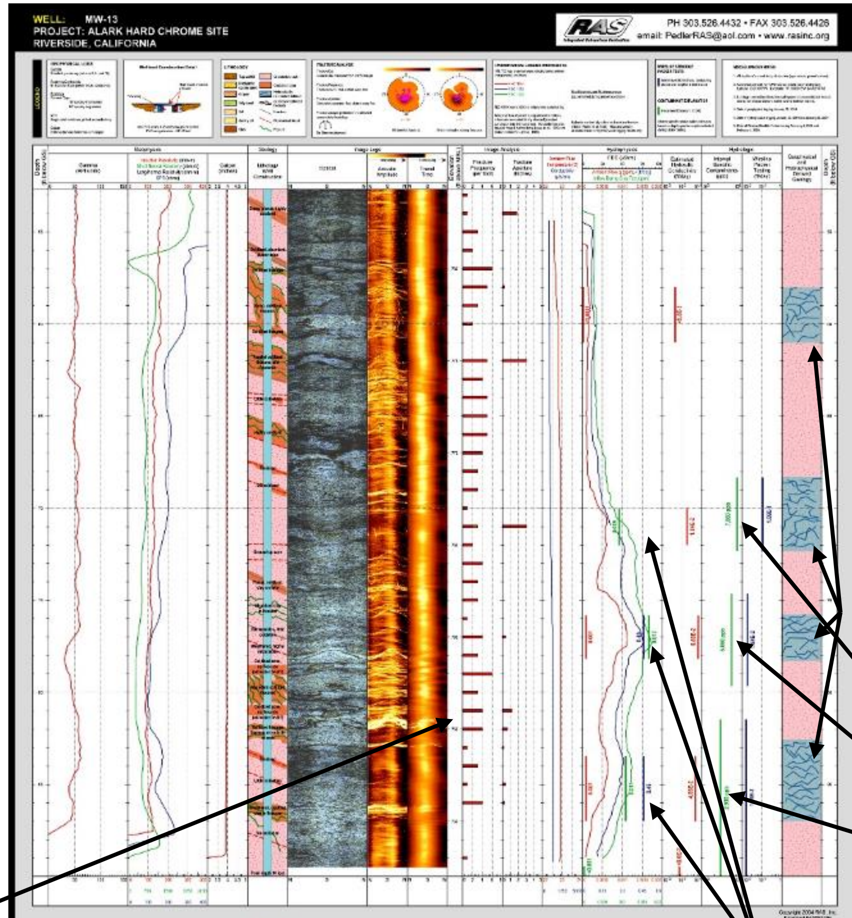
CASE STUDIES

Results:



CASE STUDIES

Results:



CASE STUDIES

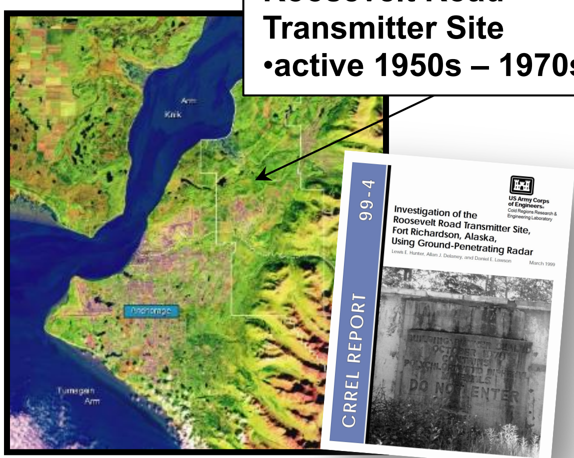
Target(s):

▪Determine if GPR could define the extent of an abandoned bunker contaminated with PCBs, map utilidors, pipes and identify buried excavation surfaces

Method(s):

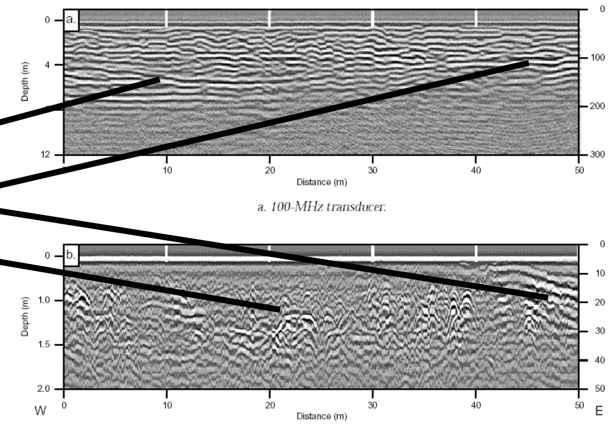
▪ GSSI System 10+ GPR system with 100- & 400-MHz antenna

Roosevelt Road Transmitter Site
•active 1950s – 1970s



Results:

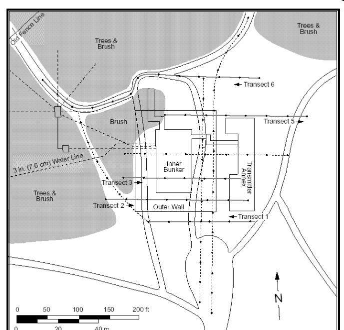
excavation surface
• sedimentary layering
• buried utilities

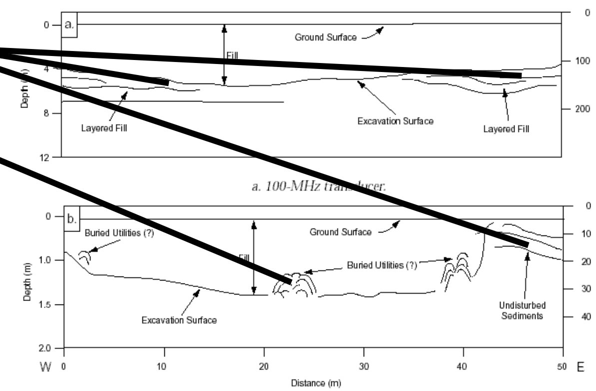


a. 100-MHz transducer.

b. 400-MHz transducer.

• excavation surface
• sedimentary layering
• buried utilities





a. 100-MHz transducer.

b. 400-MHz transducer.

Figure 10. Interpretive depth sections for transect 1.

CASE STUDIES

Results:

Raw Data

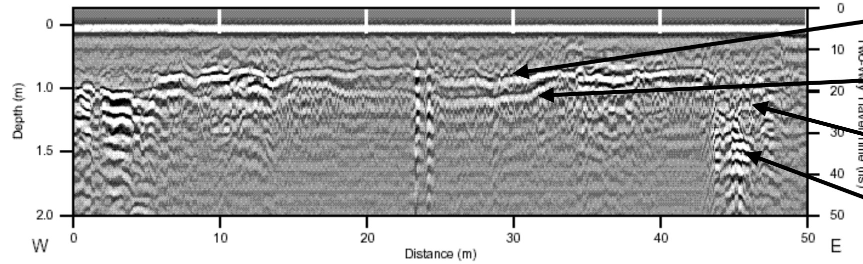


Figure 13. 400-MHz profile recorded along transect 3.

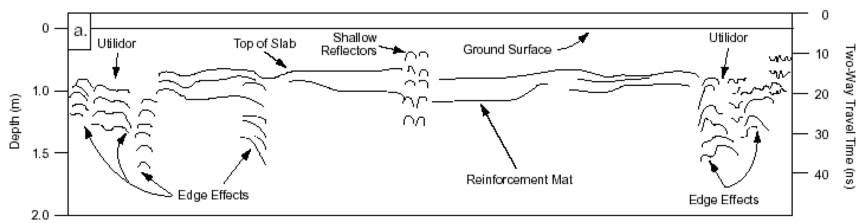
Reinforced concrete roof

Hyperbolas off rebar

Edge effects

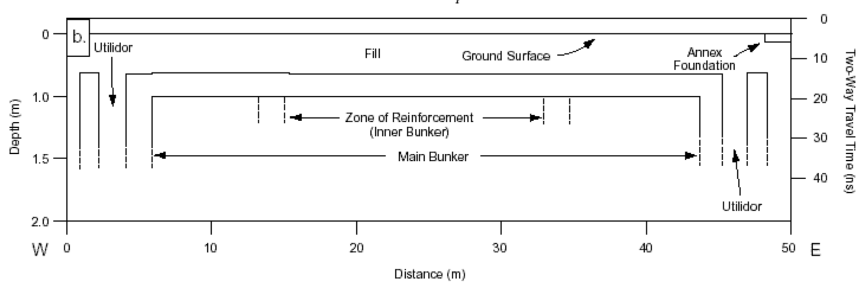
Utilidor floor

Interpretation



a. 400-MHz profile.

Annotated Interpretation



b. Annotated sketch.

Figure 14. Interpretive depth sections for transect 3.

Results:

GPR provided quick cost effective method to locate abandoned bunker and associated utilidors

Project: Roosevelt Road Transmitter
Location: Fort Richardson, AK

CASE STUDIES

Target(s):

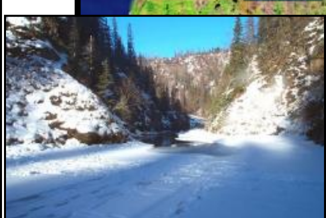
- Bathymetric mapping using GPR from frozen lake surface

Method(s):

- 50 & 100-MHz GPR using an pulseEKKO 100 GPR system

Ship Creek Reservoir

- Water source for Fort Richardson, Elmendorf AFB, and Anchorage



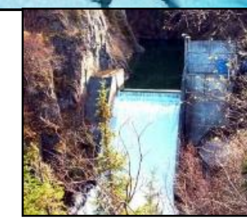
Monitoring sediment infilling at the Ship Creek Reservoir, Fort Richardson, Alaska, using GPR

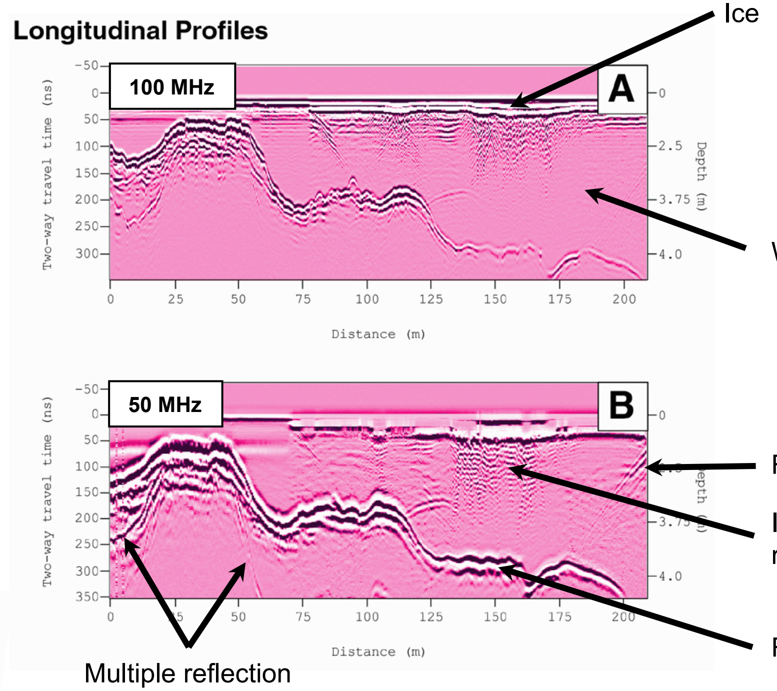
LEWIS E. HUNTER[1,2], MICHAEL G. FERRICK[1] & CHARLES M. COLLINS[3]

[1]Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, 72 Lyme Road, Hanover, New Hampshire 03755, USA
[2]Present address: US Army Corps of Engineers, Sacramento, CA 95814, USA
[3]Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Building 7040, Fort Wainwright, Alaska 99703, USA

Abstract: The Ship Creek Reservoir serves as the municipal water supply for Fort Richardson, ...

Results:





Project: Fort Richardson Reservoir
Location: Fort Richardson, AK

Executing District: ERDC-CRREL
Responsibility: L. Hunter

BUILDING STRONG®

CASE STUDIES

Results:

Table 2. Ship Creek Reservoir Sedimentation Rate Estimates

Period	Years	Survey Length (m)	Total Accumulation (m^3)	Mean Annual Accumulation (m^3/yr)	Annual Unit Accumulation (m^3/yr/m)
1976-81	5	183	56,577	37,626	62.7
1983-88	5	183	73,397	47,659	80.3
1988-89	1	427	35,934	117,894	82.8
1989-95	6	427	354,753	193,145	138.0
1989-95	6	259	122,329	67,726	77.8
1995-01	6	251	91,746	50,168	60.2
Total	23	—	611,795	—	—

Results:

- Volume estimates between 1976 to 1995 derived from repeat bathymetric surveys made before and after reservoir dredging
- 1995 to 2001 estimate determined by comparing 1995 bathymetric results to 2001 radar survey
- Radar survey results comparable to bathymetric surveys
- Survey performed over 2 day period with party of 2

CASE STUDIES

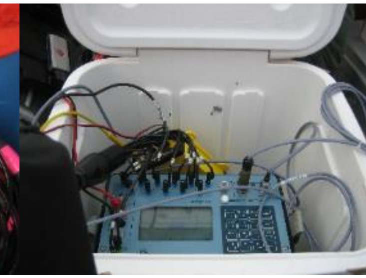
Target(s):

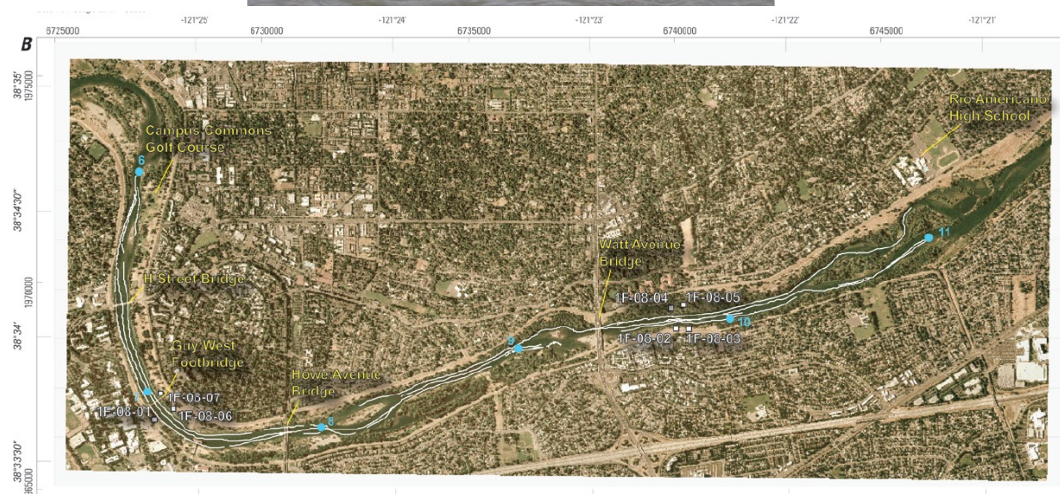
- Stratigraphy
  - (Locating dense layer that will retard downward erosion)

Method(s):

- DC Resistivity





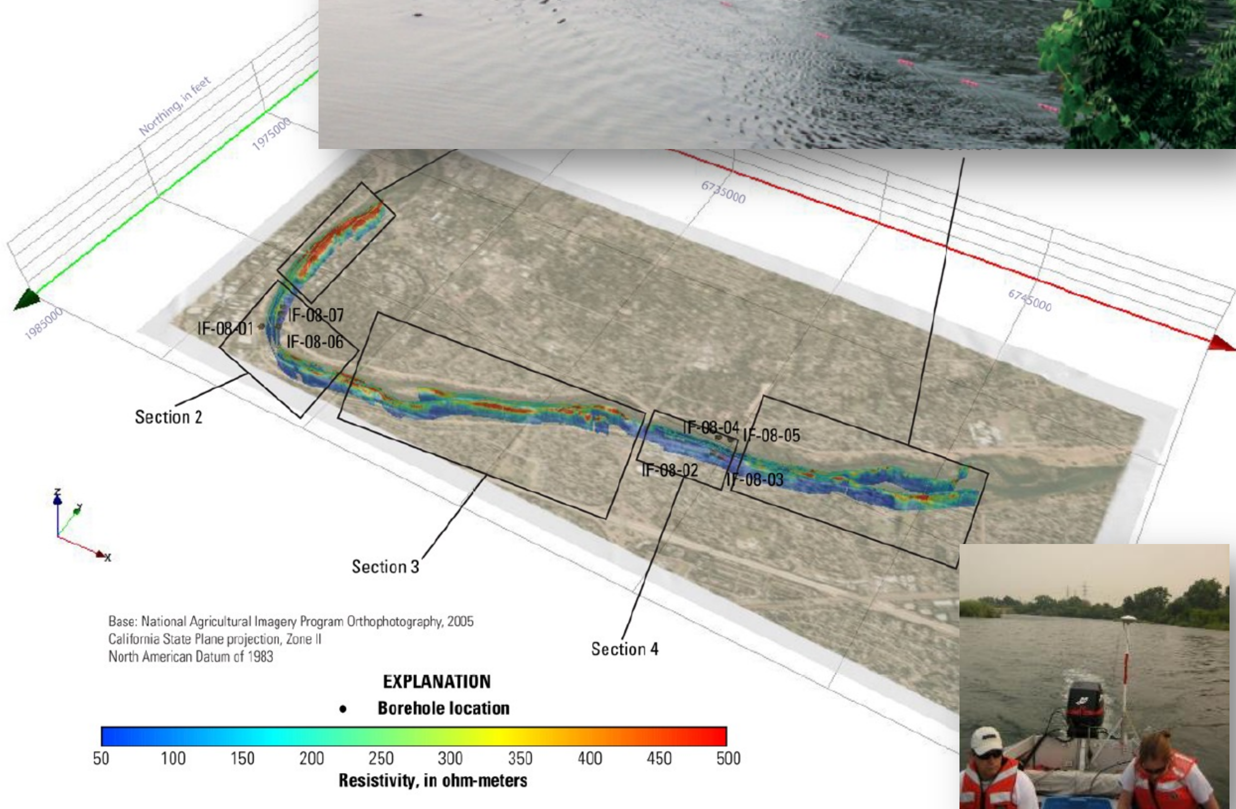



Project: American River GRR
Location: Sacramento, CA

Executing District: SPK (w/USGS: B. Burton & L. Ball)
Responsibility: L. Hunter

CASE STUDIES

Results:



- 3 water-borne continuous resistivity profiling lines
- inverted resistivity profiles used to interpretations the extent & thickness of geologic layers
- an intermittent high-resistivity layer extends to a depth of up to 30 ft (9 m)
- underlain by a low-resistivity layer (high-clay content) extending below 60 ft (18 m)
- high-resistivity layer is absent immediately upstream of the Watt Avenue Bridge
- low-resistivity layer extends to the surface where a scour-resistant unit is observed

Project: American River GRR
Location: Sacramento, CA

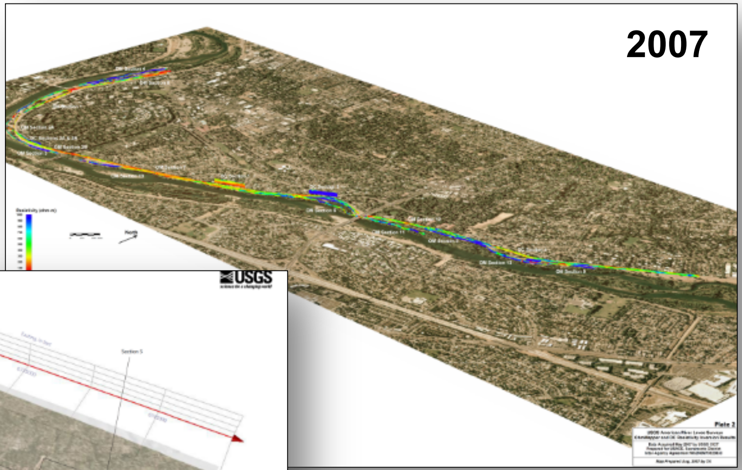
CASE STUDIES

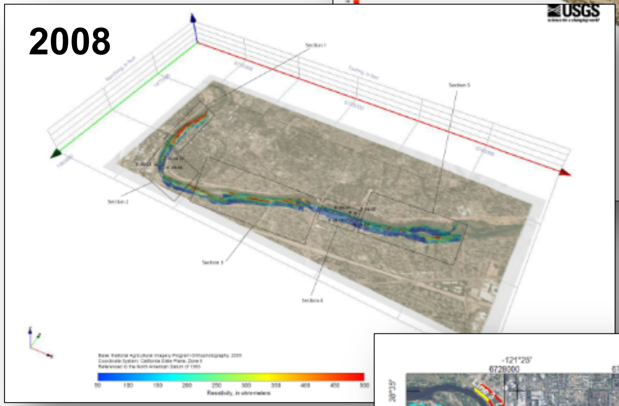
Target(s):
- Stratigraphic investigations
- Define “erosion resistant” layer

Method(s):
- DC Resistivity
- Capacitively-coupled resistivity
- FDEM (Duel EM – test)
- Re-evaluation of airborne EM collected for DWR

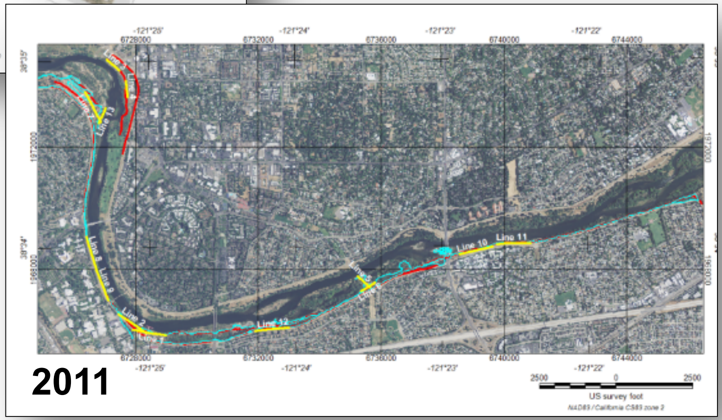
- **May 2007**
  - **Capacitively-coupled resistivity (OhmMapper)**
  - **DC resistivity**
  - **Frequency-Domain EM (FDEM)**
  - **All on right bank**
- **May-June 2008**
  - **Waterborne DC resistivity**
  - **Channel**
- **June 2011**
  - **Capacitively-coupled resistivity (OhmMapper)**
  - **DC resistivity**
  - **Testing of Dual EM (FDEM)**
  - **Mostly left bank, right bank from Campus Commons Golf Course to Cal Expo**

Results:





3-D model by T. Asch (USGS)

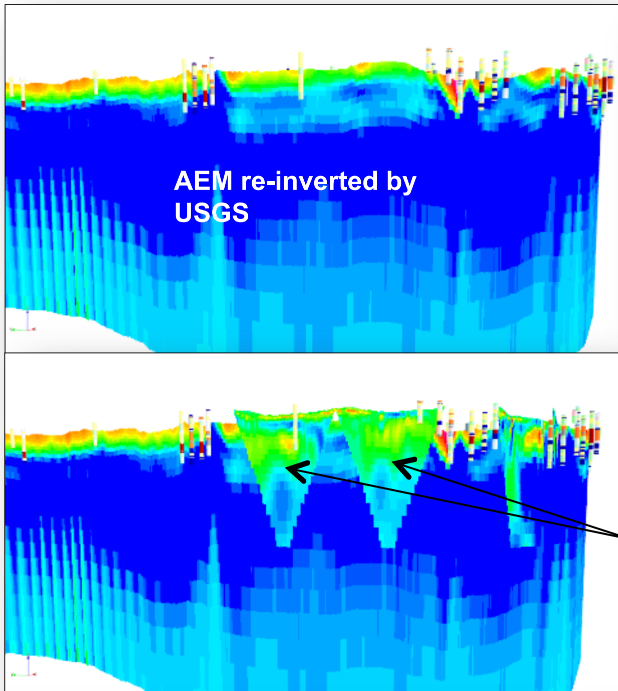


Project: American River GRR
Location: Sacramento, CA

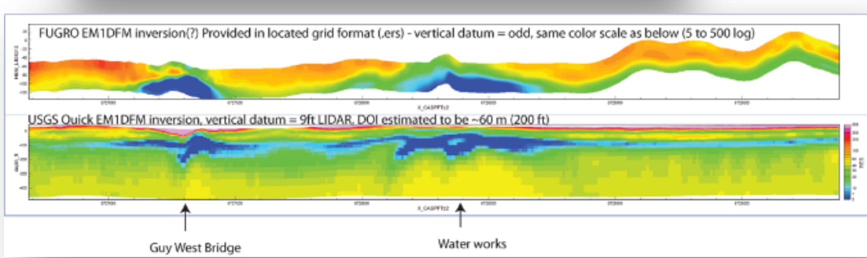
Executing District: SPK (w/USGS: T. Asch)
Responsibility: L. Hunter

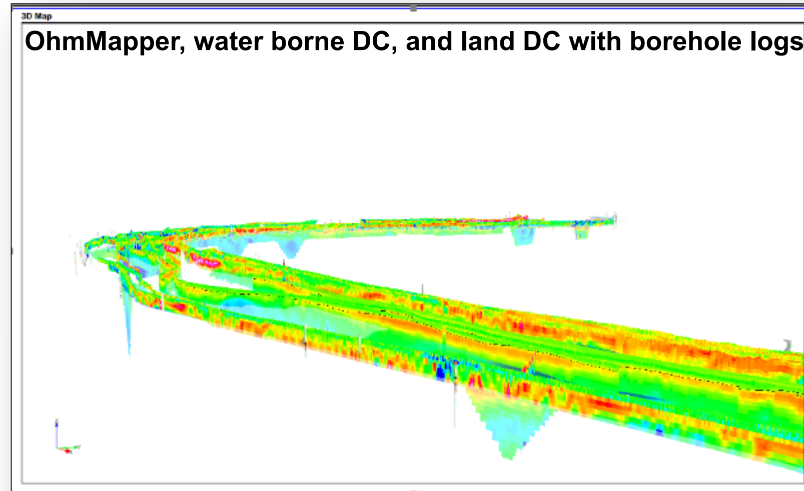
CASE STUDIES

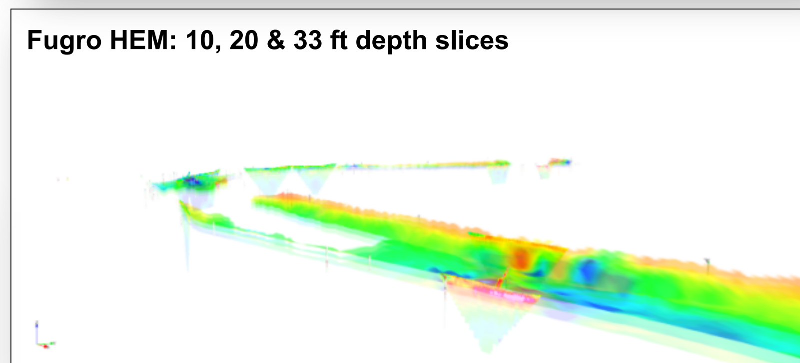
Results:



Compared with closely located inverted ground DC resistivity data

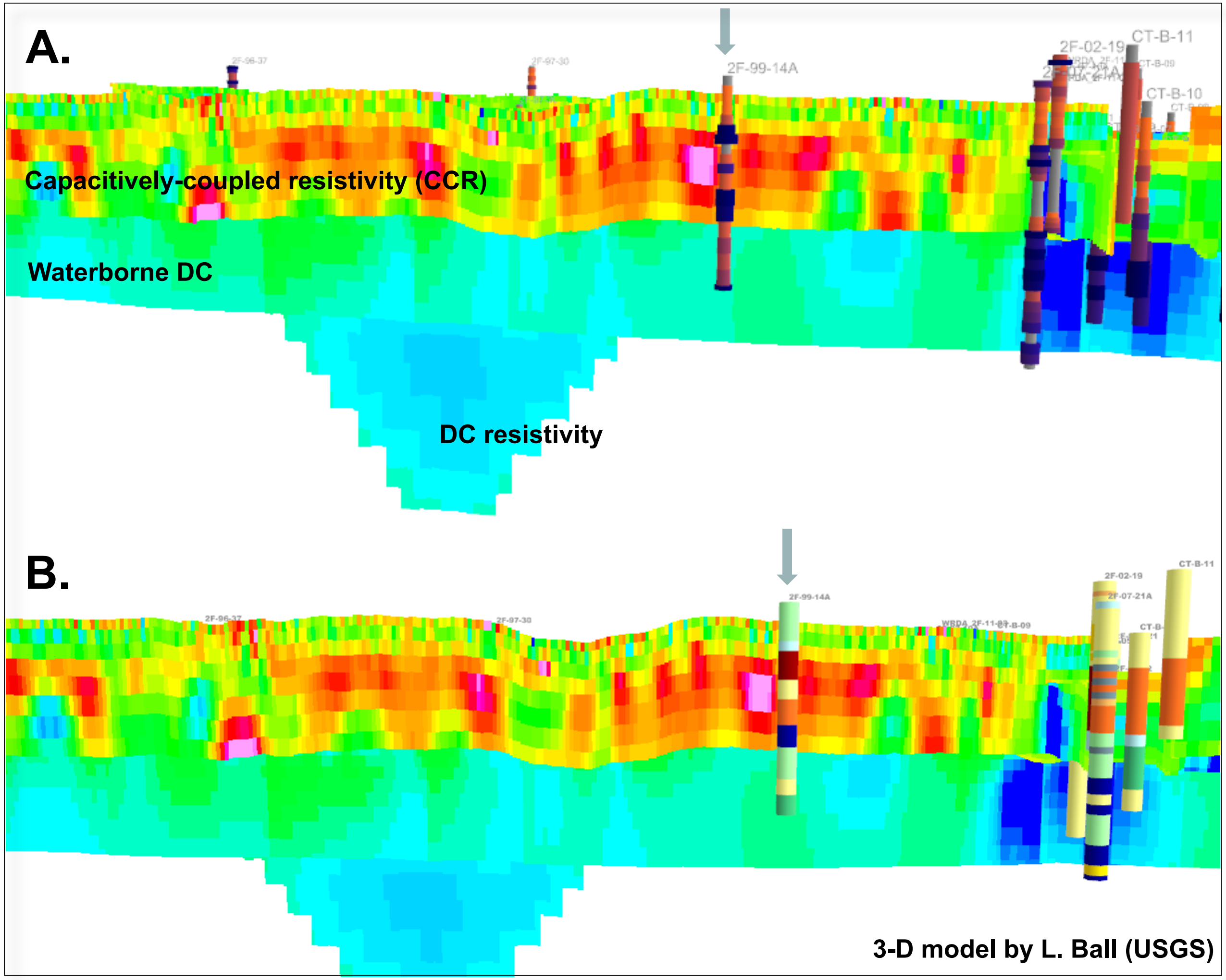




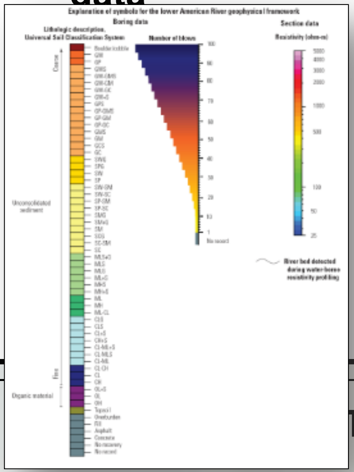


3-D model by L. Ball (USGS)

CASE STUDIES



- Strong correlation between
  - resistor
  - high blow-count layer
  - gravel/sand and gravel (2F-99-14A)
- Arrows indicate close boreholes. Because this is 3D, other boreholes aren't necessarily close to transects
  - Included to show the complexity and variability of boring data



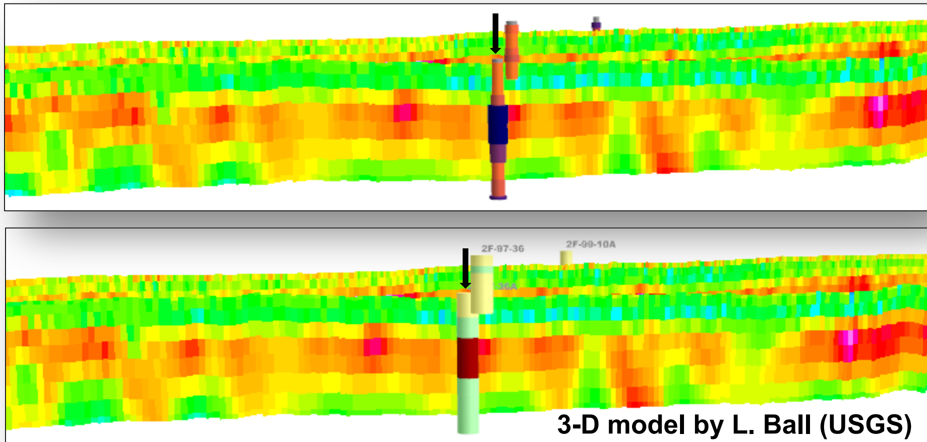
Project: American River GRR
Location: Sacramento, CA

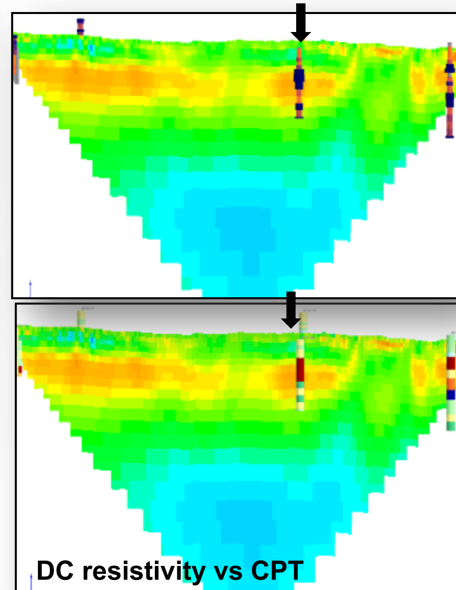
A. CPT

B. soil classification

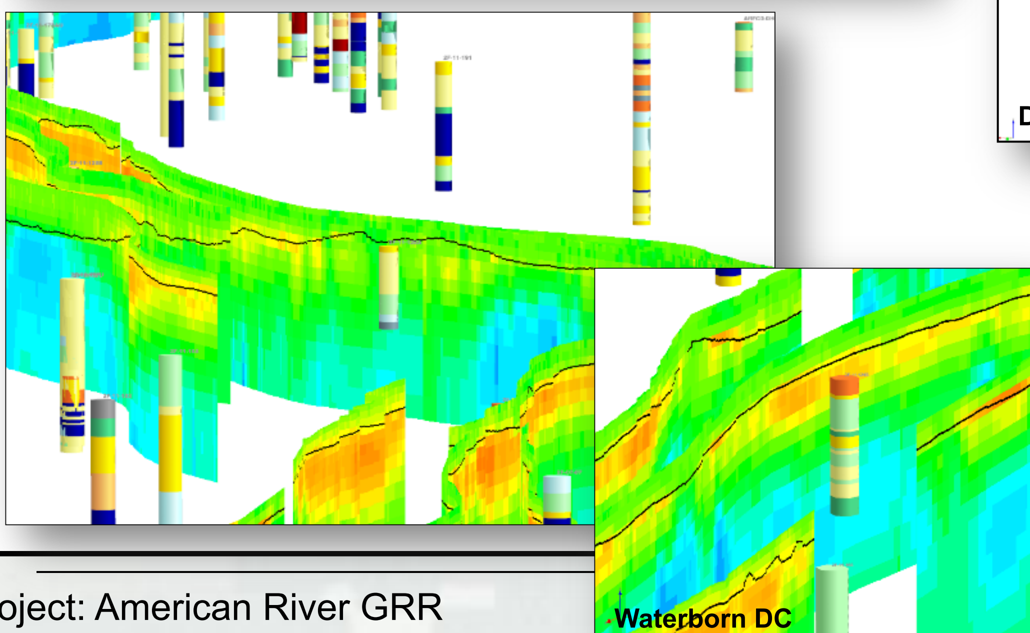
TRONG®

CASE STUDIES





- Agrees well
  - ➢ Gravel is thicker
  - ➢ Appears to extend all the way to the next survey line
- stiffness break at contact between sand and gravel
  - ➢ sand is stiffer than gravel



- ➢ Sand is consistently moderate resistivity
- ➢ Gravel is high resistivity
- ➢ Silts and clays are low resistivity (conductive)

CASE STUDIES

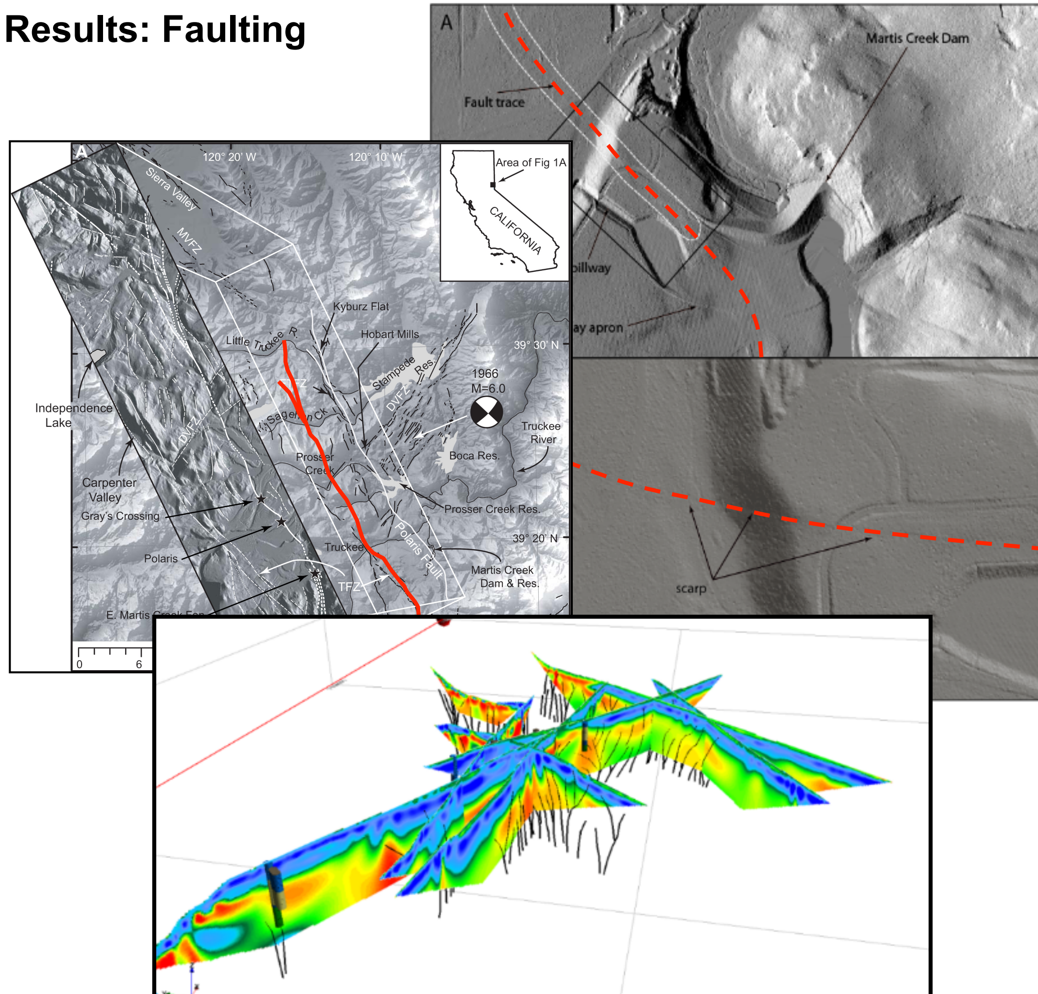
Target(s):

- Depth to bedrock
- Water table/seepage
- Variations in foundation properties/ stratigraphy
- Identification of liquefiable zones
- Faulting

Method(s):

- P- & S-wave seismic refraction
- DC Resistivity
- Continuous source audio-magnetotellurics (CS-AMT)
- Self-potential

Results: Faulting



Project: Martis Creek Dam
Location: Truckee, CA

Executing District: SPK (w/USGS)
Responsibility: L. Hunter

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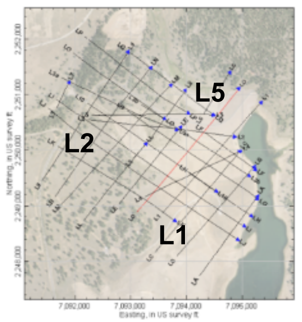
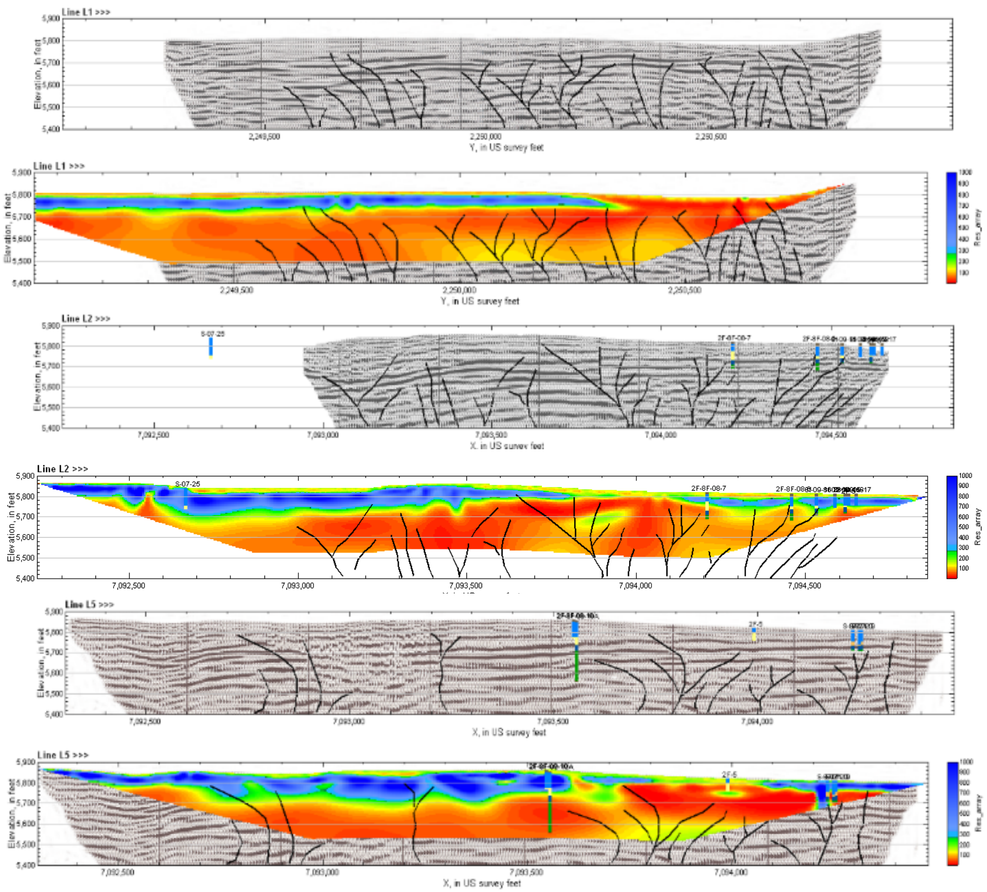


CASE STUDIES



Wells and Coppersmith (1994)*

- **Surface rupture length (SLR)**

Eq. 1 M = 5.08 + 1.16 x log(SLR)

- **Subsurface rupture area (RA)**

Eq. 2 M = 4.38 + 1.49 x log(RA)

Hanks and Bakun (2002)

Eq. 3 M = log(RA) + 3.98 $\pm$ 0.03 (for A $\leq$ 537 km^2)

* Regression lines for all fault-types

POLARIS FAULT, TRUCKEE, CA

Length (km)	Depth (km)	Area (km^2)	Eq. 1 M	Eq. 2 M	Eq. 3 M
30	15	450	6.79	6.67	6.63
35	15	525	6.87	6.74	6.70
38	15	570	6.91	6.77	6.74

Conservative estimates indicate Polaris Fault may be capable of a M 6.6 to 6.9 event

Project: Martis Creek Dam
Location: Truckee, CA

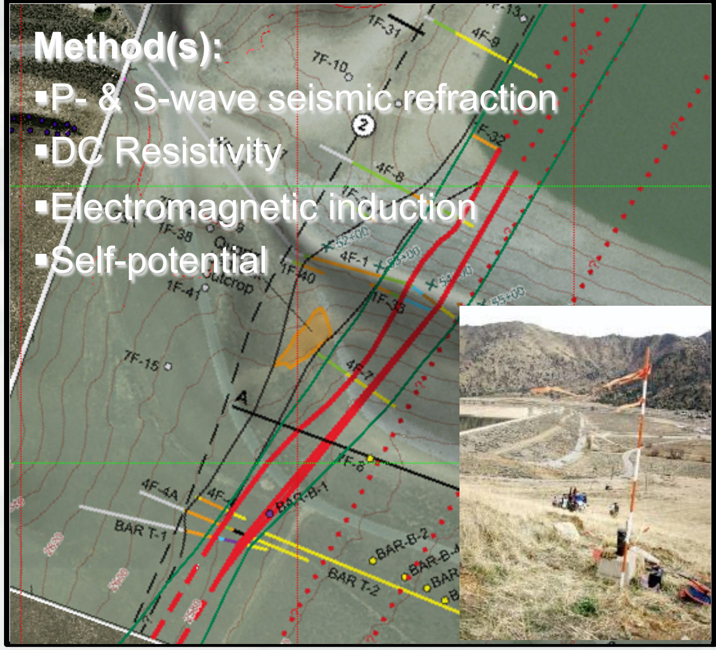
CASE STUDIES

Target(s):

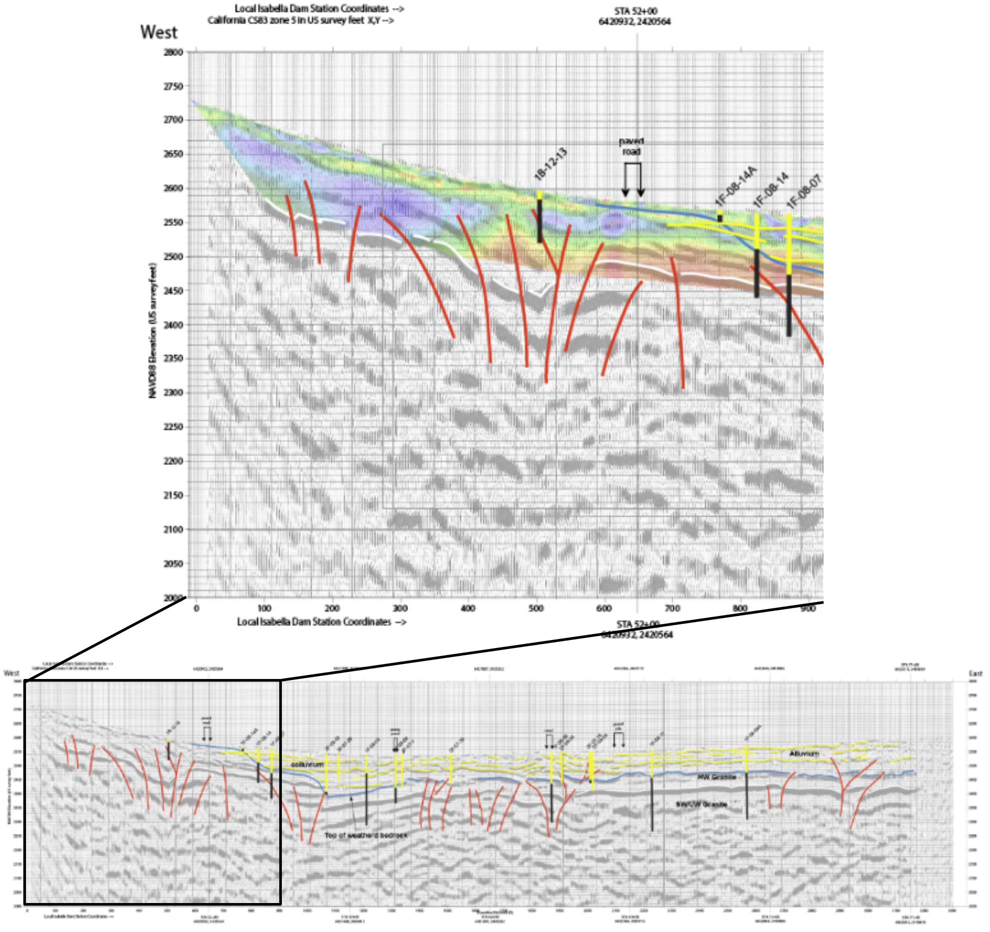
- Depth to bedrock
- Water table/seepage
- Variations in foundation properties/ stratigraphy
- Identification of liquefiable zones
- Faulting

Method(s):

- P- & S-wave seismic refraction
- DC Resistivity
- Electromagnetic induction
- Self-potential



Faulting



Project: Isabella Dam
Location: Lake Isabella, CA

Executing District: SPK (w/USGS)
Responsibility: L. Hunter w/J. Jackson

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CASE STUDIES

Target(s):

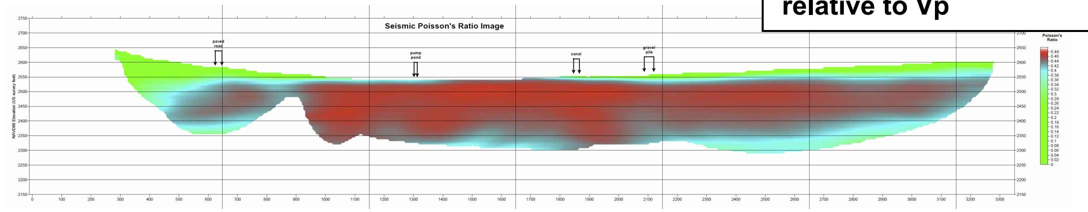
- Depth to bedrock
- Water table/seepage
- Variations in foundation properties/ stratigraphy
- Identification of liquefiable zones
- Faulting

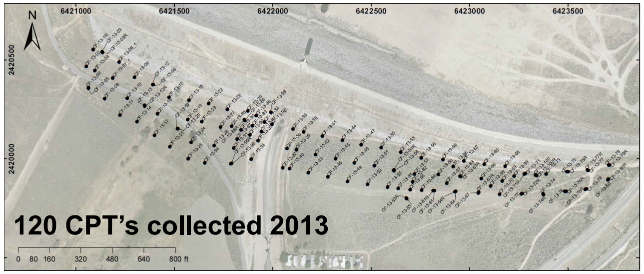
Method(s):

- P- & S-wave seismic refraction
- DC Resistivity
- Electromagnetic induction
- Self-potential

Results: Liquefaction

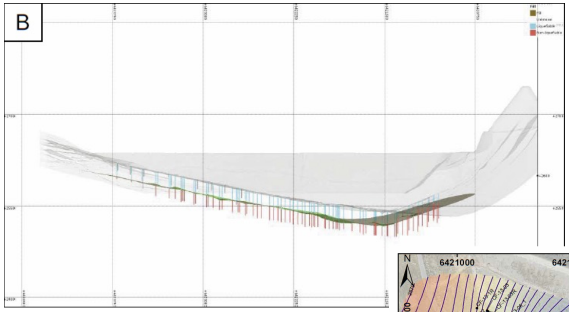
Poisson's ration used to look for zones where Vs is proportionally low relative to Vp

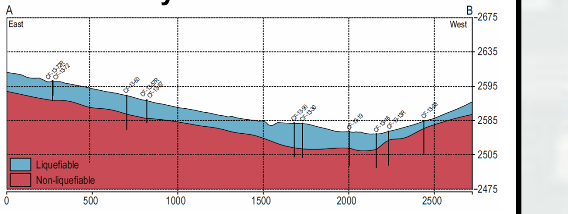


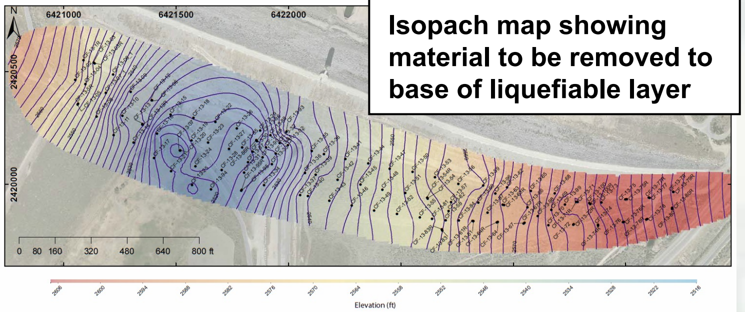


120 CPT's collected 2013

Factor of safety against liquefaction (FS_{liq}) calculated based on Youd et al. (2001) & Idriss & Boulanger (2008) to determine amount of material to remove to get below upper liquefiable layer







Isopach map showing material to be removed to base of liquefiable layer

Project: Isabella Dam
Location: Lake Isabella, CA

Executing District: SPK (w
Responsibility: L. Hunter

CASE STUDIES

Target(s):

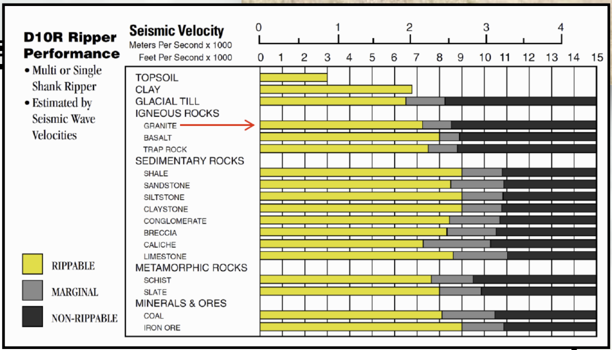
- Depth to bedrock
- Water table/seepage
- Variations in foundation properties/ stratigraphy
- Identification of liquefiable zones
- Faulting

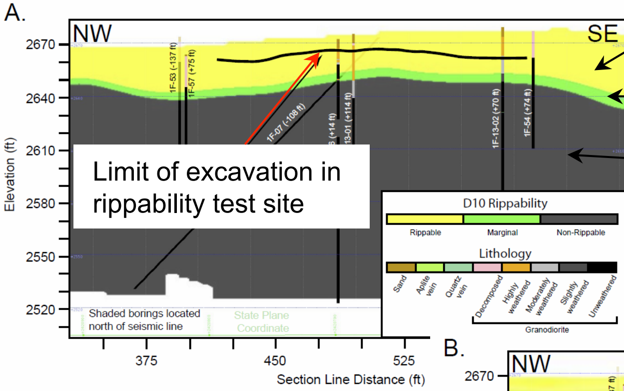
Method(s):

- P- & S-wave seismic refraction
- DC Resistivity
- Electromagnetic induction
- Self-potential

Rippability

Caterpillar rippability chart
- Granite
  - ➢ Rippable ~7.2 kfps
  - ➢ Marginally 7.2 – 8.5 kfps



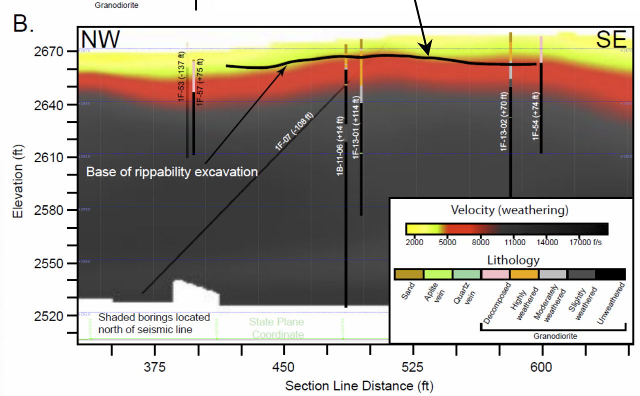


Rippable

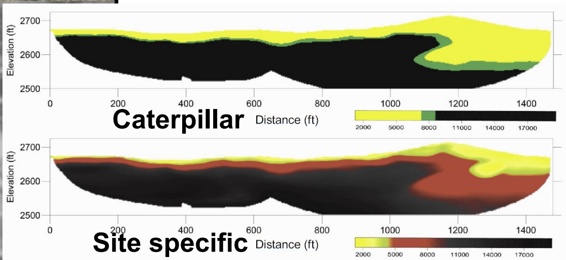
Marginally rippable

Non-rippable

Observed rippable base 4 – 5 kfps



Re-project w/new color scales



Project: Isabella Dam
Location: Lake Isabella, CA

Executing District: SPK (w/USGS)
Responsibility: L. Hunter

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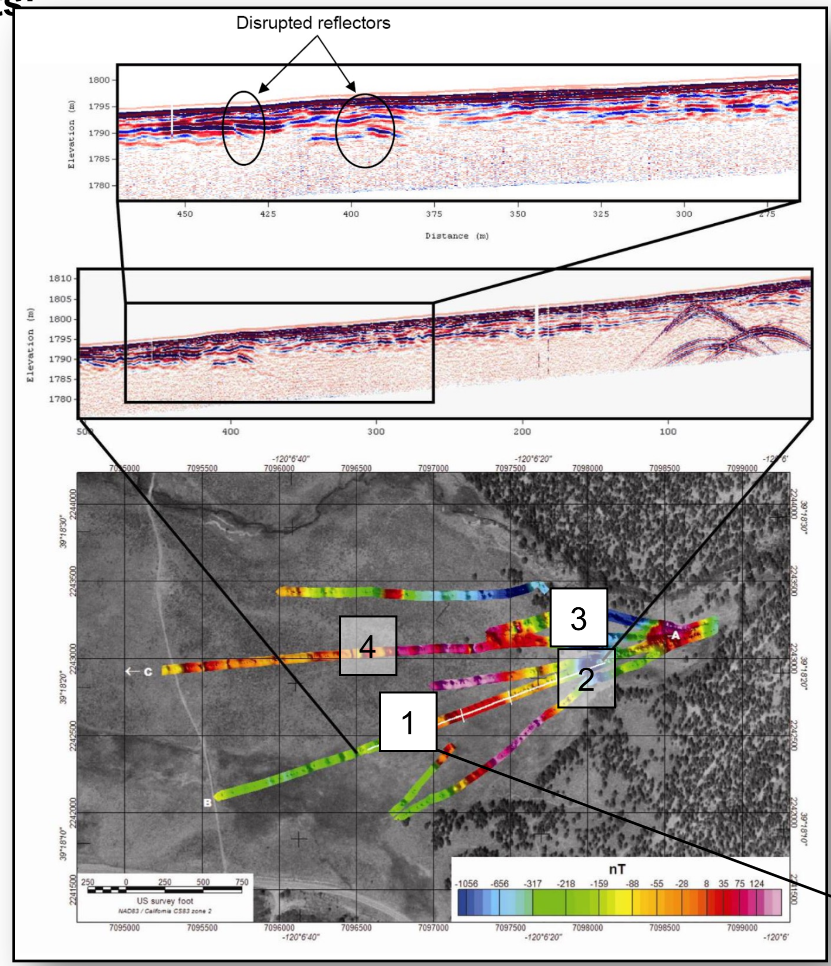
CASE STUDIES

Results:

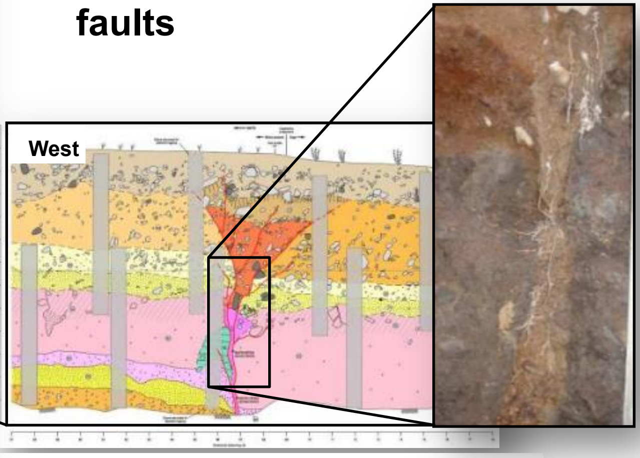


Initial verification:

- GPR & magnetics
  - Anomalies corresponding to lineaments

Selected potential trench locations using LiDAR and geophysics

- Sites 1 & 3 both encountered faults



From Kleinfelder-Geomatrix Joint Venture, 2009 – Trench Report

CASE STUDIES

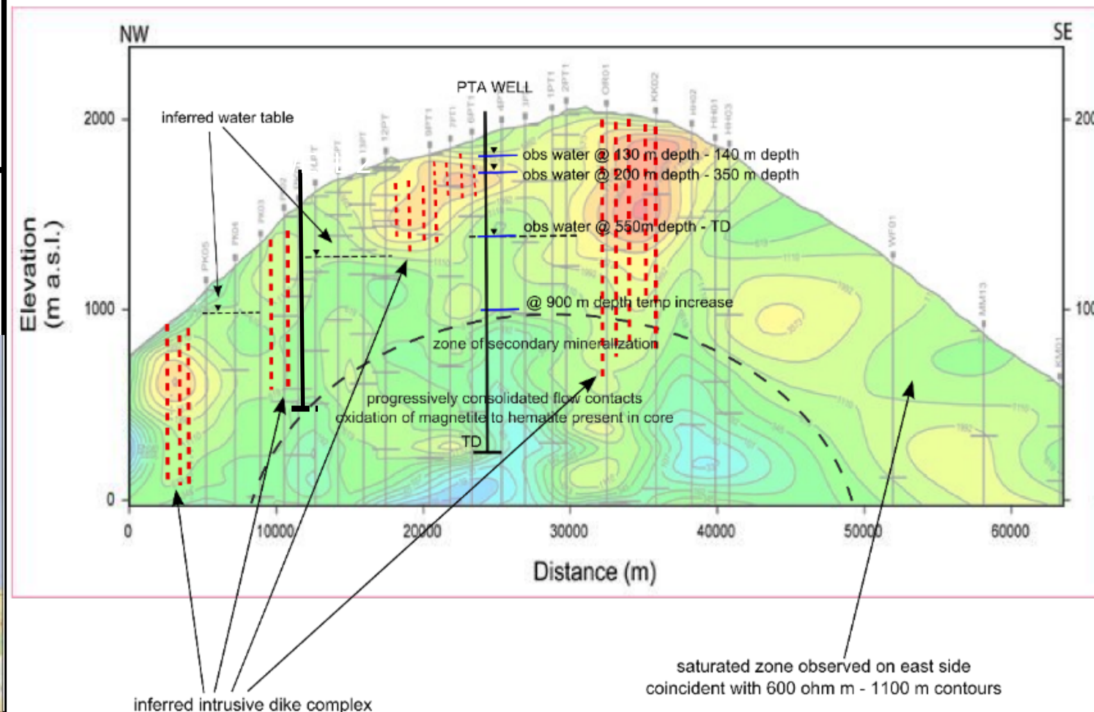
Target(s):

- Survey goal was to look for water in the saddle between Mauna Kea and Mauna Loa

Method(s):

- Magnetotellurics and Audio-magnetotellurics

Results:



- **Perched layers from 130-140 m, 200-350 m &550 m depth**
- **Cores:**
  - **Identified zones of secondary mineralization.**
  - **Alternating confining layers after confining layers**

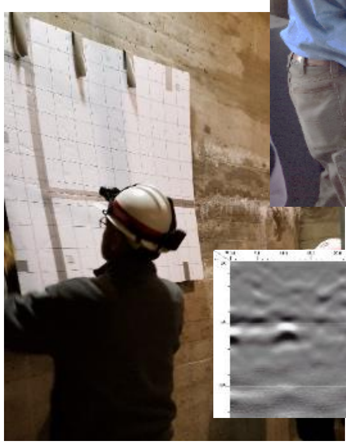
CASE STUDIES

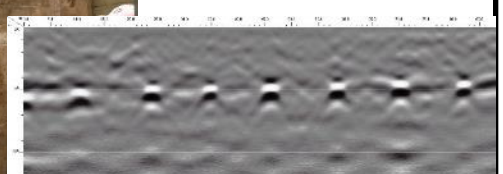
Target(s):

- **Concrete evaluation**
  - **Does crack correspond to construction joint?**
  - **Does vertical rebar run continuously across crack or is it lapped properly?**
  - **Are rebar locations consistent with drawings. 12” o.c.?**

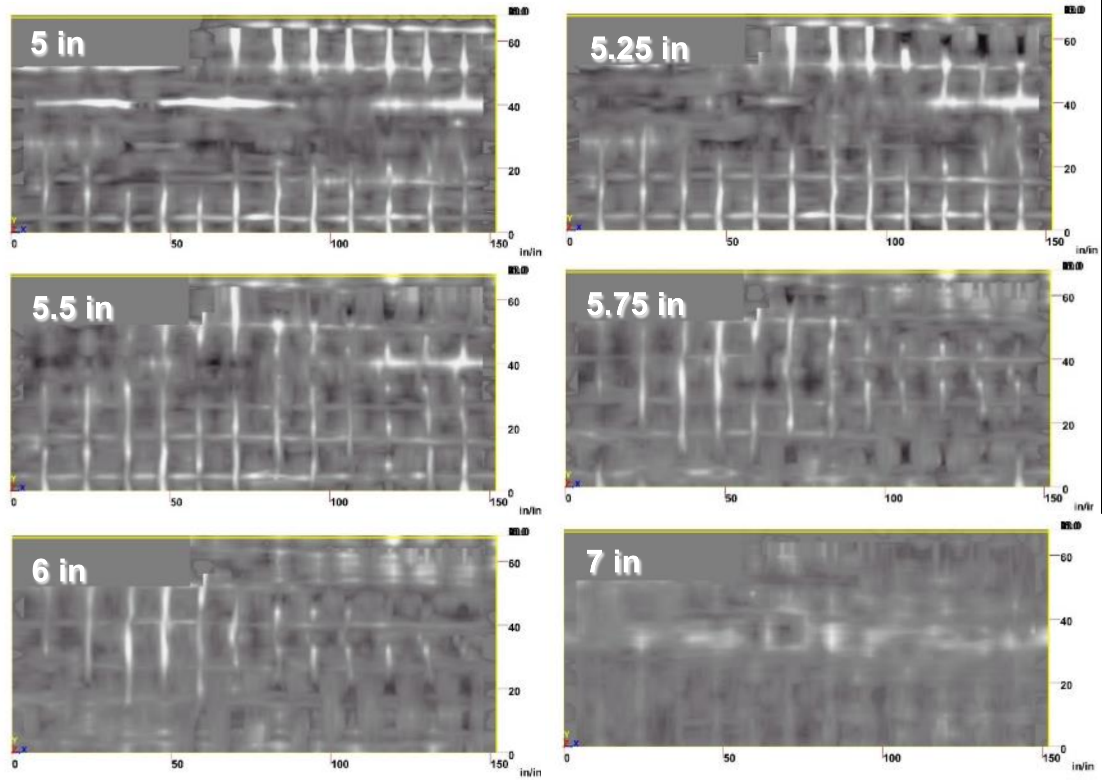
Method(s):

- GPR





Results:



- **Survey confirmed 12-in centers in the rebar**
- **Waterstop appears to be coming into view @ 7-in**