

# **Achieving MNA Remedy** *(Monitored Natural Attenuation)* **Using Electrical Hydrogeology**

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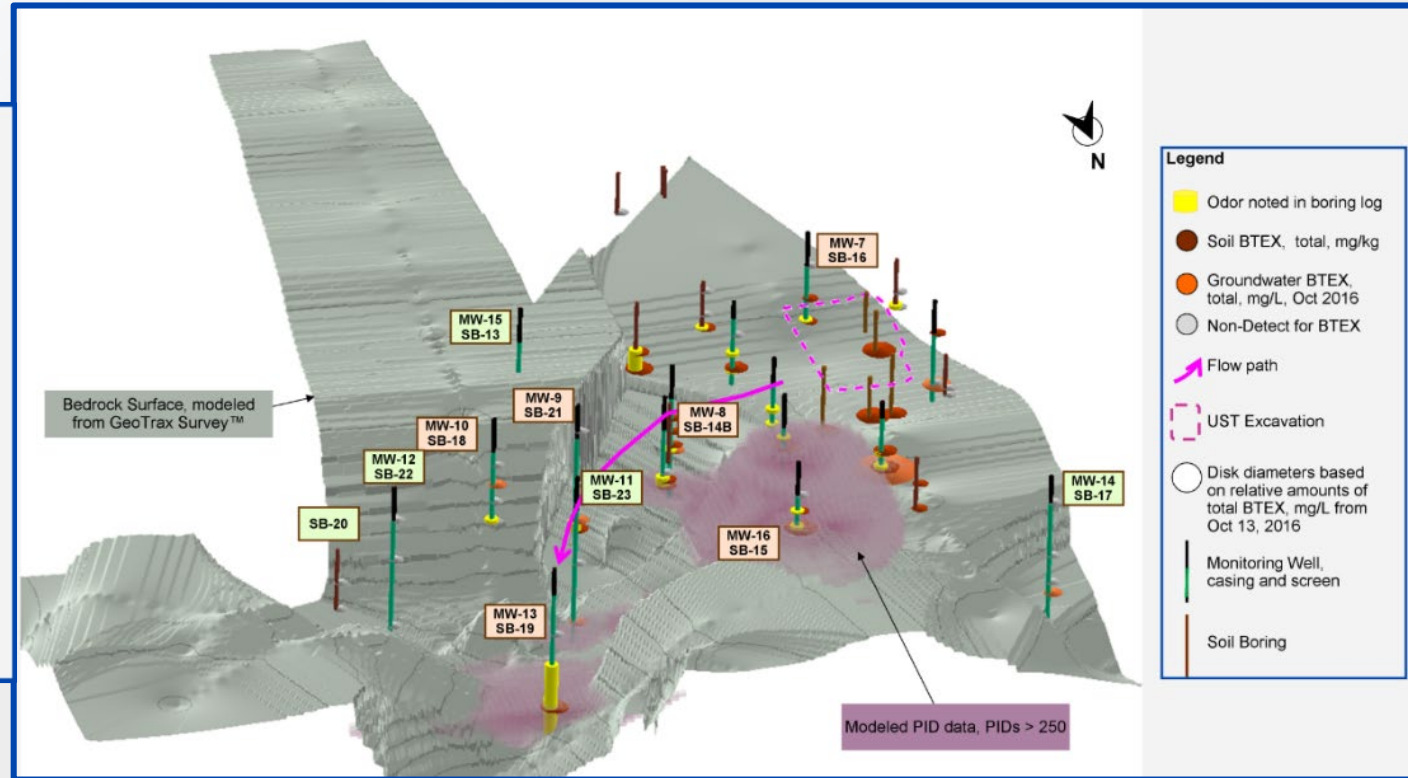
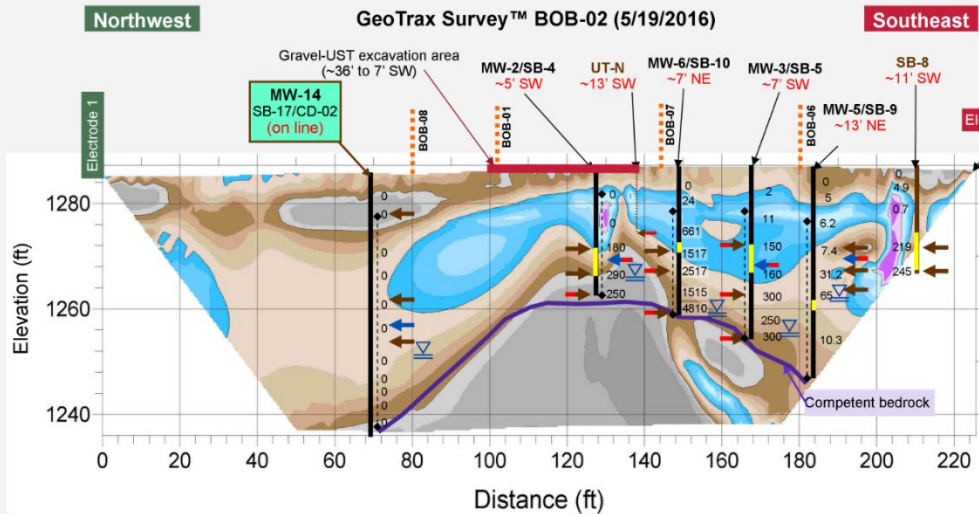
**Stuart W. McDonald, P.E.**  
Aestus, LLC

**Brian Thomas, P.E.**  
Golder Associates Inc.



# What is Electrical Hydrogeology?

## Missouri Karst LNAPL Site



## Scan, then confirm

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



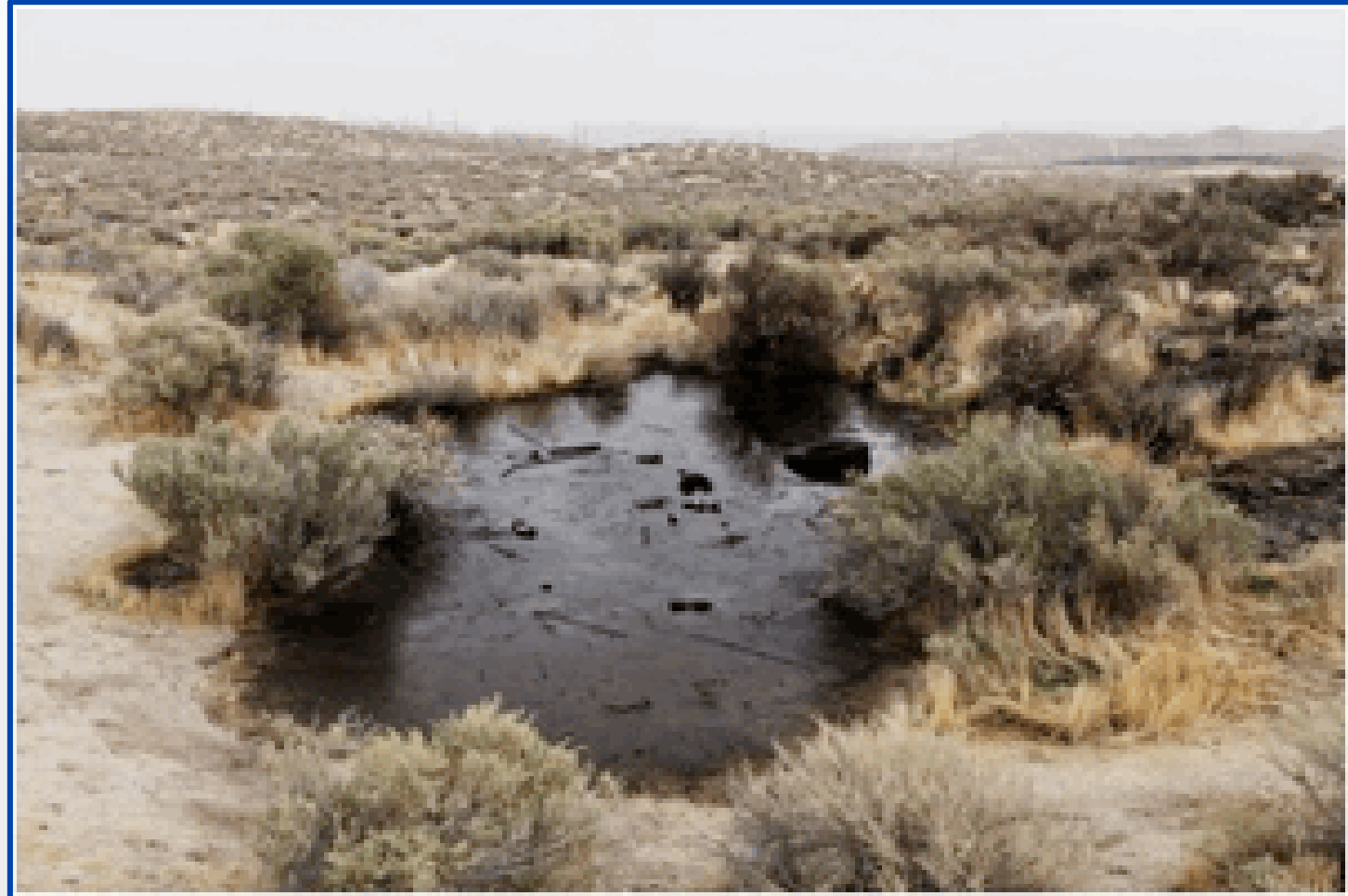
**Conceptual Site Model**  
22,000 electrical data points  
Pathways delineated

# Electrical Evaluation of MNA

1. MNA vs time and space
2. MNA vs electrical properties
3. Star City, AR
  - Ultra-HRSC Process for CSM
  - Regulation
4. Questions/Discussion

# MNA vs Time – Will it go away?

T  
ORP  
DO  
BTEX

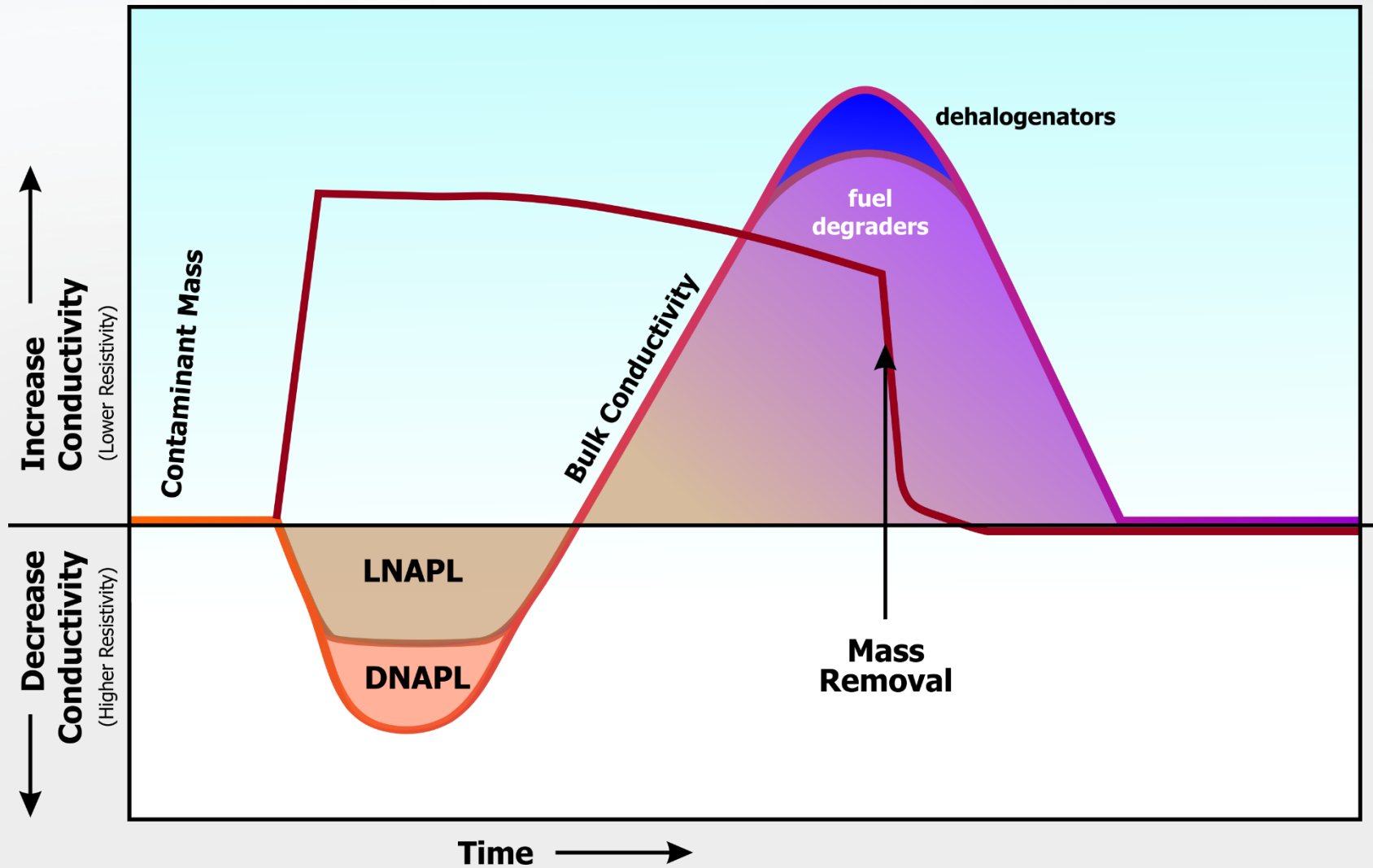


*A natural oil seep near McKittrick, CA. (Photo: Todd D'Addario) (loe.org)*

# MNA Checklist

1. Source stopped?
2. Horizontal and Vertical Extent
3. Mobility
4. Ecology
5. Presence of degrading microbes

# Electrical Properties of Microbes

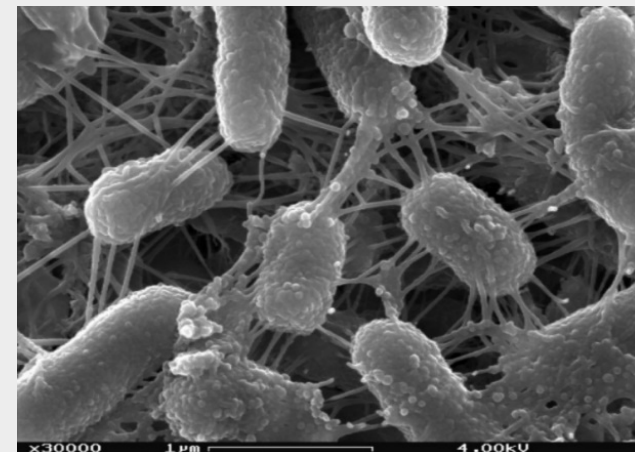
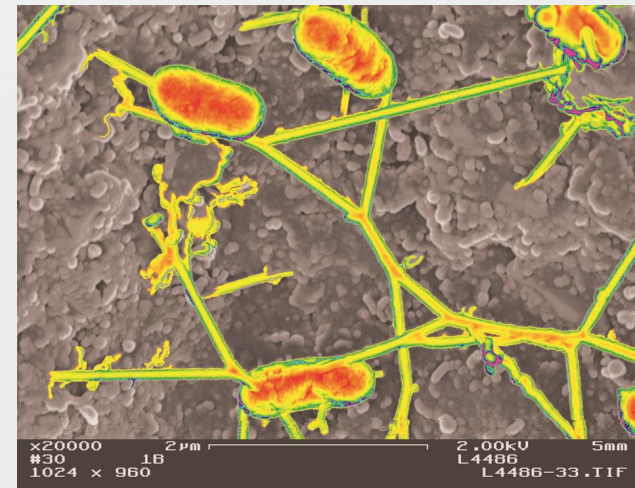


Modified from  
*Che-Alota et al., 2009*



# Electrical View of Microbes

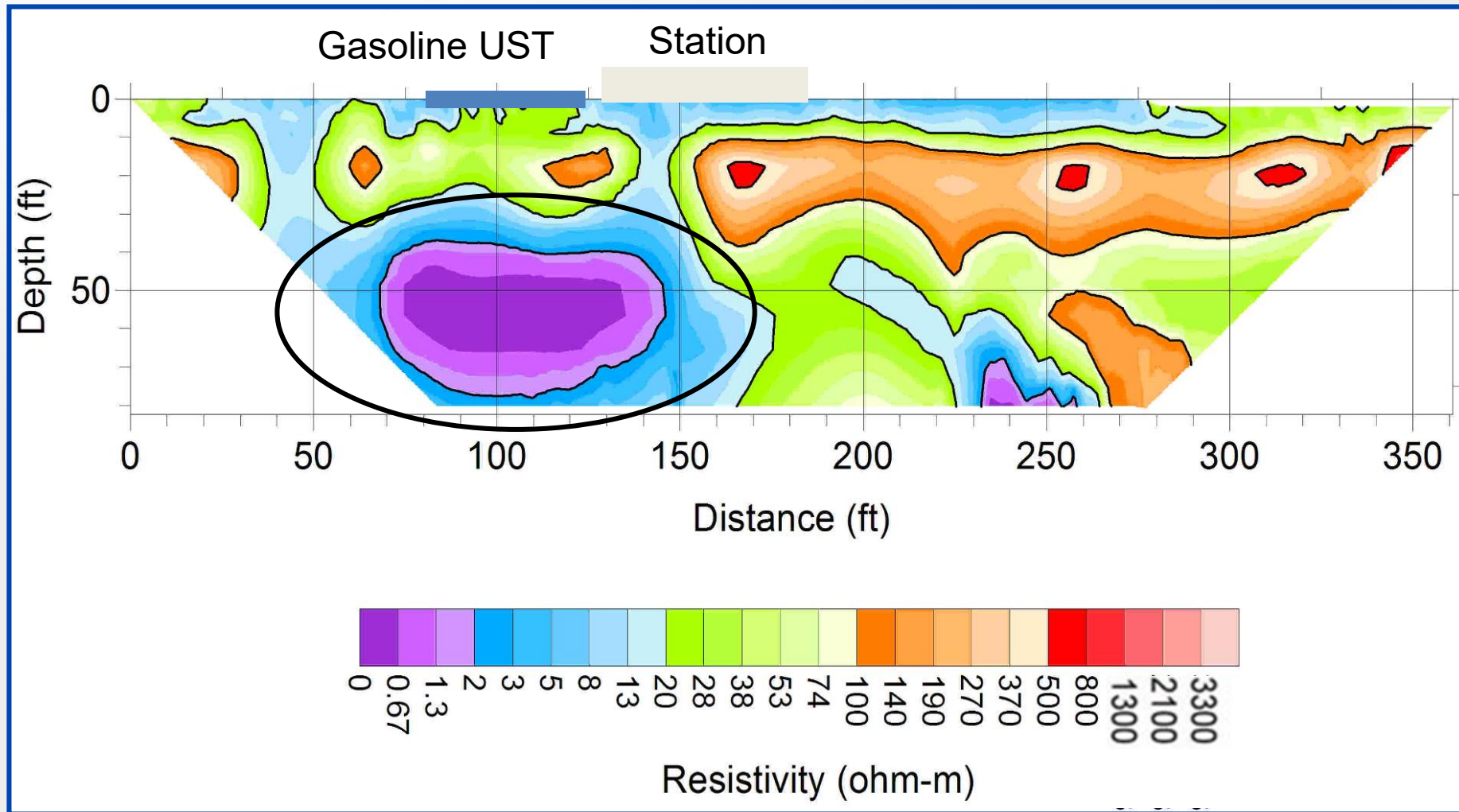
"Nanowires" (Electron Microscopy)



[bluetechblog.com/2010/06/15/make-electricity-not-sludge/](http://bluetechblog.com/2010/06/15/make-electricity-not-sludge/)

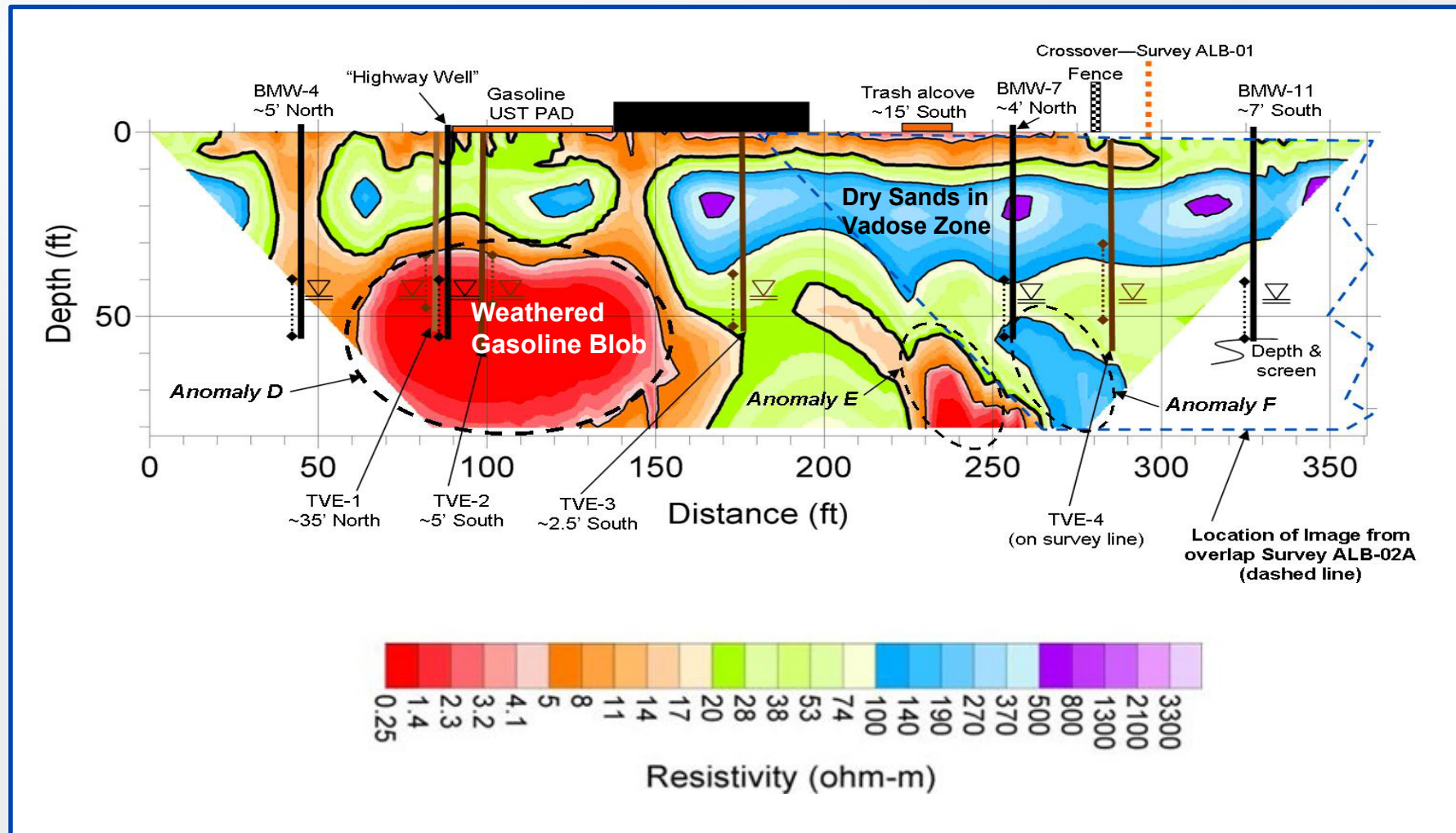
Image courtesy of Dr. Estella Atekwana

# Small Microbe House – New Mexico





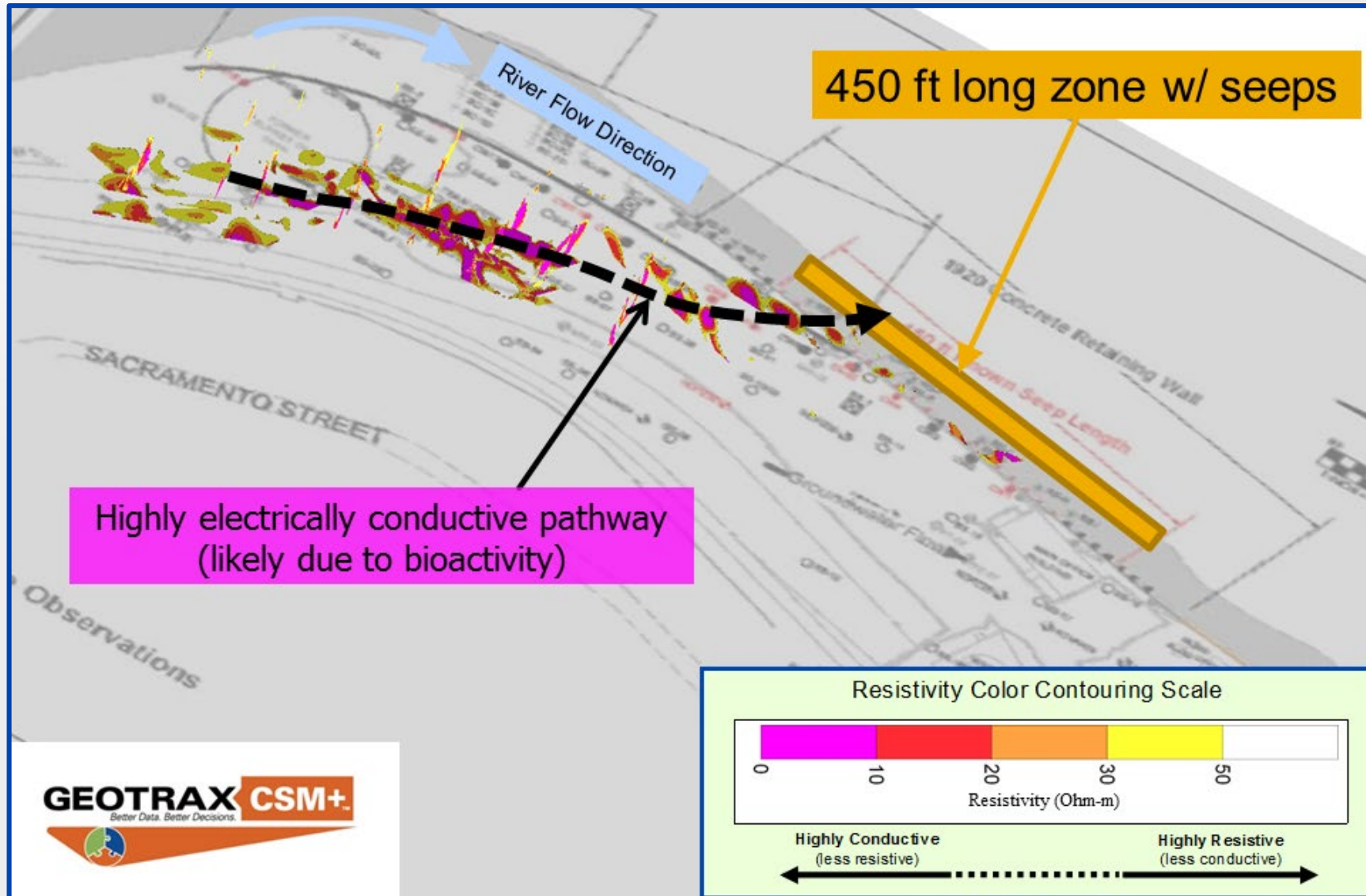
# Small Microbe House – New Mexico



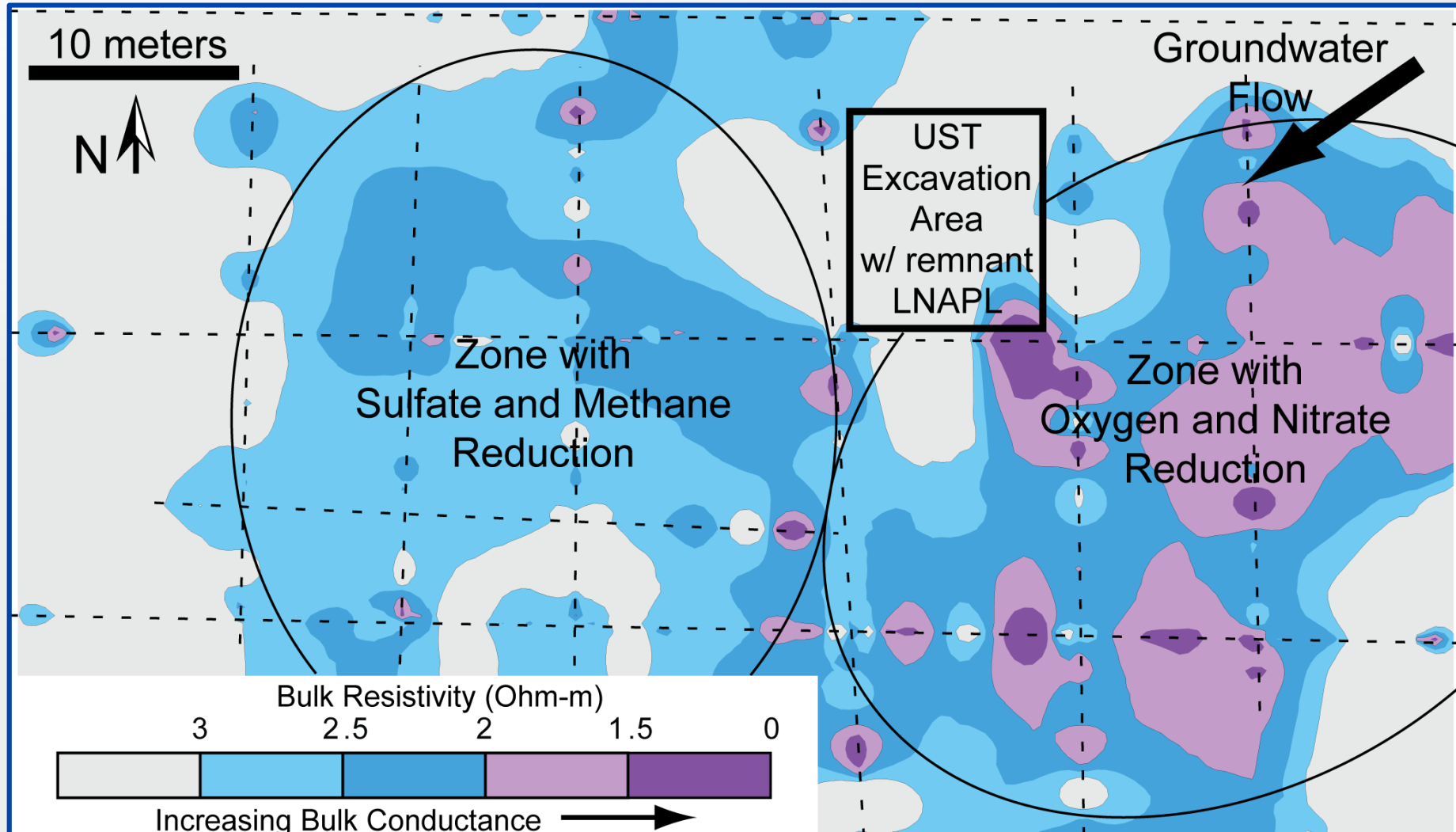




# Microbial Subdivision - California



# Microbial City - Colorado





# Case Study: Pipeline Break, AR

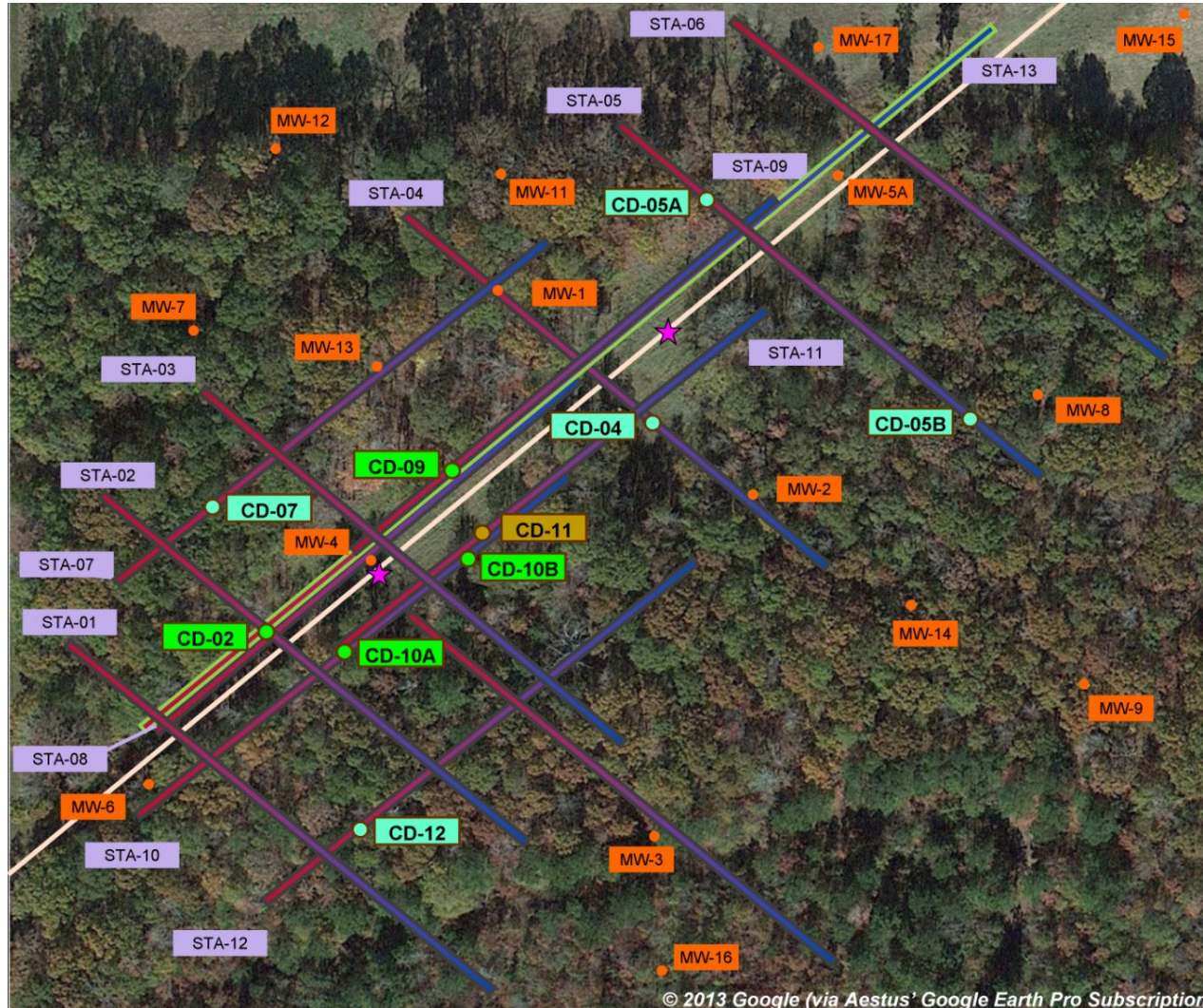




# Case Study: Pipeline Break, AR

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

# GeoTrax Survey™ Lines and Wells



## LEGEND:

### GeoTrax Survey™ Orientation and Designation

**2.0 Meter Electrode Spacing (12 Surveys)**  
 Survey Line ~ 361 feet Long (110 m)  
 Image Depth ~ 72 feet  
**STA-01**

**4.0 Meter Electrode Spacing (1 Survey)**  
 Survey Line ~ 722 feet Long (220 m)  
 Image Depth ~ 144 feet  
**STA-13**

Enterprise P-31 10" Pipeline

Approximate Release Locations

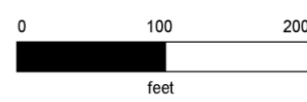
Monitoring Well Locations  
**MW01**

#### As-Built Confirmation Drilling Locations (Sept 2014)

**CD-07** Soil Borings completed as Temporary Monitoring Wells

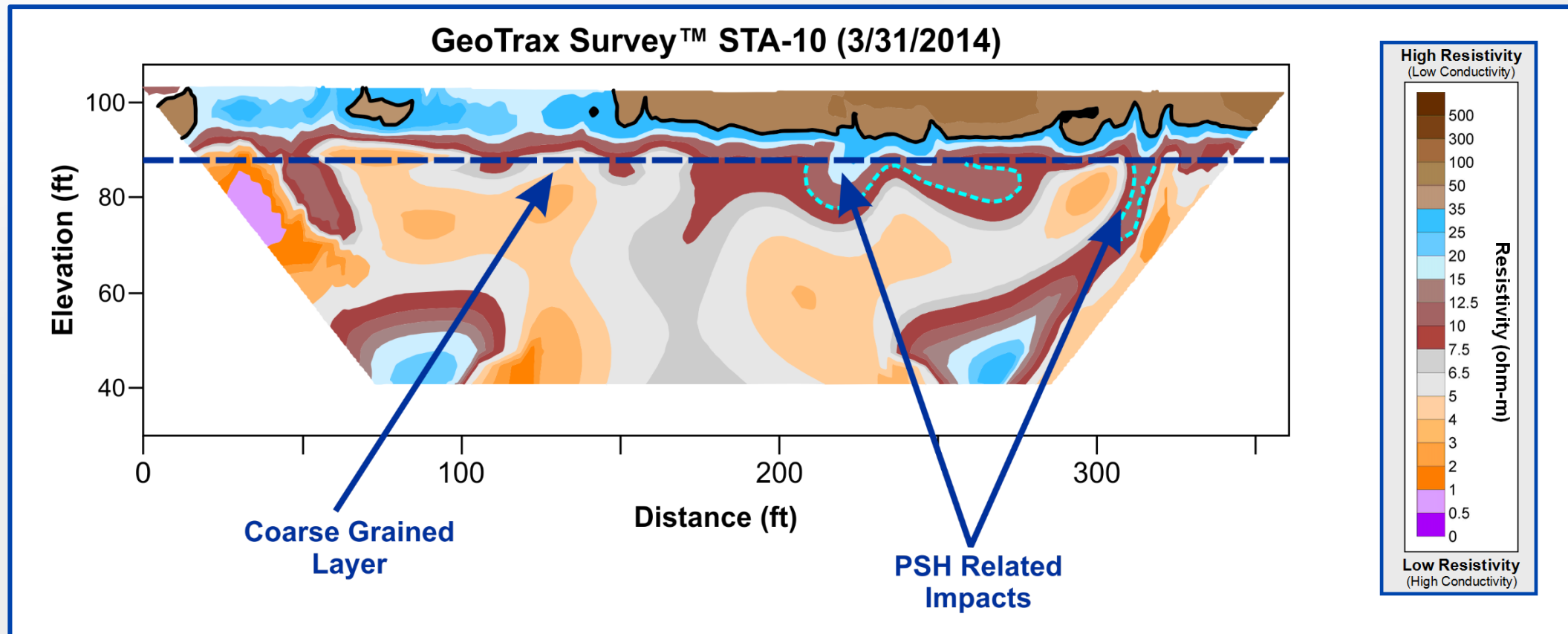
**CD-02** Soil Borings completed as Permanent Recovery Wells

**CD-11** Soil Borings



# GeoTrax Survey™ Highly Conductive

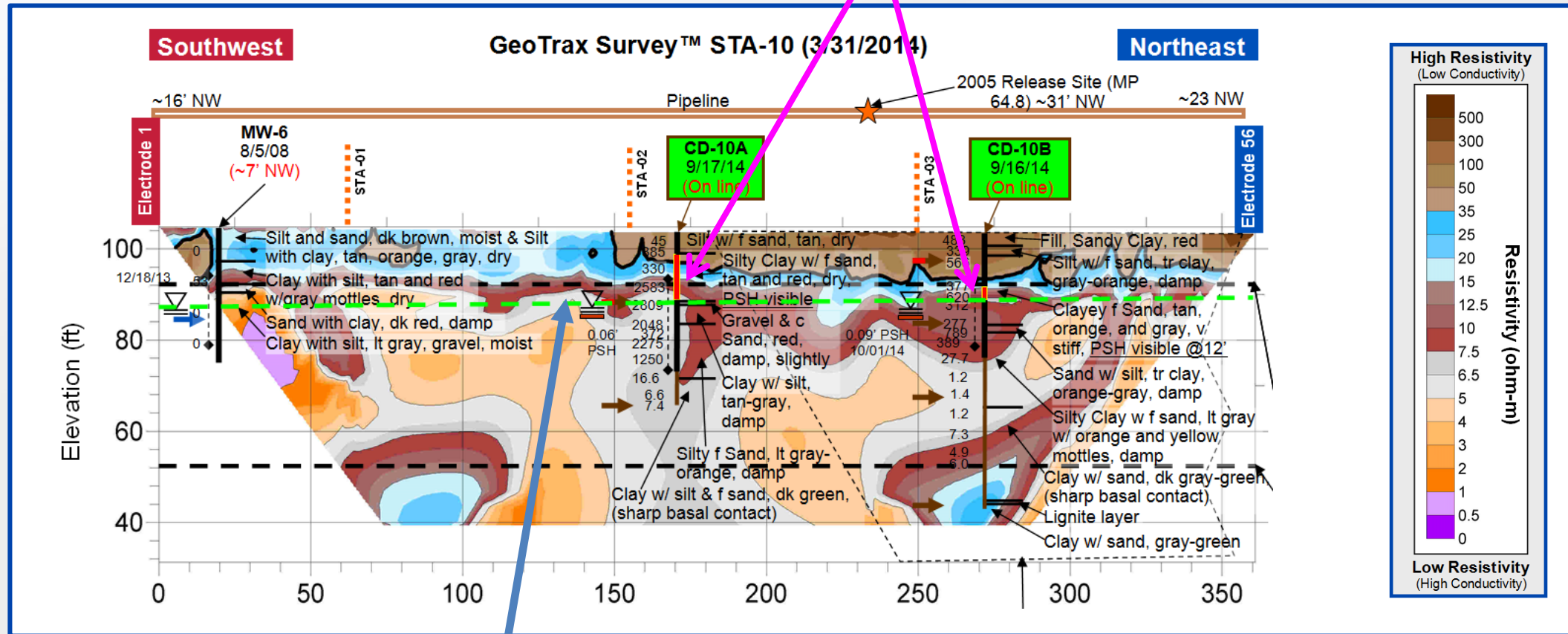
“Blob” anomalies crossing the coarse grained layer are targets for PSH related impacts





# Data Integration Evaluating Targets

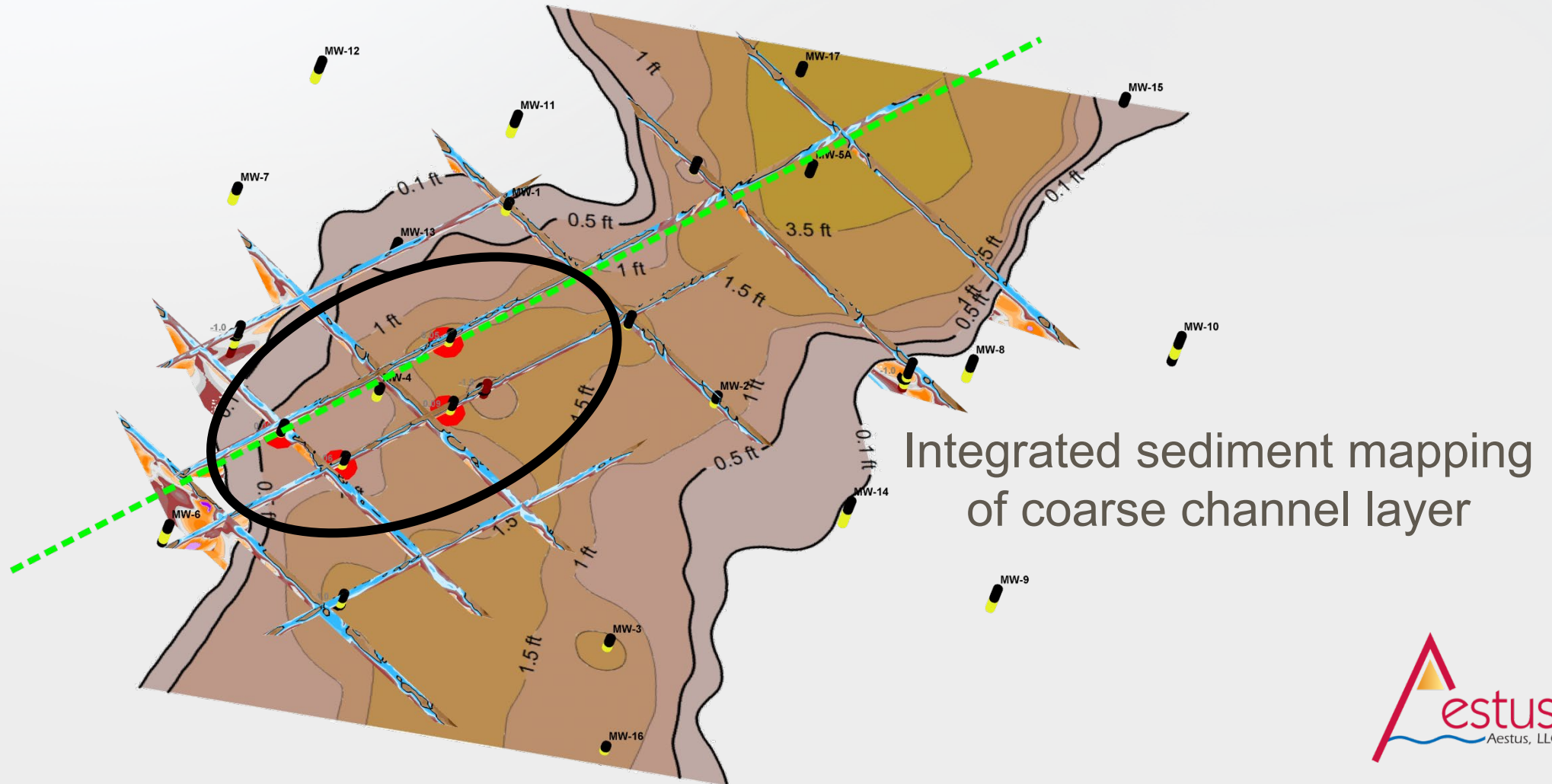
PSH related targets



Coarse grained layer

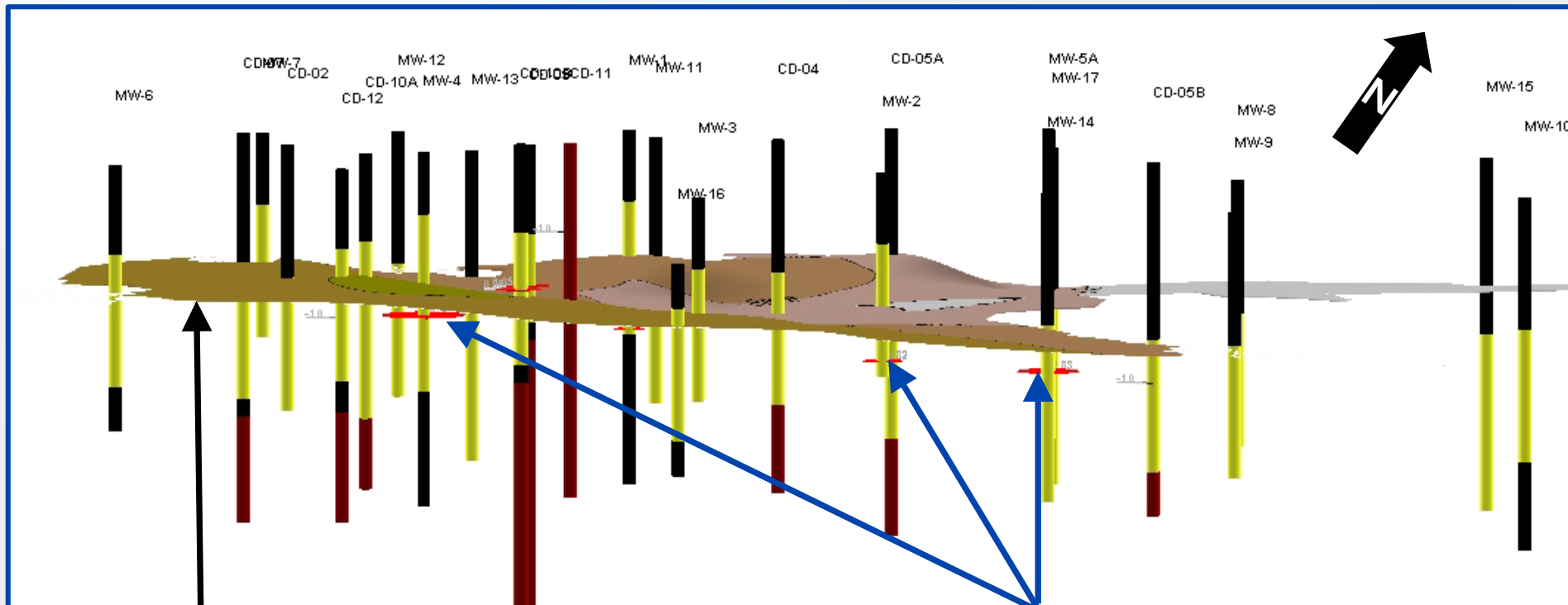
# Updated CSM (Graphical Explanation)

PSH related impacts bounded by lateral extent of coarse-grained layer



# Updated CSM (Graphical Explanation)

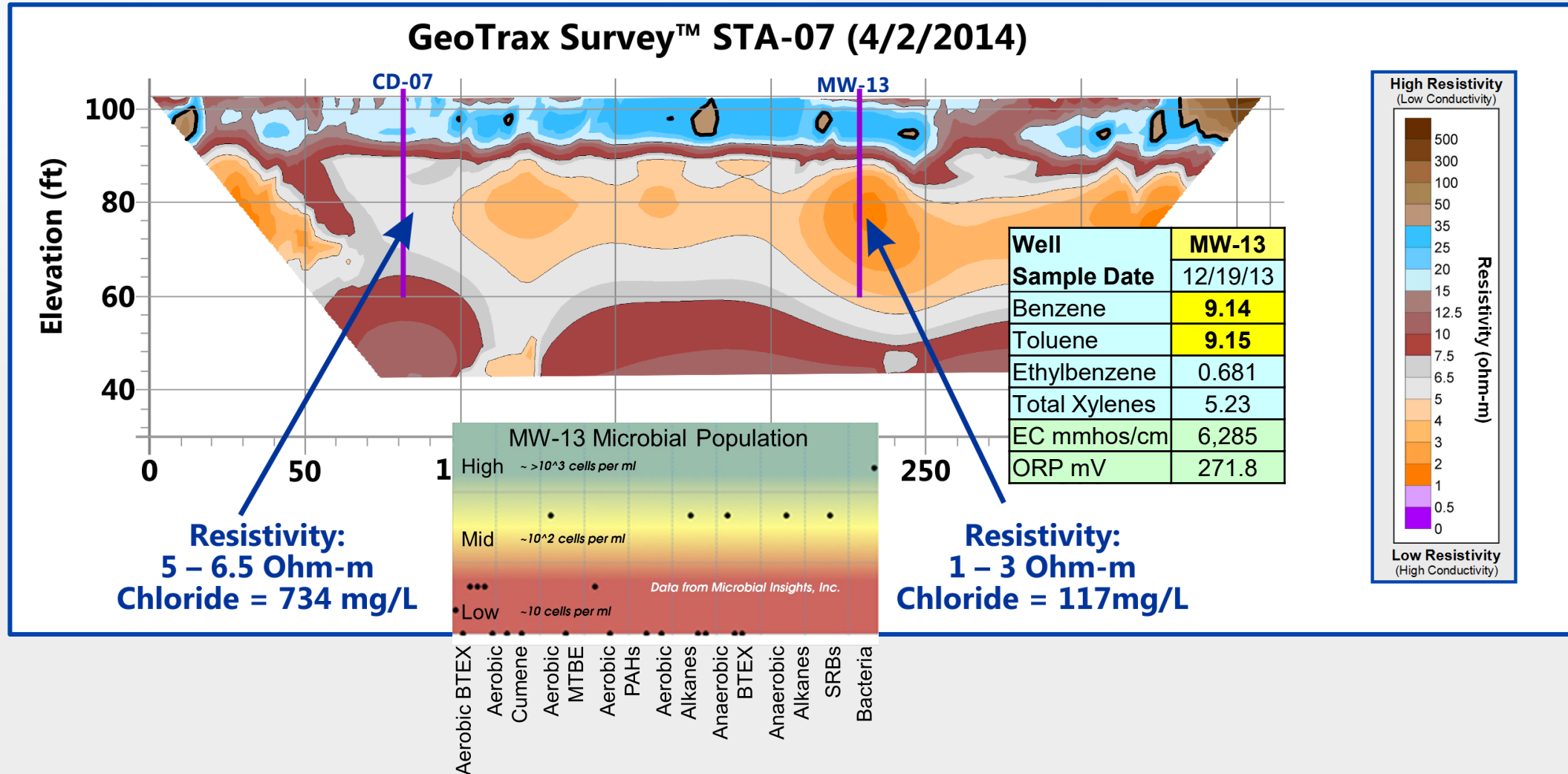
“Blob” anomalies crossing the coarse grained layer are targets for PSH related impacts



Modeled base of coarse layer

PSH mostly in finer grained sediment below coarse layer

# Low EC and Cl<sup>-</sup> at Conductors, Colonies present





# Biodegradation: Multiple Lines of Evidence

- In general, low site ER (w/ low Cl<sup>-</sup> at impacted wells) suggests widespread biological activity
- Coarse grained layer may act as natural horizontal "air sparge system" (positive ORP and DO values)
- Microbial activity confirmed with Microbial Insights Petroleum QuantArray

# Remedial Design Inputs

- “Blob” anomalies crossing the coarse grained layer are targets for PSH related impacts
- Multiple lines of evidence indicate PSH degradation likely ongoing
- **Can material migrate easily?**

# Key Factors for HRSC MNA

- Integrative Team looking for Technical Solution
  - Client/PRP
  - Consultants
  - Regulators
  - Electrical Hydrogeologists
  - Microbiologists
- Microbial Patterns Highly Variable
- Iterative Process to Answer Questions



# Questions/Discussion



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