

Utilizing Electrical Hydrogeology for Regulatory Approval of an MNA Remedy



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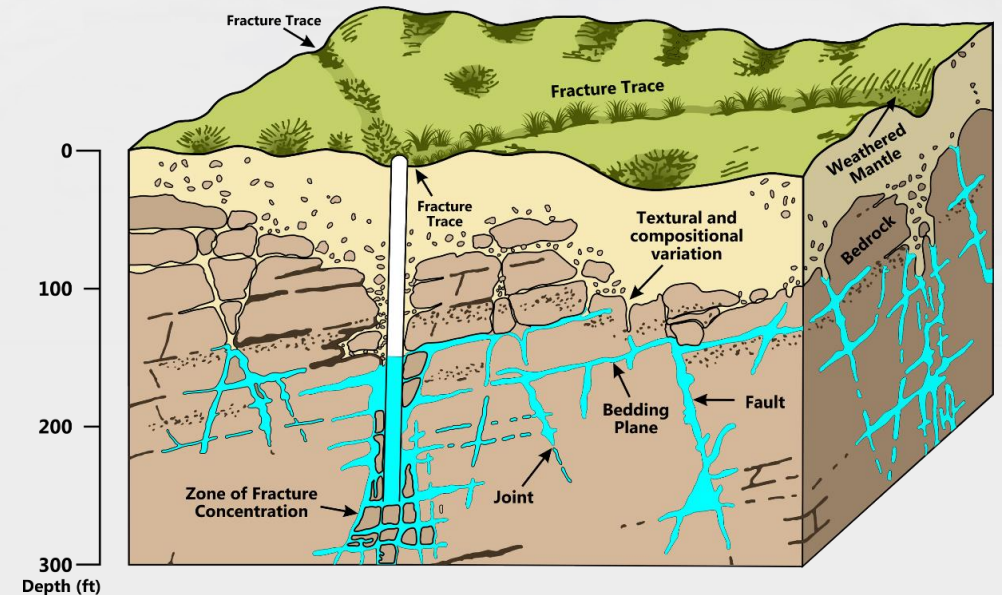
Executive Summary

- What is Electrical Hydrogeology?
- Interpreting electrical “pictures”
- Case Study – Star City, Arkansas
- Case Study – Oklahoma City, Oklahoma
- Conclusions/Final Comments
- Future Considerations
- Acknowledgements



What is Electrical Hydrogeology?

- Hydrogeology = the branch of geology concerned with water occurring underground or on the surface of the earth
- Electrical hydrogeology = assessing the hydrogeology of a site using data-dense ERI process (*GeoTrax Survey™*)
- Acronyms
 - ERI = Electrical Resistivity Imaging
 - CSM = Conceptual Site Model
 - HRSC = High-Resolution Site Characterization
 - RDC = Remedial Design Characterization



Industry Problem & Solution

GEO TRAX SURVEY™
Scan. Visualize. Understand.



www.aestusllc.com



The Solution: HRSC & RDC

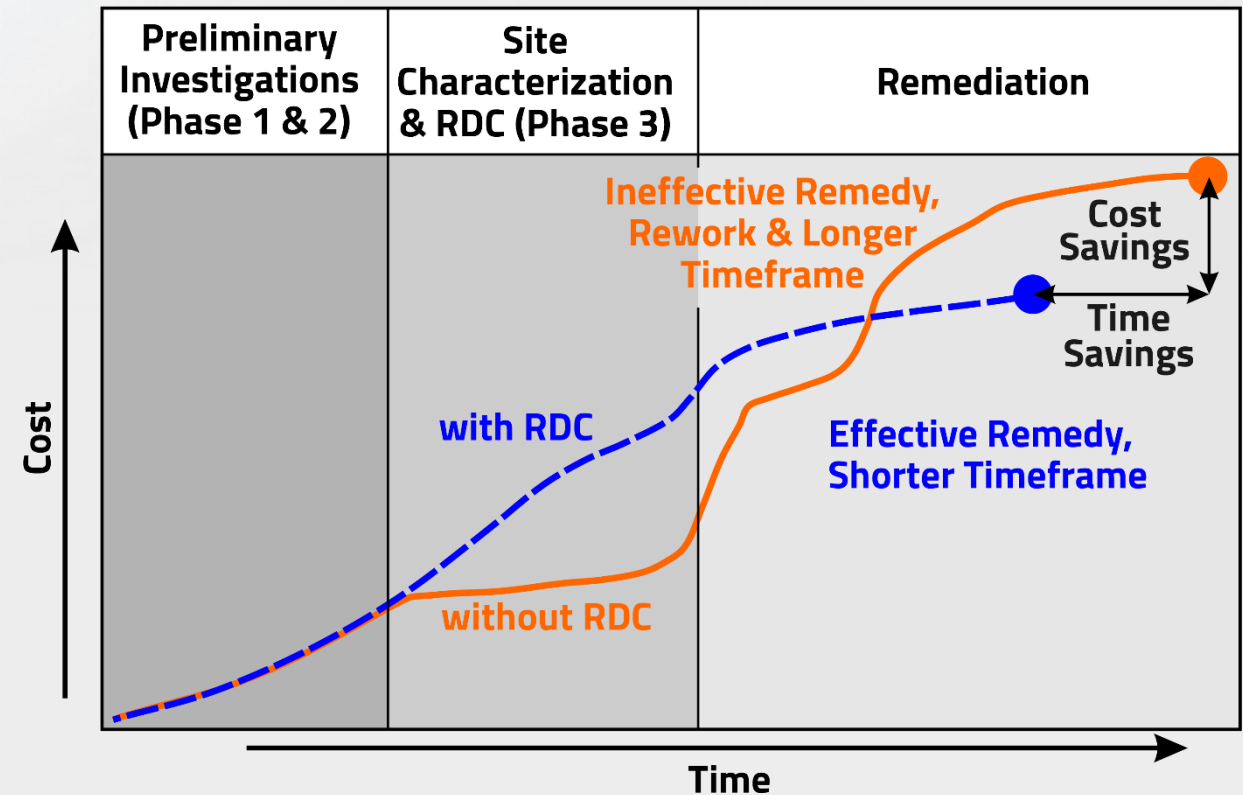
Investing in characterization will save significant **time and money** on an overall project basis

~10,000 wells to "see" this way



Cape Cod (LeBlanc et al. 1991); Borden (Sudicky et al. 1983)

Use of Phase 3 RDC (Remedial Design Characterization)

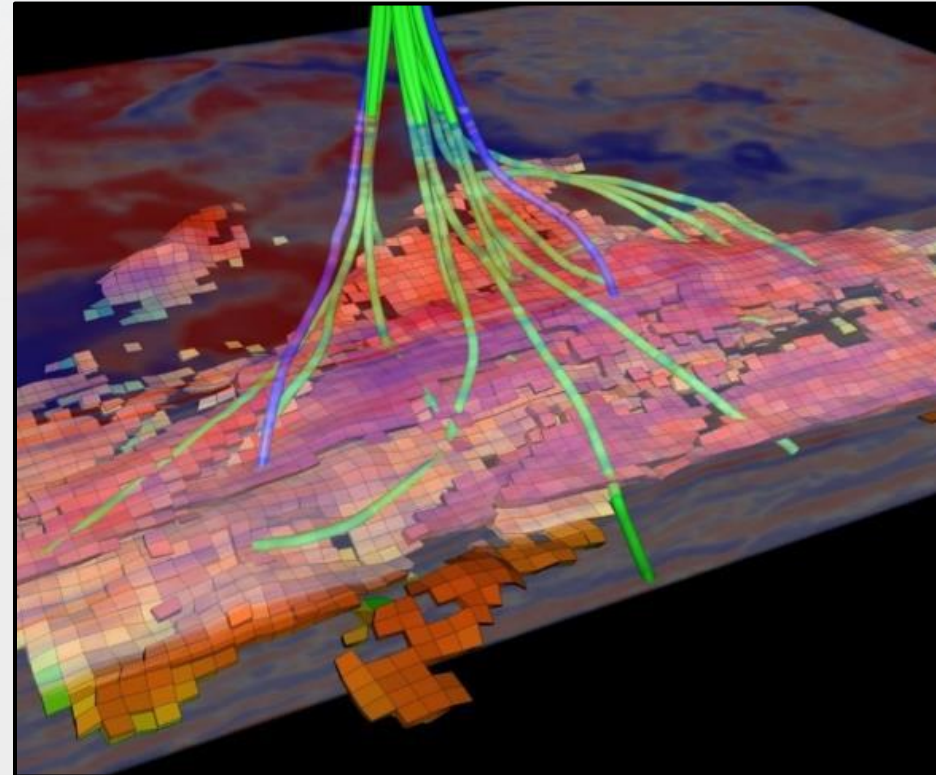


Interstate Technology & Regulatory Council). 2020. *Optimizing Injection Strategies and In situ Remediation Performance*. OIS-ISR-1. Washington, D.C.: Interstate Technology & Regulatory Council, OIS-ISR-1 Team.

Scan and Target Approach: Aligning with Other Industries



X-ray of Skull
nydailynews.com



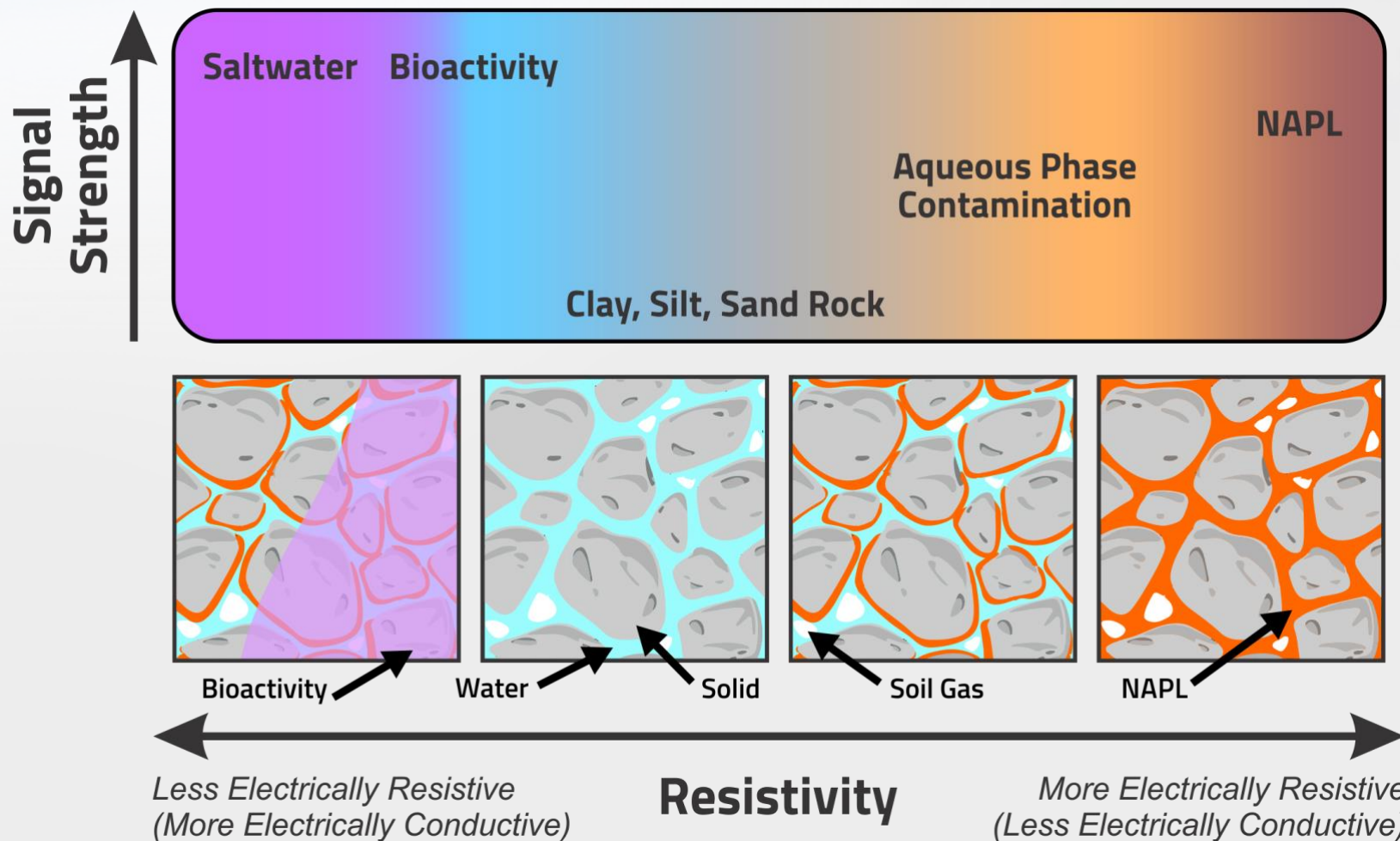
3-D Seismic North Sea
dgi.com

GeoTrax Survey™ Field Deployment

- Must be in a straight line
- Line length = 5 x imaging depth

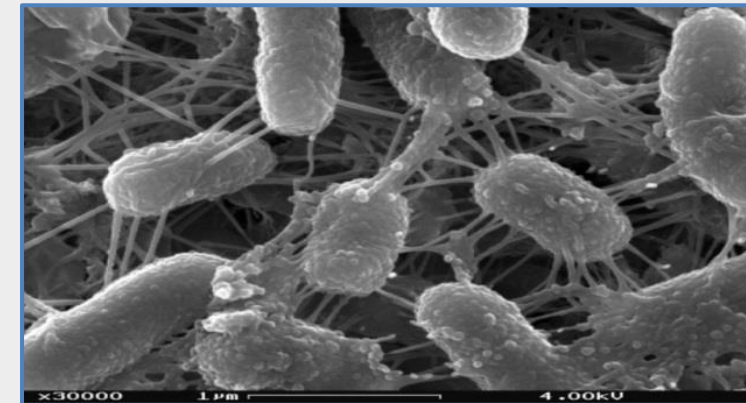
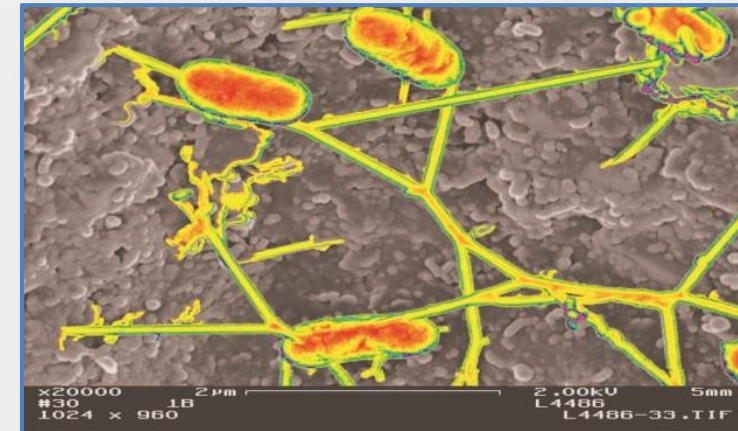


Typical Electrical Properties



Reason for Bioactivity Detection

“Nanowires”
(Electron Microscopy)



Microbiology in the Subsurface is like...



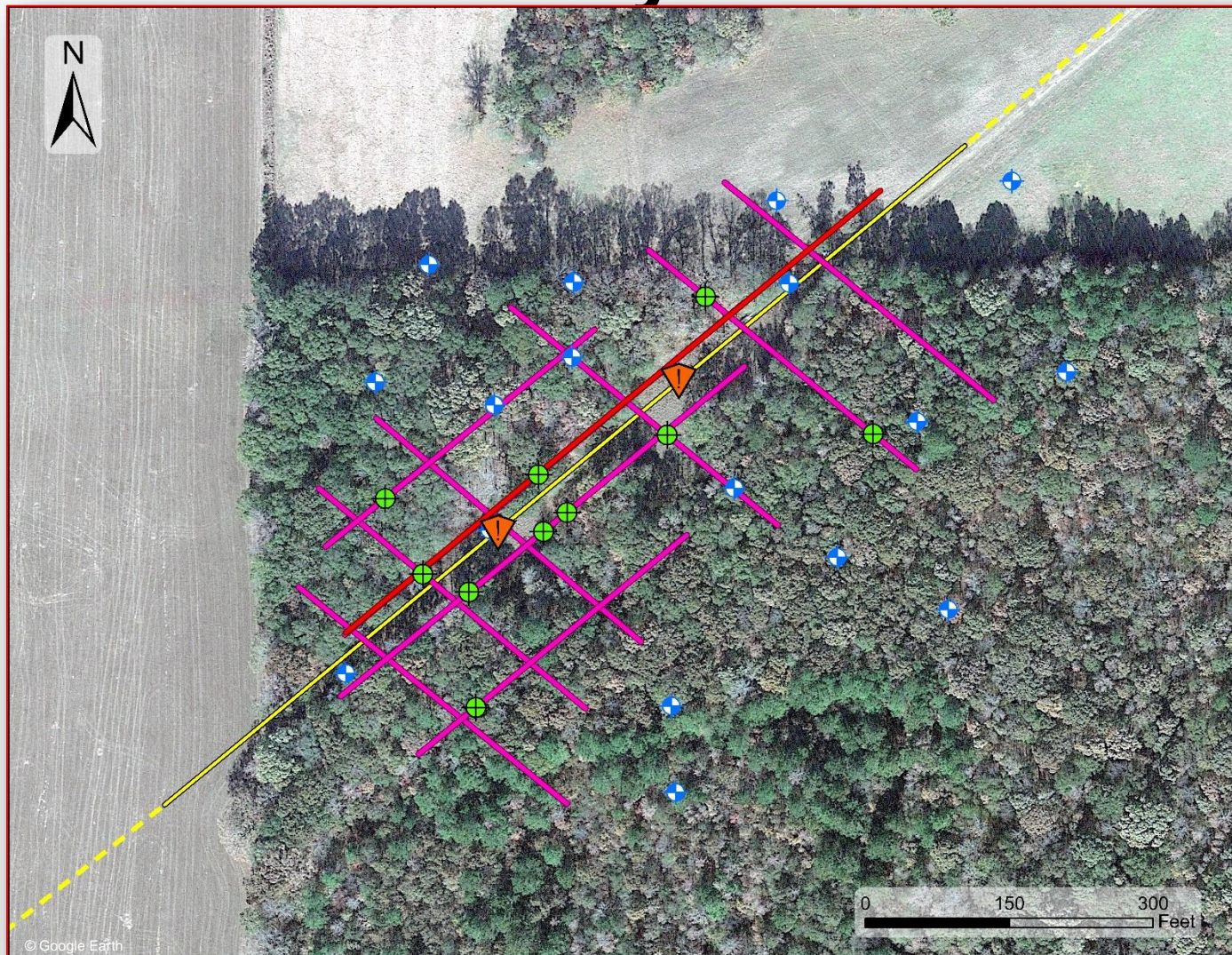
“Under the most rigorously controlled conditions of pressure, temperature, volume, humidity, and other variables, any experimental organism will do as it damn well pleases.” –*The Harvard Law*

Case Study: Pipeline Break, AR

1. What is the distribution of impacts?
2. What is the habitat for remediation?



Case Study: Pipeline Break, AR GeoTrax Survey™ Lines and Wells

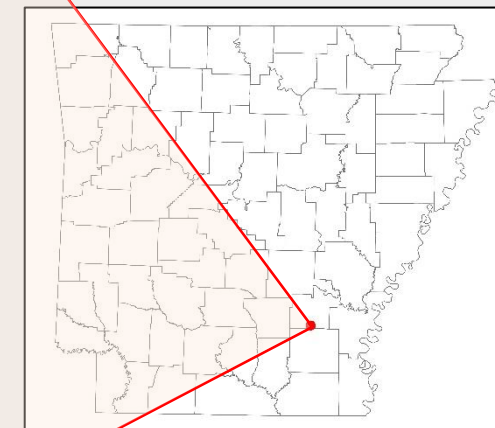


SURVEY LINE SPECIFICATIONS
Total Number of GeoTrax Survey™ Lines = 13

E 1	E 56	
		2.0 Meter Electrode Spacing (12 Lines)
STA-01		Line Length ~361 feet (~110 m) Image Depth ~72 feet (~22 m)
		4.00 Meter Electrode Spacing (1 Lines)
STA-13		Line Length ~722 feet (~220 m) Image Depth ~144 feet (~44 m)

LEGEND

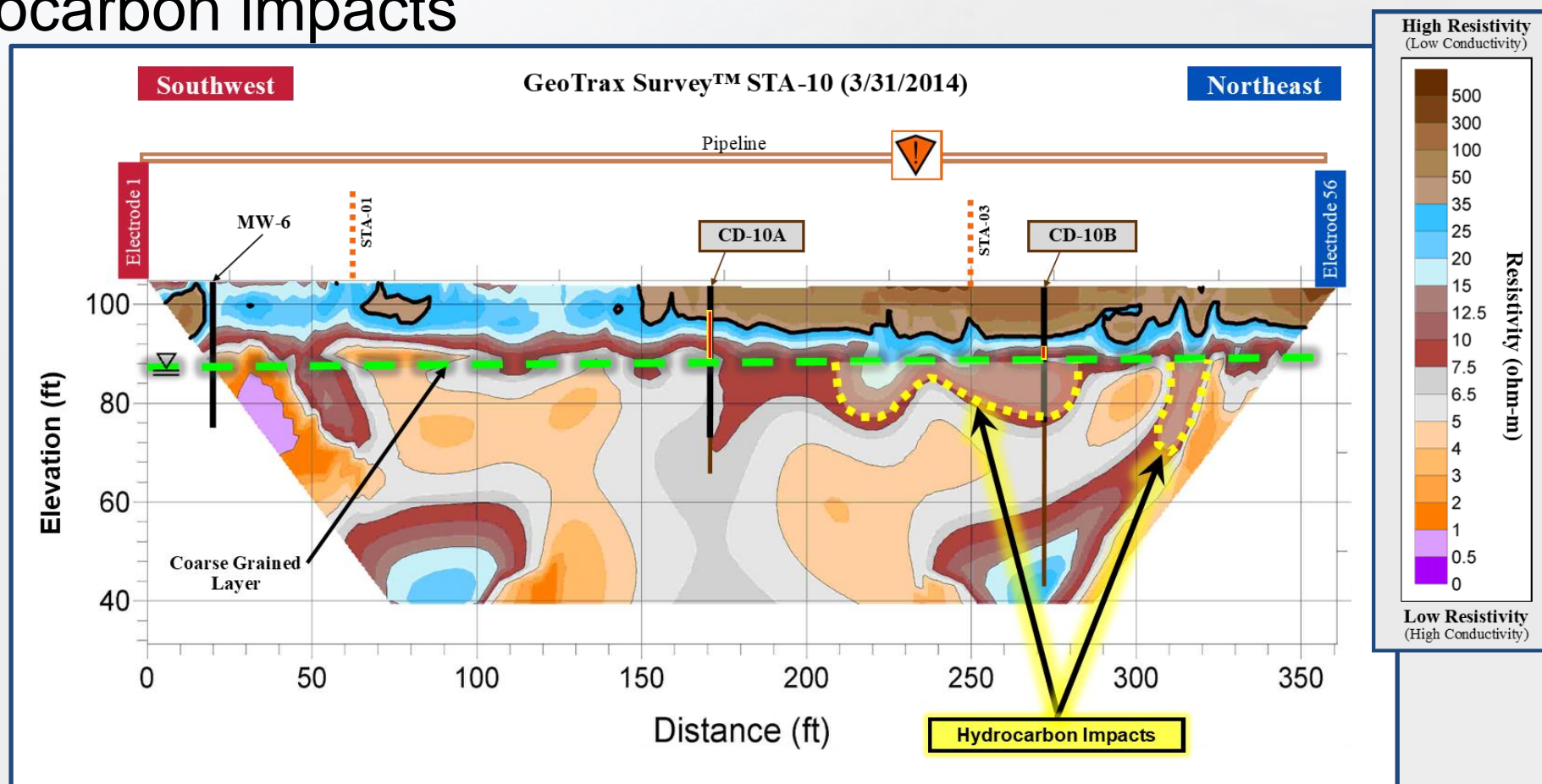
	Monitoring Well		Pipeline
	Confirmation Drilling Location		Pipeline break/release



Case Study: Pipeline Break, AR

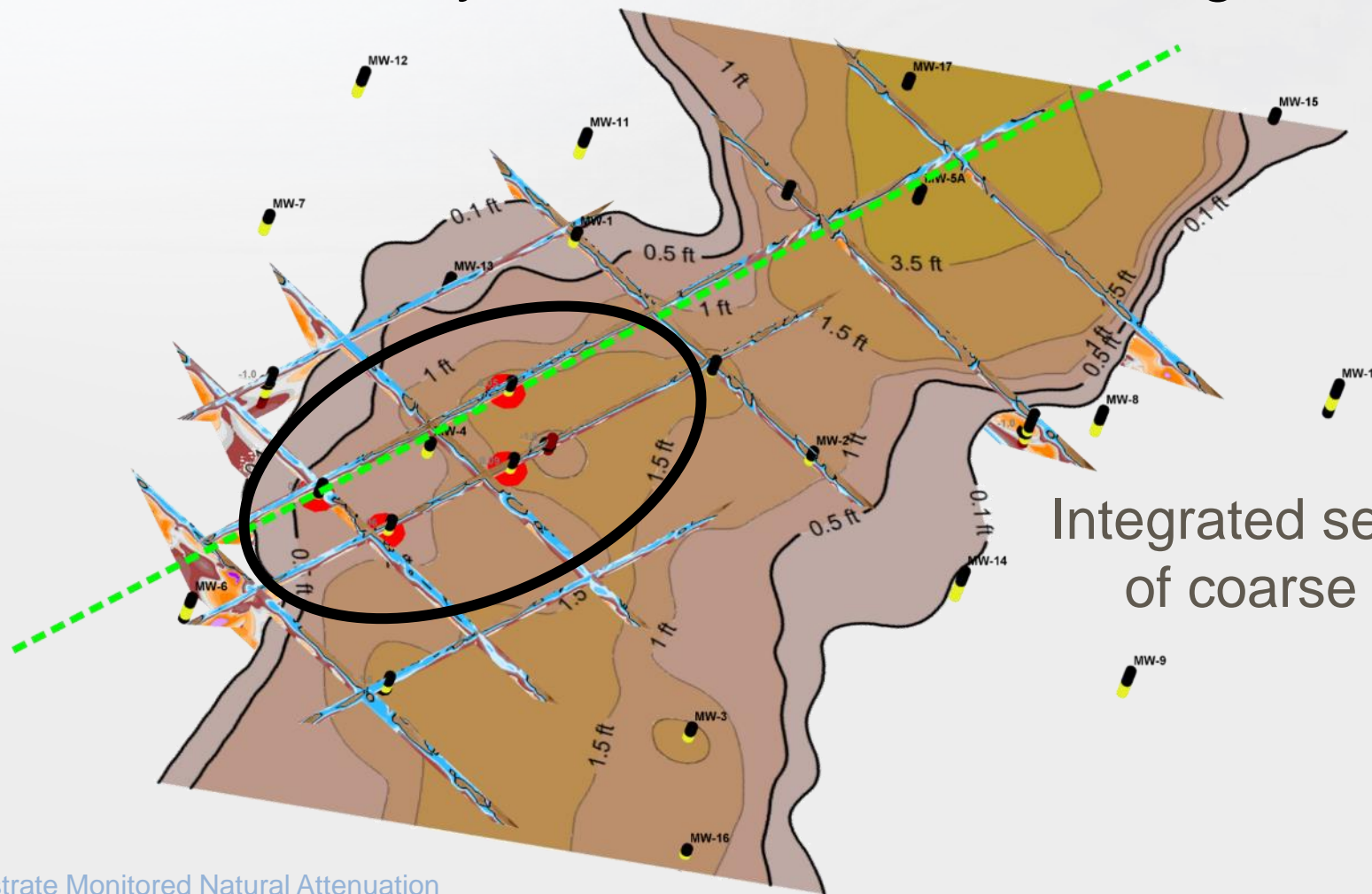
GeoTrax Survey™ Targeting

“Blob” anomalies crossing the coarse grained layer are targets for hydrocarbon impacts



Case Study: Pipeline Break, AR Geologic CSM (Graphical Explanation)

Hydrocarbons bounded by lateral extent of coarse-grained layer

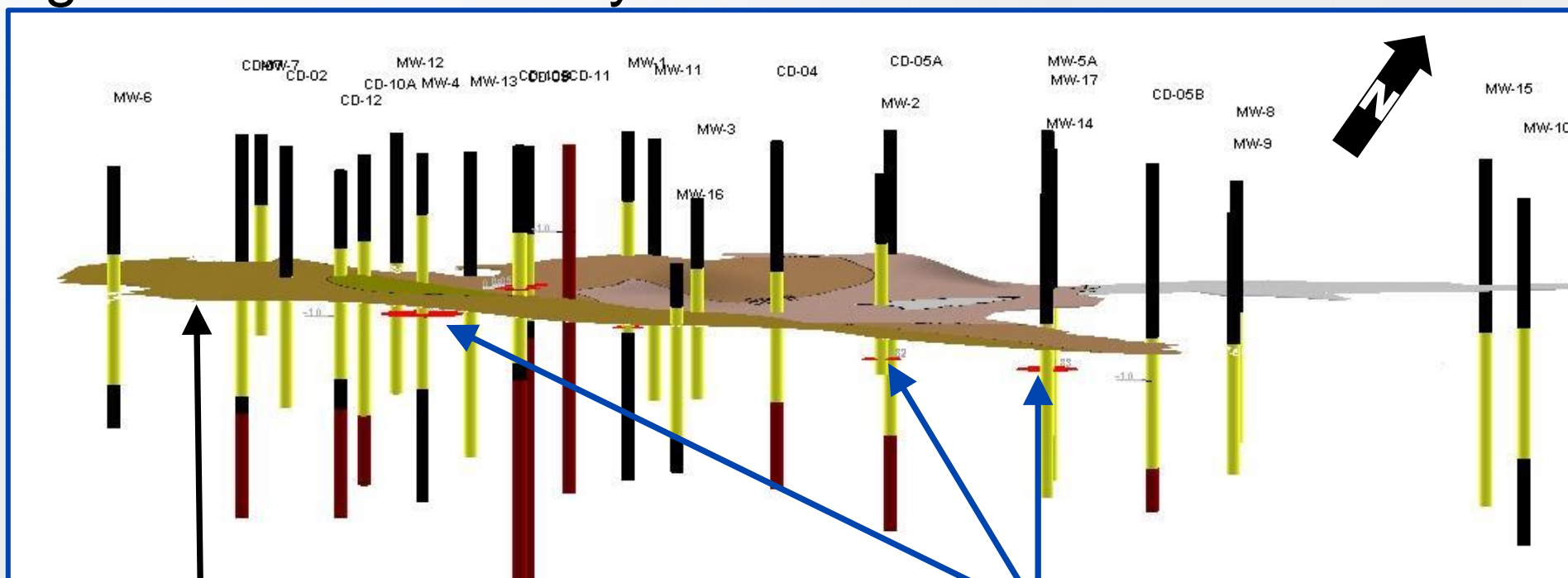


Integrated sediment mapping of coarse channel layer

Case Study: Pipeline Break, AR

Updated CSM (Graphical Explanation)

“Blob” anomalies crossing the coarse grained layer were targets for higher saturations of hydrocarbons

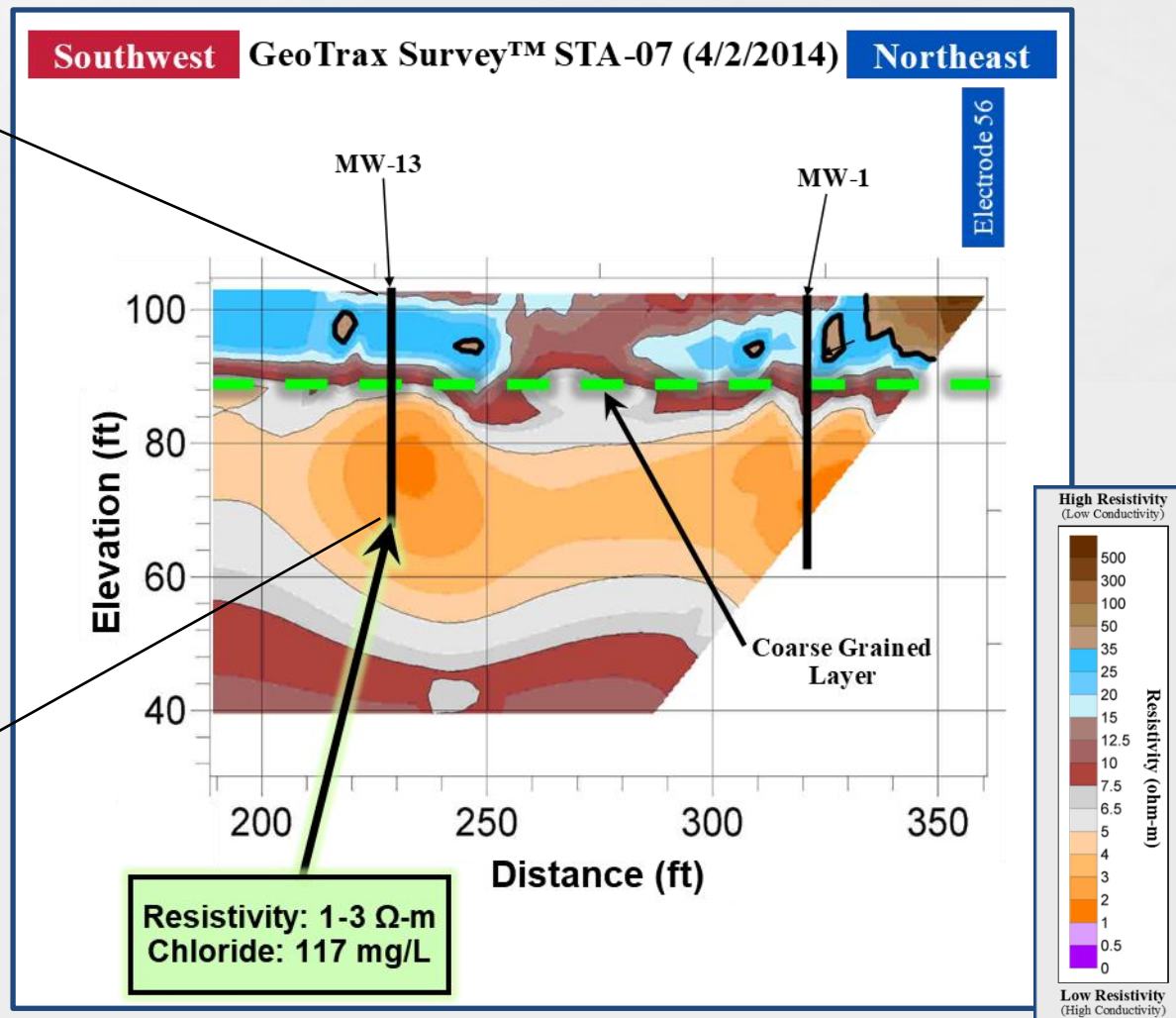
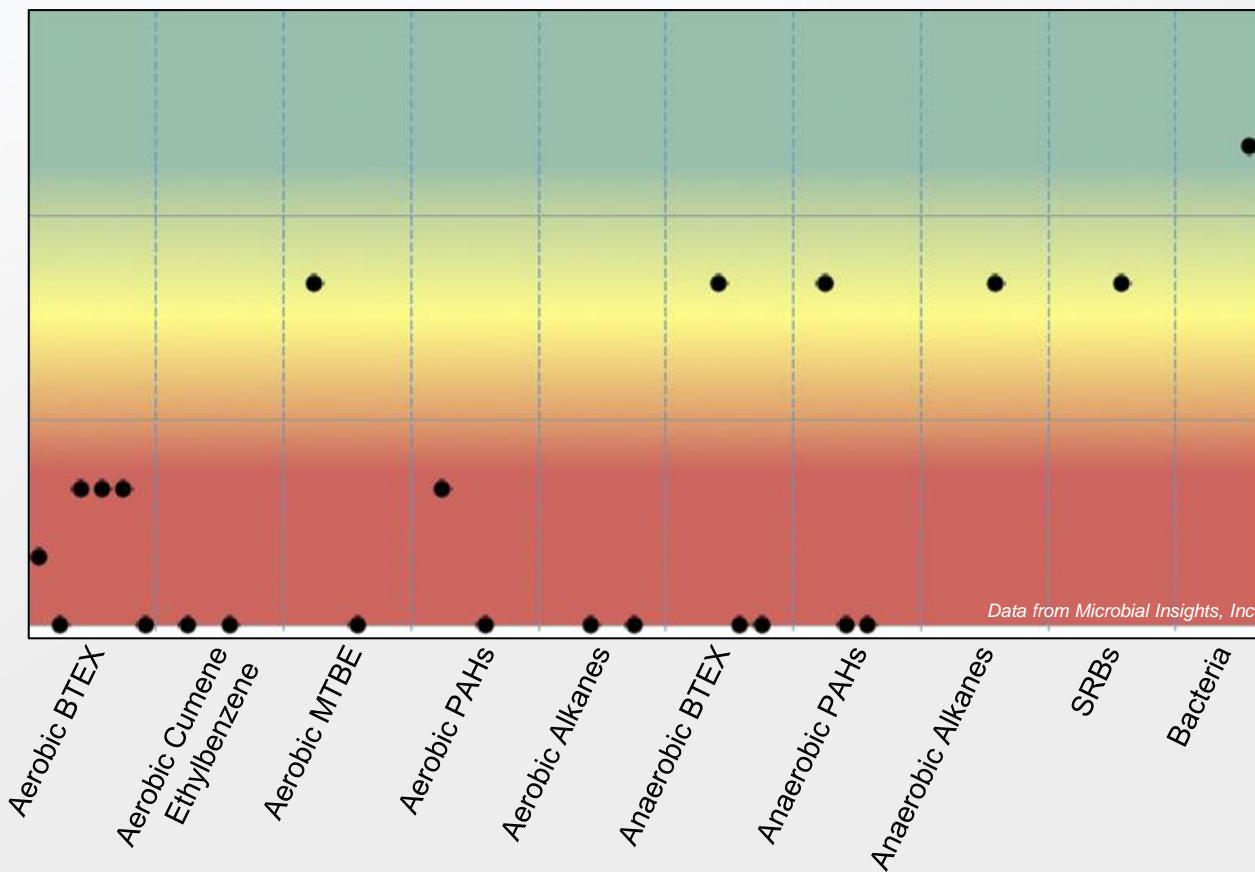


Modeled base of
coarse layer

Hydrocarbons mostly in finer grained
sediment below coarse layer

Case Study: Pipeline Break, AR Understanding the Conductors

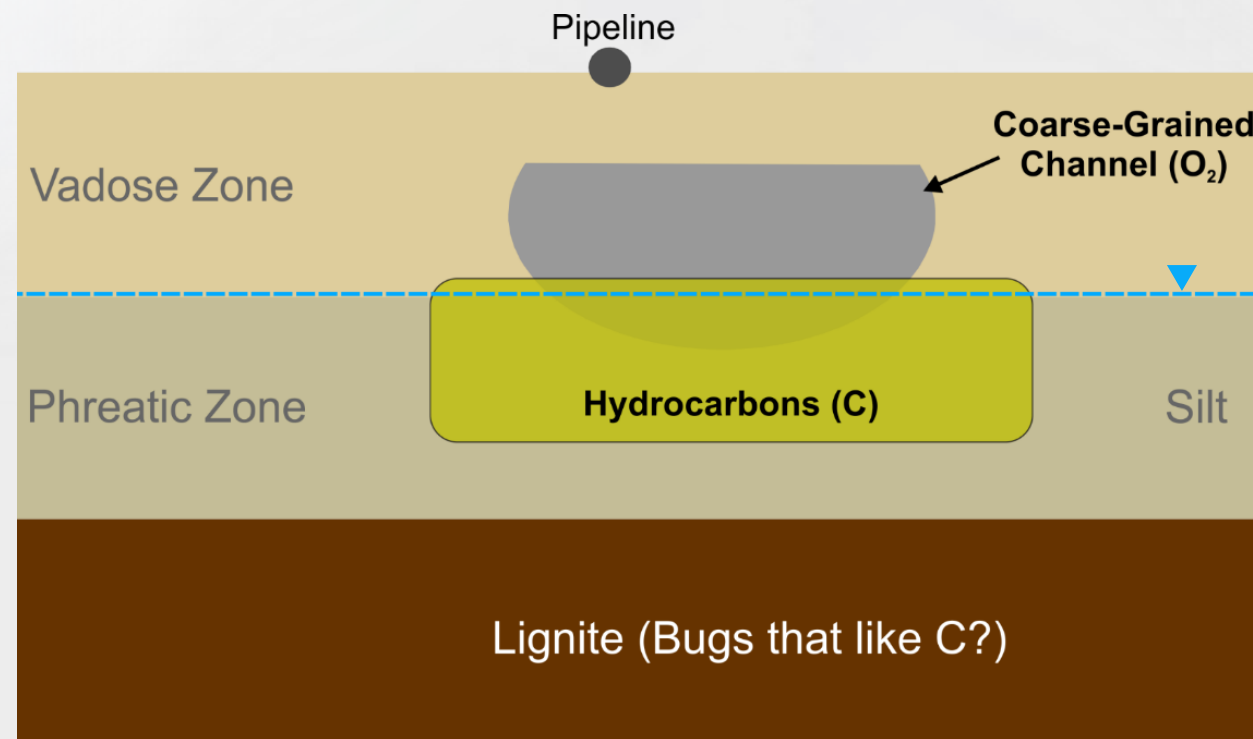
MW-13 Microbial Populations



Geologic CSM: Pipeline Break, AR

What we learned...

- Hydrocarbon generally in finer grained sediment below coarse grained layer
- Hydrocarbon limited by lateral extent of coarse grained layer
- Electrical “blob” anomalies crossing the coarse grained layer were targets for hydrocarbons
- No evidence of deep hydrocarbons, just lignite



Case Study: Pipeline Break, AR

Biodegradation: Multiple Lines of Evidence

- **Electrical and chemical:** In general, highly electrically conductive areas (w/ low Cl^- at impacted wells) suggests widespread biological activity
- **Geochemical Habitat:** Coarse grained layer may act as natural horizontal “air sparge system” (positive ORP and DO values)
- **Biological:** Microbial activity confirmed with Microbial Insights (Petroleum QuantArray)

Case Study: Pipeline Break, AR

Better CSM Allows for Better Remedial Planning

- State Regulators **approved MNA as remedy** based on multiple lines of evidence and confirmation for any trailing questions
- “Blob” anomalies crossing the coarse grained layer are targets for high saturation of hydrocarbons – CONFIRMED
- Multiple lines of evidence indicate hydrocarbon degradation likely ongoing
- Can material migrate easily? – NO, field tested mobility

Case Study: Former Fueling Station, Oklahoma

Site Overview

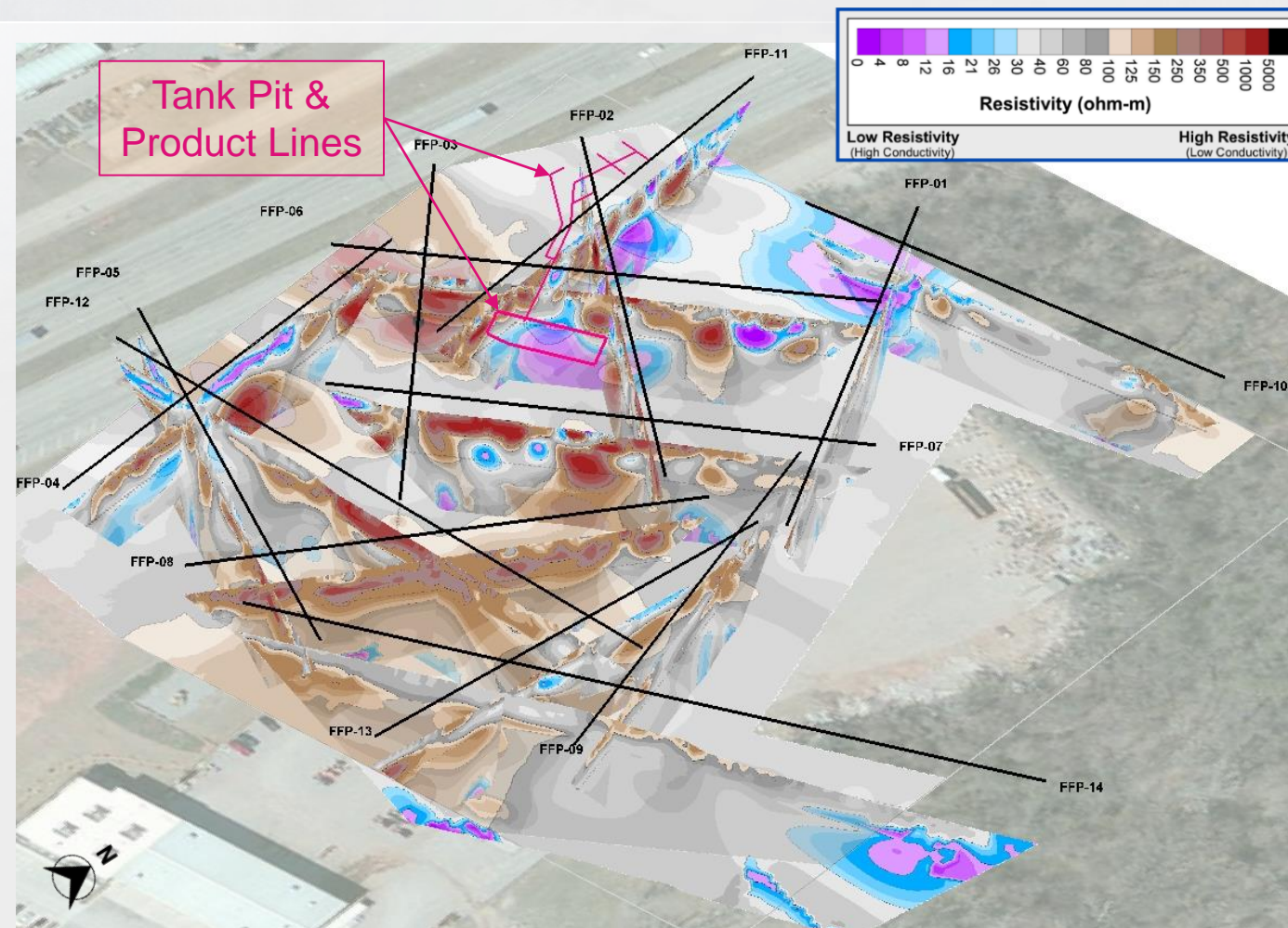
- Truck stop until ~2005
 - 2 Documented releases in 1990s
 - 7 USTs removed in 2008
- Previous remedial efforts
 - 2008: FP recovery system
 - 2013: EFR® (enhanced fluid recovery) ~800 liters of FP removed
 - 2017 Surfactant injections



Case Study: Former Fueling Station, Oklahoma

Site Overview

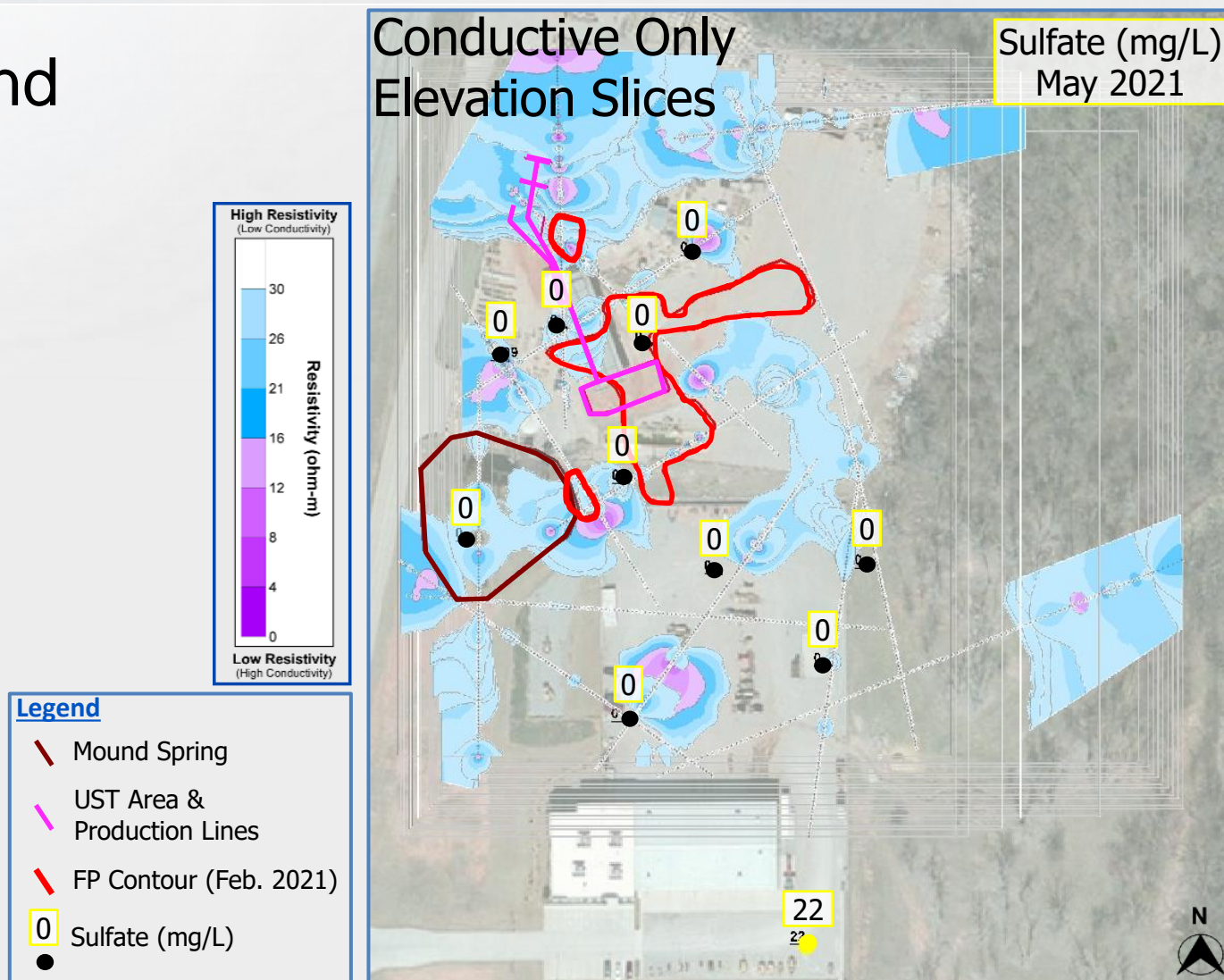
- Fractured Garber-Wellington Formation
- Heterogeneous distribution of contaminants
- Electrical mapping of subsurface in 3D provided key project insights



Case Study: Former Fueling Station, Oklahoma

Conductive Anomalies Related to Bio

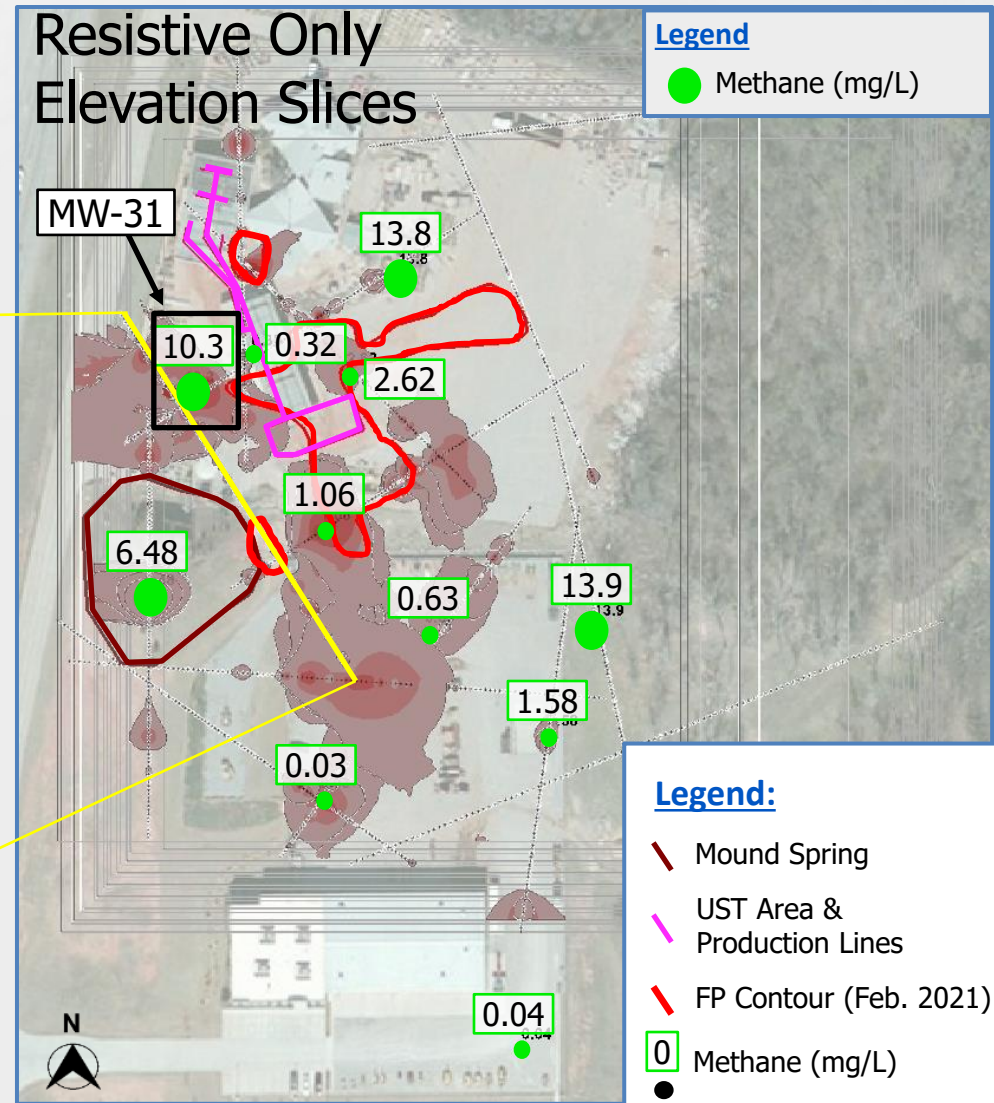
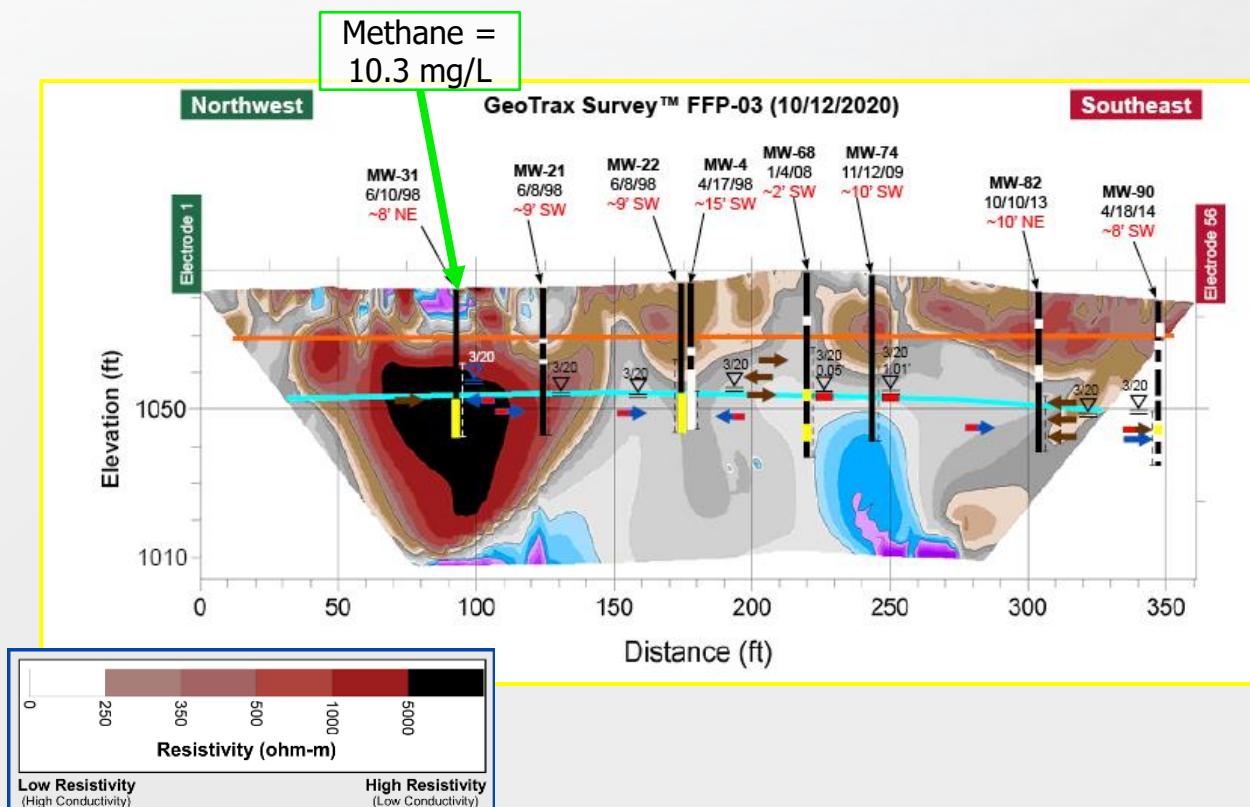
- Conductors likely correspond with zones of bioactivity
- Located on plume fringes
- Bioactivity appears limited
 - Presence of undegraded product
 - Lack of sulfate near plume



Case Study: Former Fueling Station, Oklahoma

Resistive Anomalies Related to Bio

Methane production causing resistive signatures



Case Study: Former Fueling Station, Oklahoma

Better CSM Allows for Better Remedial Planning

- Electrical imaging provided evidence for existence and location of bioactivity
- Integrating sampling data and electrical imagery demonstrated sulfate depleted near electrically conductive zones
- Updated CSM basis for MNA (In Review)

Key Factors for HRSC MNA

- Integrative Team looking for Technical Solutions
 - Client/PRP
 - Consultants
 - Regulators
 - Electrical Hydrogeologists
 - Microbiologists
- Microbial Patterns Highly Variable (Mold Grows as it Pleases)
- Iterative Process to Answer Questions



Improvements Moving Forward

1. Sample bioactivity to clarify which samples are optimal to characterize biostructure
2. Monitor sites electrically over time with “electrical wells”
3. Need to improve our bioactivity “farming” techniques



Key Takeaways

- Aestus' GeoTrax electrical hydrogeology can be successfully utilized at any point in a project:
 - Initial high-resolution site characterization
 - Remedial design characterization (RDC)
 - Temporal monitoring
- Can be used at any site in the world to minimize uncertainty
- **Goal:** support focused remediation in less time at lower cost



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Questions?

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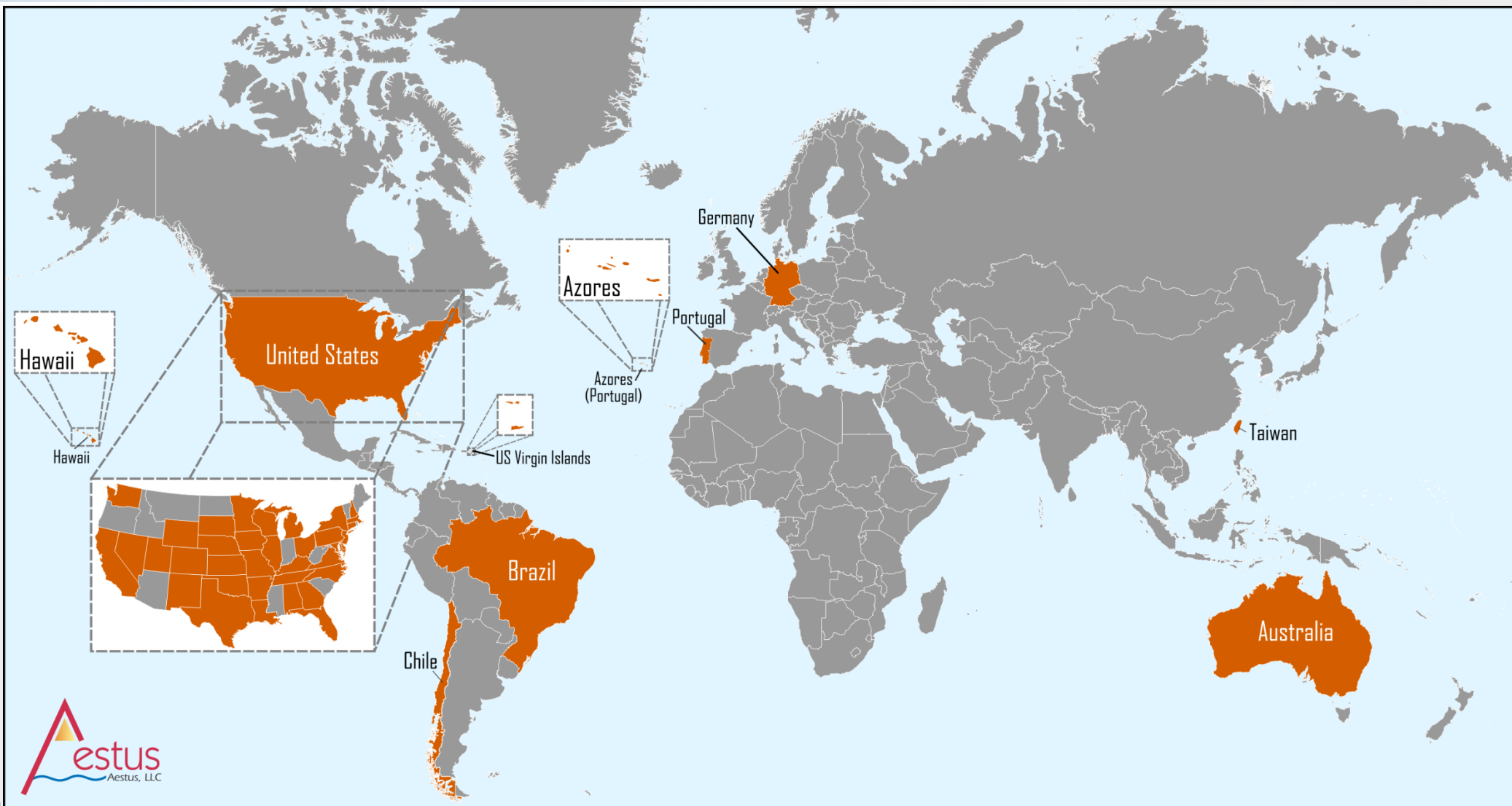
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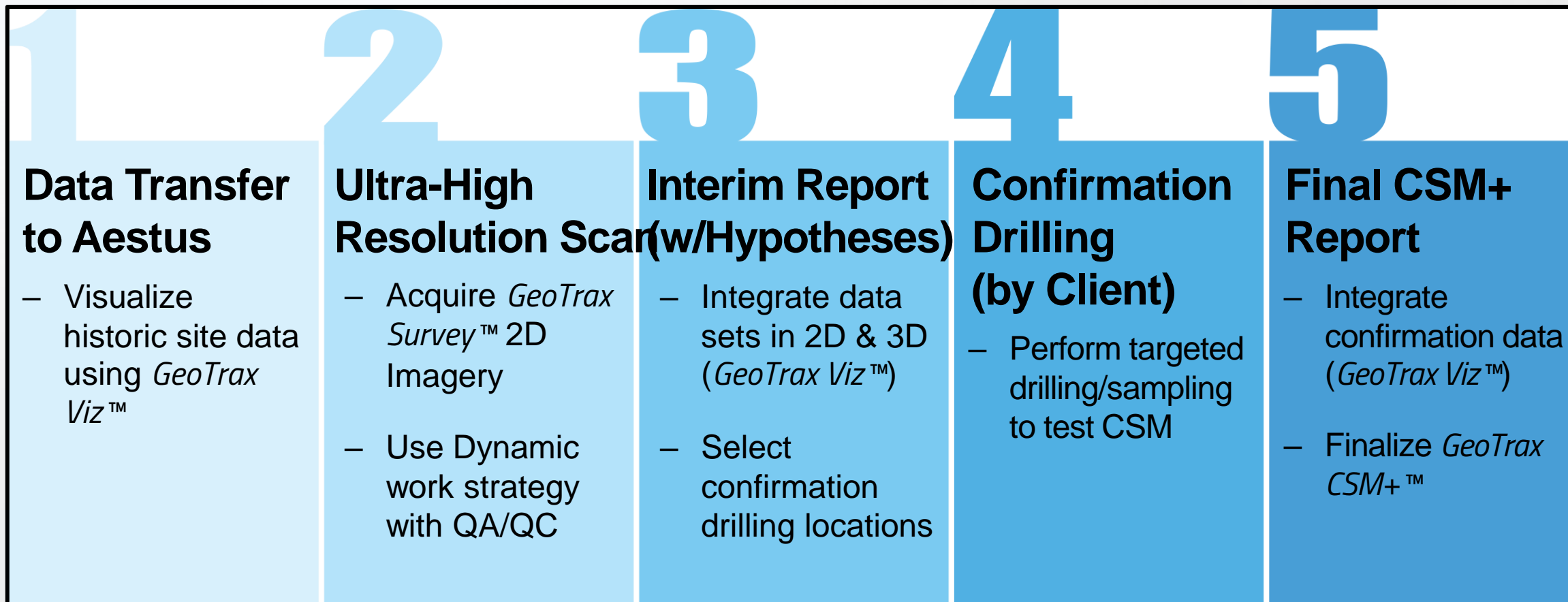
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Where in the World has Aestus Been?

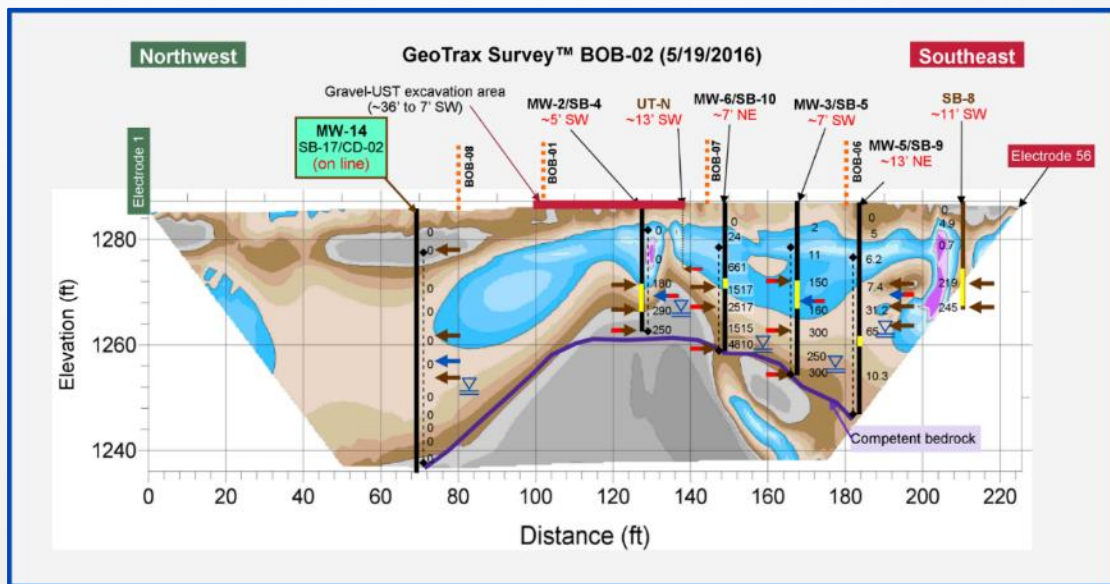


Aestus GeoTrax CSM+™ Protocols



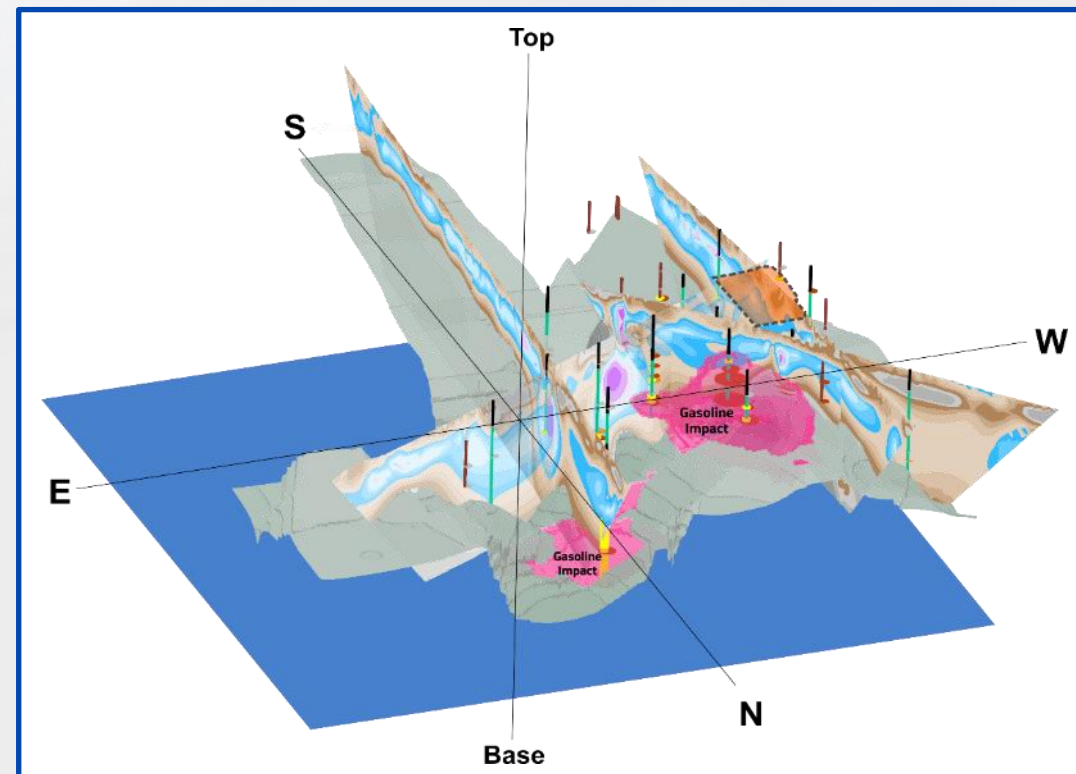
What is Electrical Hydrogeology?

Missouri Karst LNAPL Site



Scan, then confirm

2,750 electrical data points
6 borings
BTEX data
PID data



Conceptual Site Model

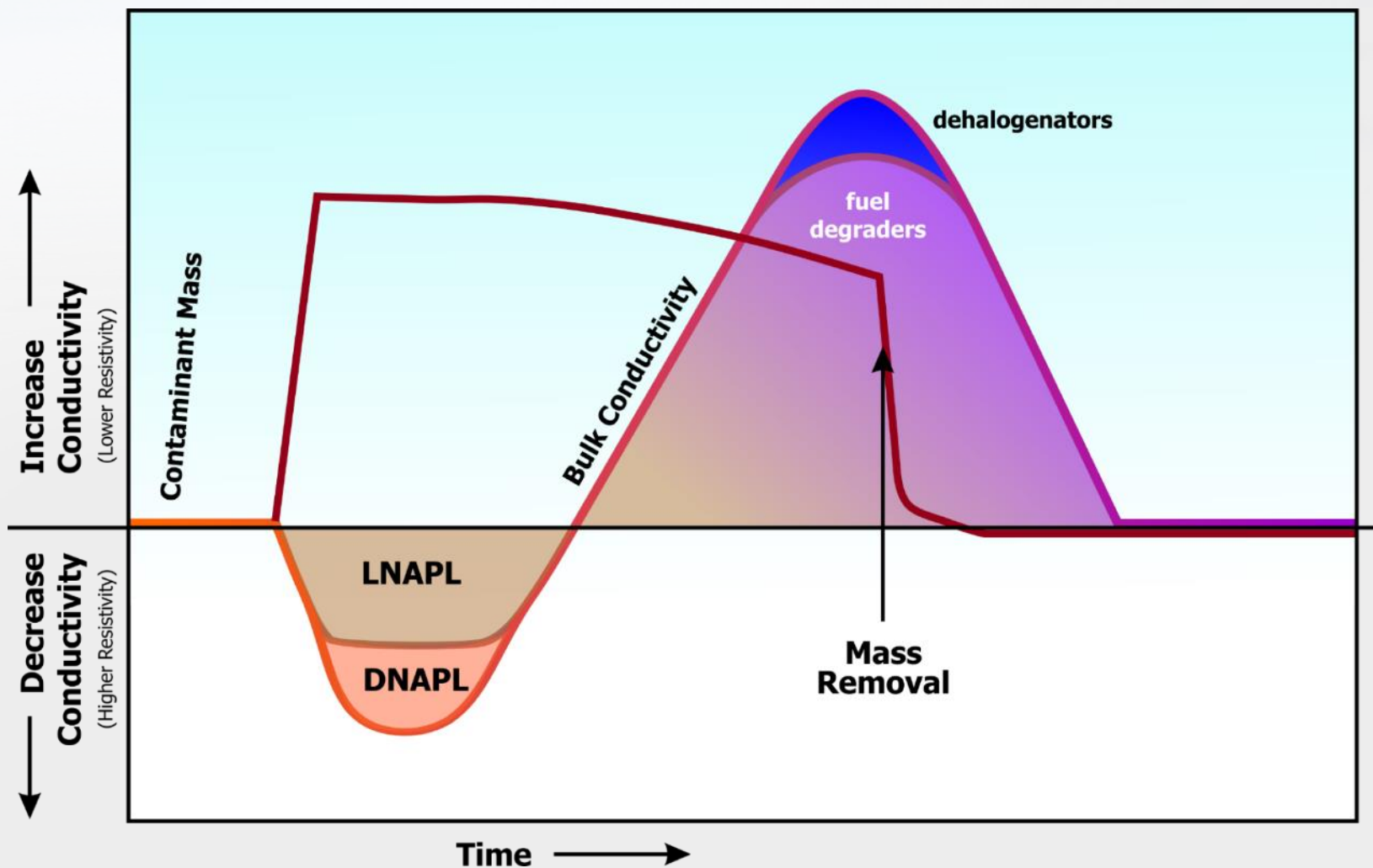
22,000 electrical data points
Pathways delineated

Lessons Learned

- “New” spills may be highly bioactive
- High saturation zones can be electrically conductive
- Effectively “farming” bioactivity requires an understanding of the habitat structure – “mold” is not highly predictable in shape



Electrical Properties of Microbes



Modified from
Che-Alota et al., 2009



What Does Aestus See?

Each data point (pixel) equals the sum of:

1. Biological activity
2. Contamination/ Injectates/etc.
3. Groundwater/Fluids
4. Soil and rocks

Signal Strength

