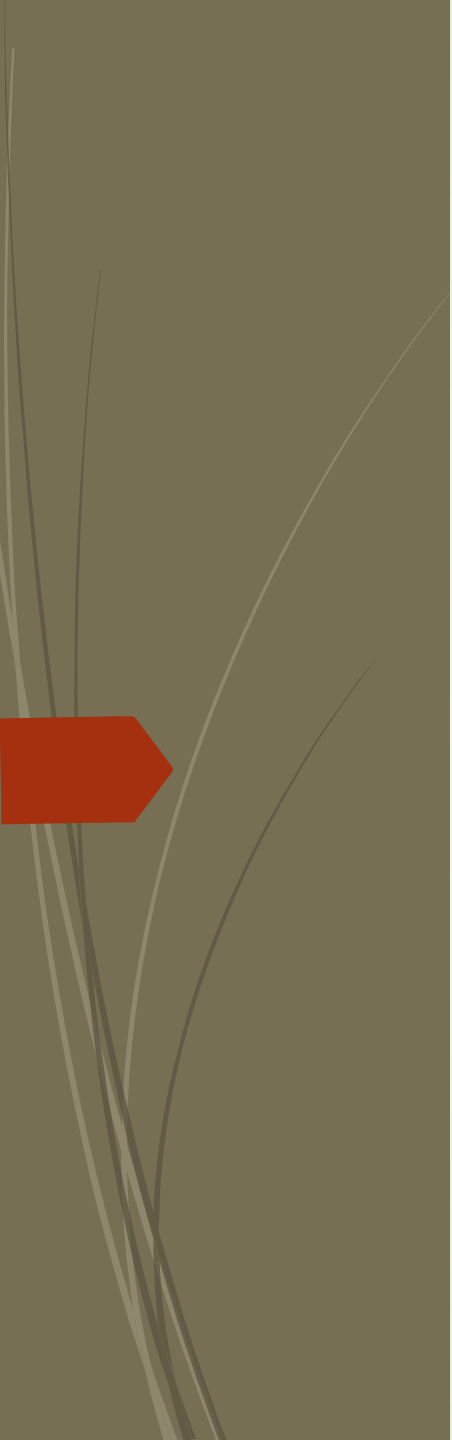




Using Surface Geophysics as a Critical Tool in Development of a Conceptual Site Model for Contaminant Fate and Transport in a Faulted Karst Setting

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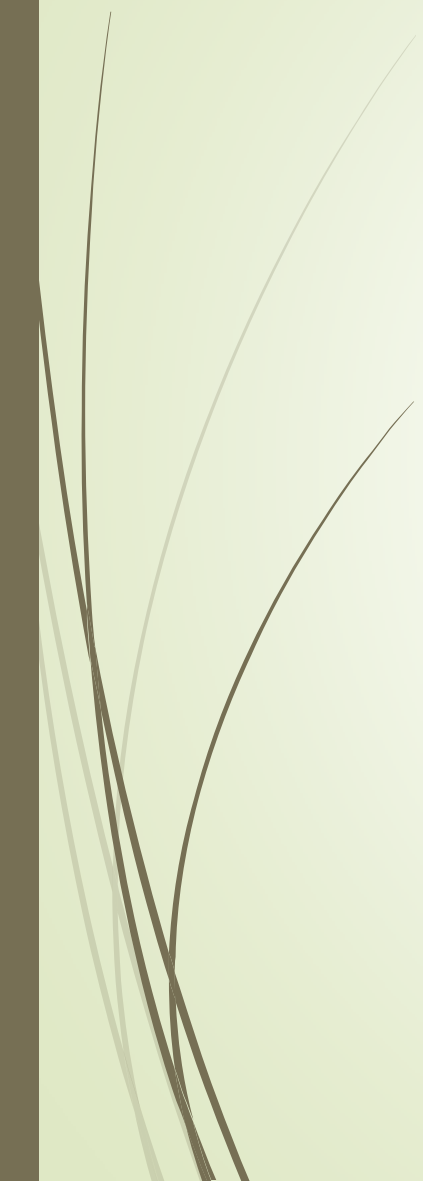
Andrew Riemer, Stantec Consulting Services, Inc

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Dr. Kevin Evans, Missouri State University

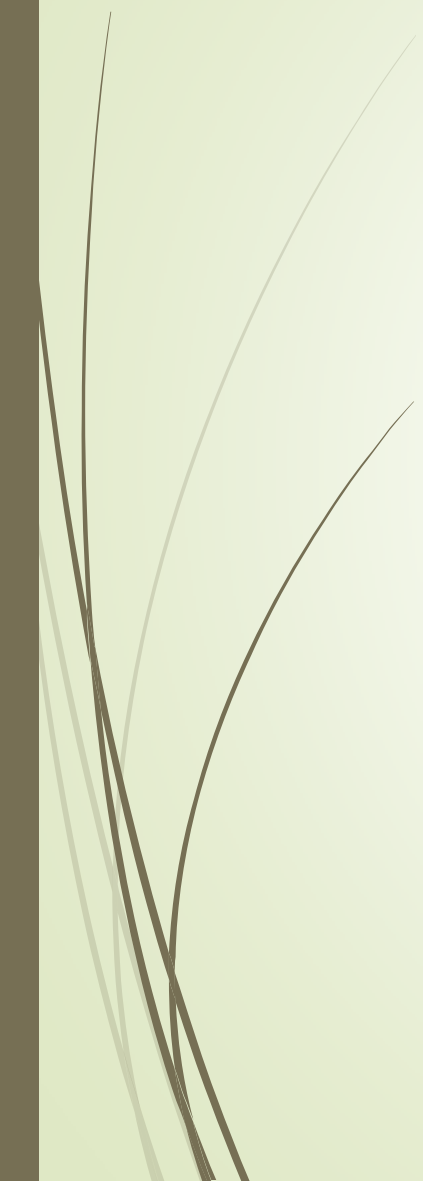


Presentation Overview

- Assessment of contaminant distribution in karst and fractured rock settings is difficult
 - Geologic structures such as fractures and fault zones can further complicate fate and transport
 - Surface geophysics can be used to focus on strategic drilling targets and refine CSMs
 - You will never “figure it all out”; the goal is to understand enough of the puzzle to develop a geophysics picture and make effective remedial decisions
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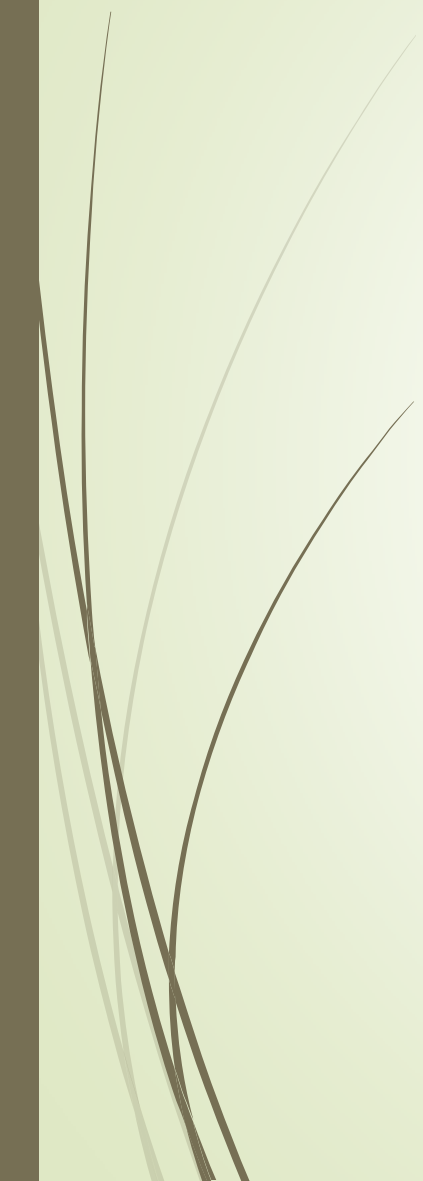
Site Conditions



- VOCs released in a karst setting via historic manufacturing operations
- Remediation on Facility has been conducted in soil/residuum and groundwater
- DNAPL concentrations persist in groundwater on Facility in the shallow karst aquifer (60 to 220 ft bgs)
- VOCs are present on Facility in a regional fractured carbonate aquifer below a unit previously characterized as an aquitard (220 to 300 ft bgs)
- Regional aquifer:
 - Extends below the aquitard to depths > 1,000 ft bgs
 - Monitoring wells deeper than 600 ft bgs can produce > 500 gpm



Project Objectives



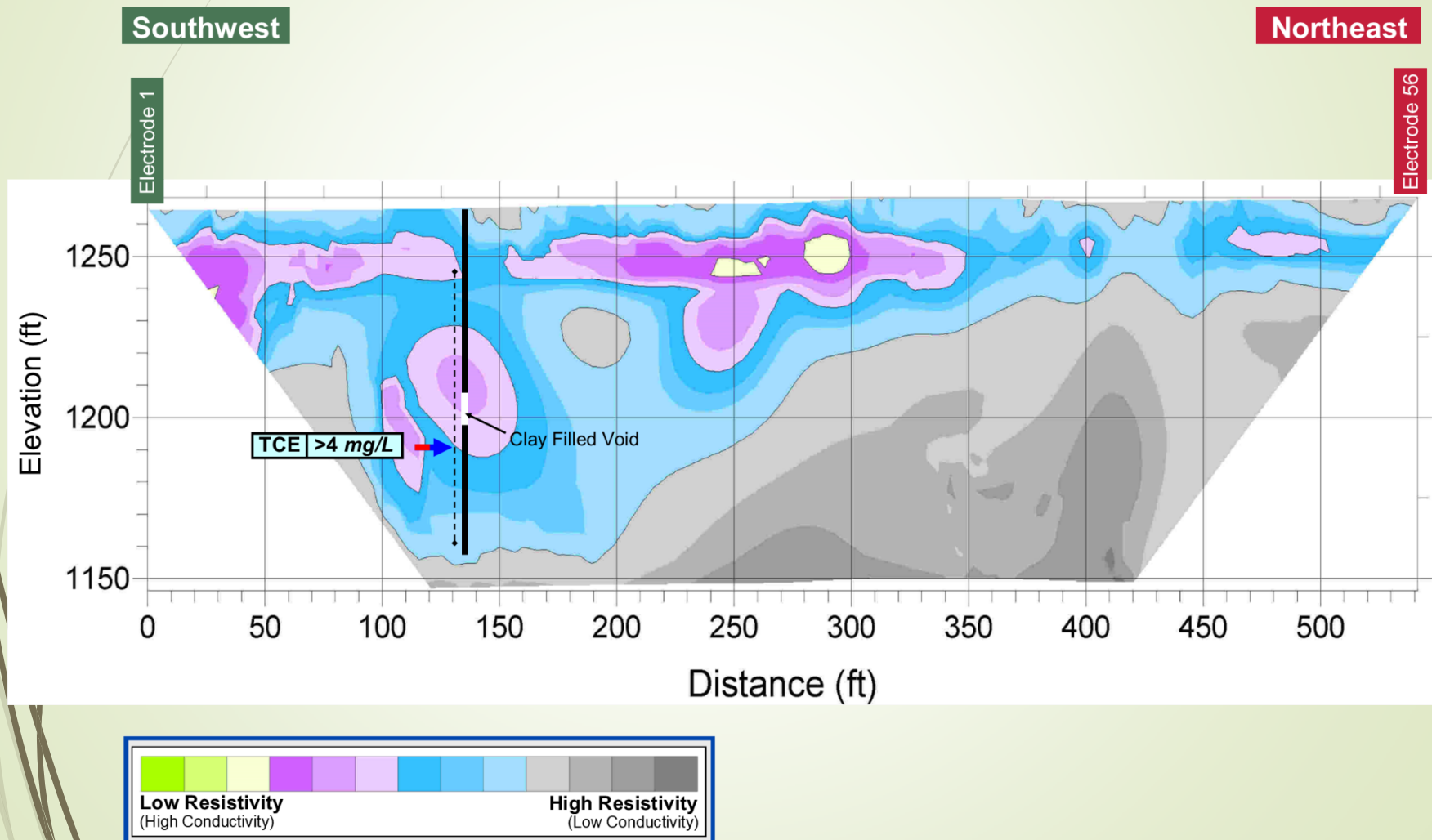
- Identify key structural and karstic features on Facility for targeted remedial actions
- Identify pathways in the karst system off Facility for installation of sentry monitoring points
- Evaluate potential pathways on Facility for migration of VOCs into the regional aquifer
- Further assess regional aquifer conditions



Phase One (Pilot Test)

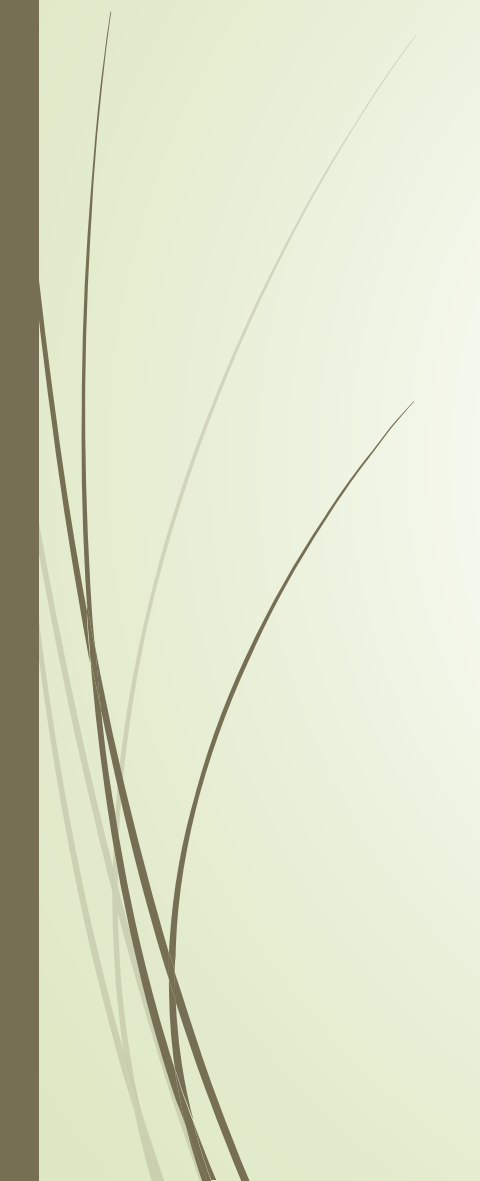
- Electrical Hydrogeology™ implemented in phased approach
 - Electrical Resistivity Imaging
 - Integration of Site data into RockWorks® Model 3D visualization
 - Targeted confirmatory drilling
- Conduct Phase One on Facility in an area of existing high data density
 - 8 lines utilizing 3-meter electrode spacing
 - Depth of assessment to 110 ft bgs (uppermost portion of the karst aquifer)
 - Technique clearly identified known karst and fracture, as well as additional features
 - Highly conductive signatures corresponded to where VOCs were known to be present

Pilot Test (110 ft bgs Image)





Phase Two



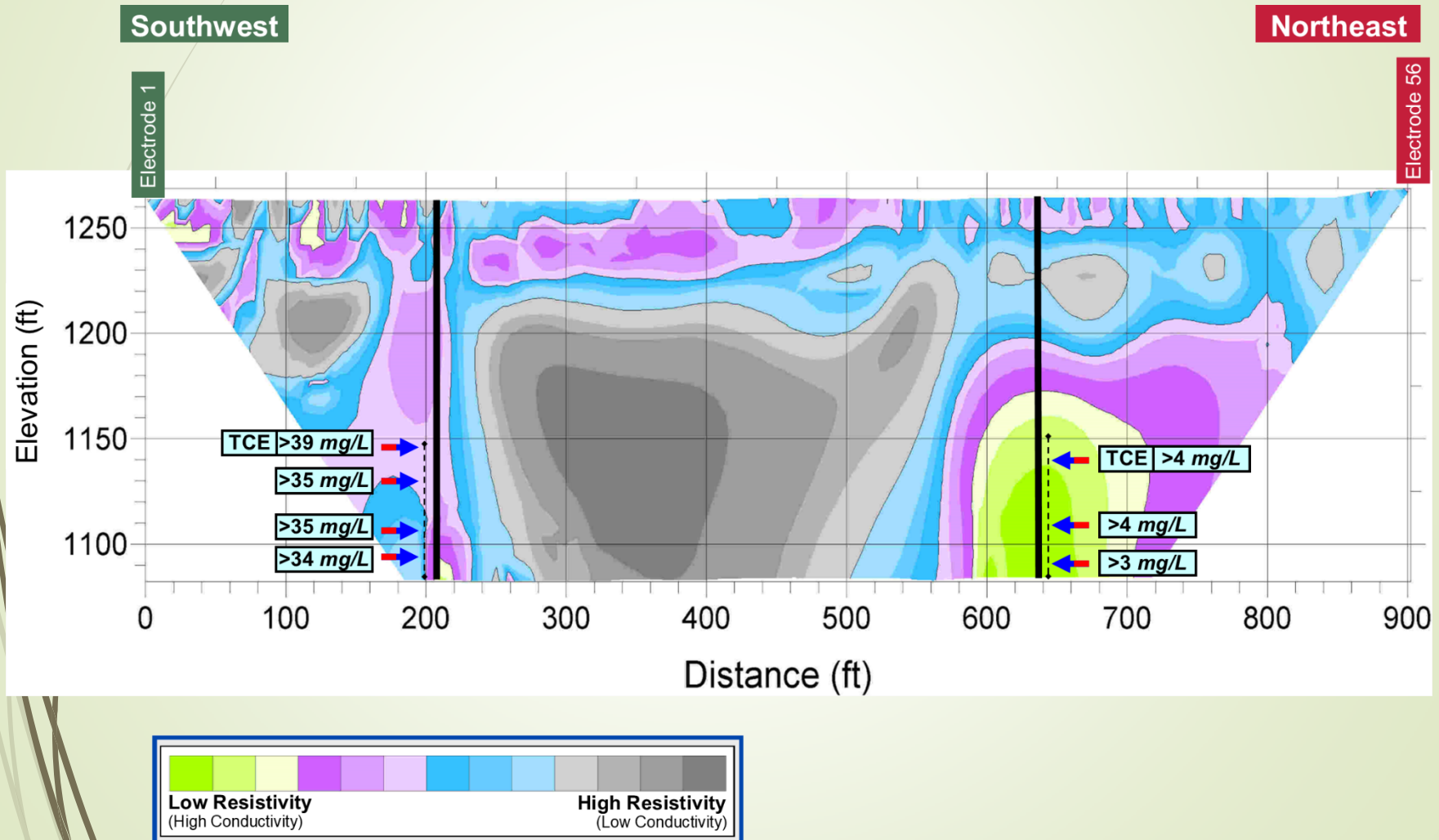
- Geophysics lines advanced in areas with considerably less data density where more information was needed
 - Potential karst transport pathways
 - Over the total depth of the shallow aquifer (approximately 220 ft bgs)
- Extend electrode spacings from 3 to 5 meters
 - Uses same number of electrodes (56) with longer lines
 - Depth of assessment extends to 180 ft bgs



Confirmatory Drilling

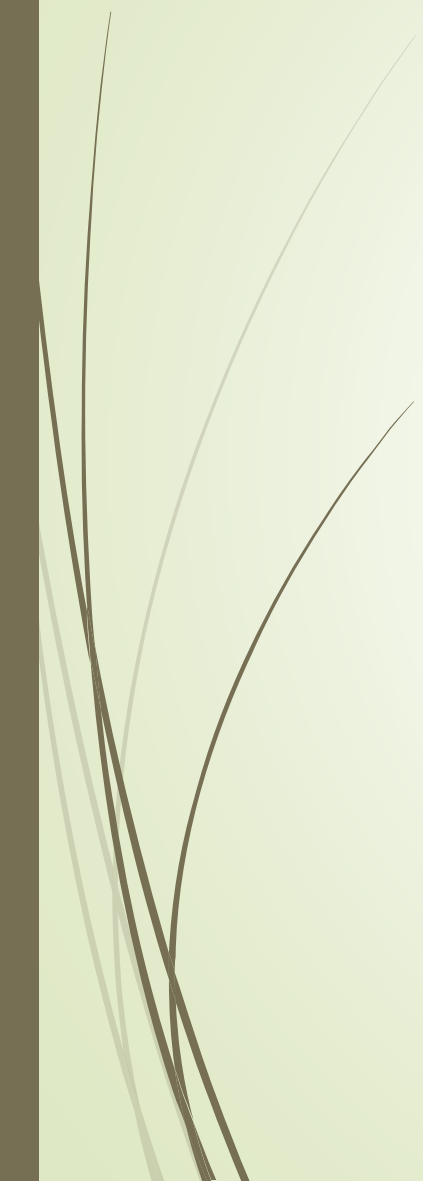
- Advanced sonic core holes and installed wells at two locations
- Confirmed presence of VOCs at both locations > 3 mg/L
 - One location “karst” feature and one a “fracture” feature
 - Higher concentrations in these areas than previously known
- Nature of conductive signature is still considered unknown
- Both wells converted for groundwater extraction
- Integration of data into the RockWorks® Model 3D visualization

Phase Two (180 ft bgs Image)





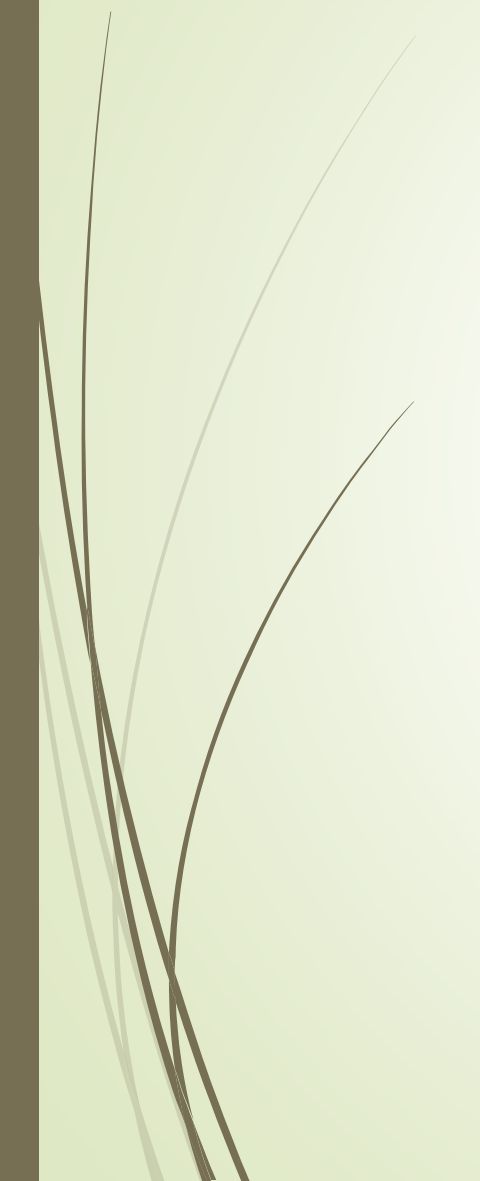
Phase Three



- Expand assessment on and off Facility
 - Lines advanced up to 1 mile away from the Facility
 - 8 to 10-meter electrode spacing utilized for shallow aquifer
 - 20-meter electrode spacing utilized for regional aquifer
 - Depth of assessment > 700 ft bgs
 - Each line > ½ mile in length
 - Overlap of lines to provide full coverage at depth
 - Focus on public right-of-way
- Greater than 5 miles of lines advanced during Phase Three scope



Phase Three (continued)

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- Key findings of Phase Three:
 - Additional areas on Facility with highly conductive signatures in the shallow aquifer
 - Off Facility karst features identified along potential flow paths
 - Conductive signatures in the regional aquifer were observed to the total depth of investigation (>700 ft bgs)

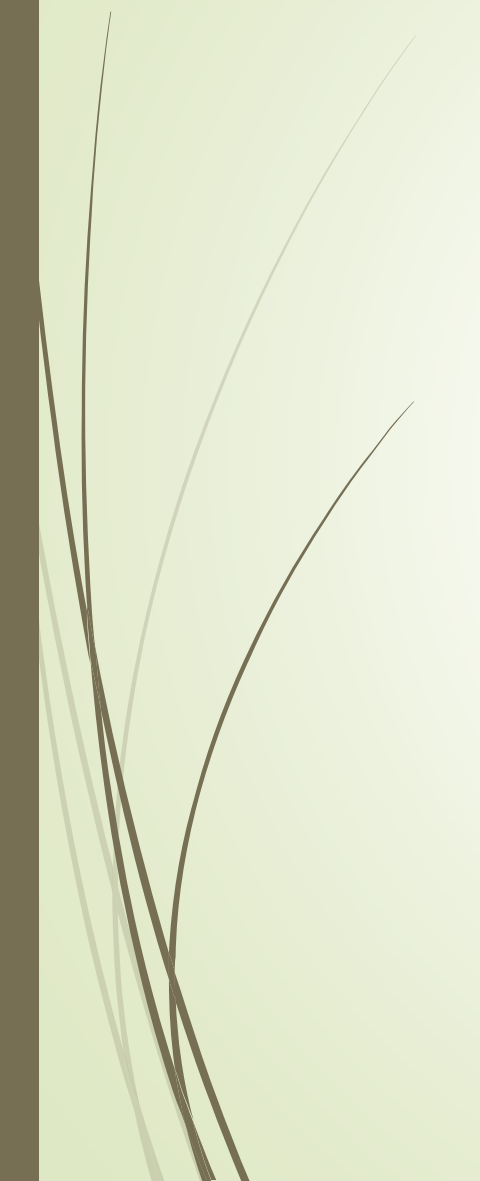


Confirmatory Drilling

- Focused on shallow aquifer
- Additional area of DNAPL identified on Facility in the shallow aquifer
 - Located in an area where such conditions were previously unknown
 - Extends to the top of the aquitard
- Karst flow paths (cave features) identified along off Facility flow paths
 - Relatively low concentrations of VOCs
- Data integrated into RockWorks® Model 3D visualization



Phase Four



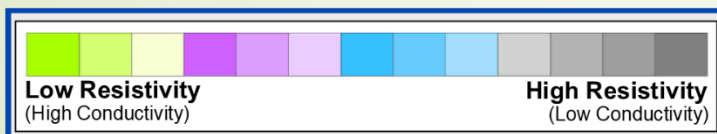
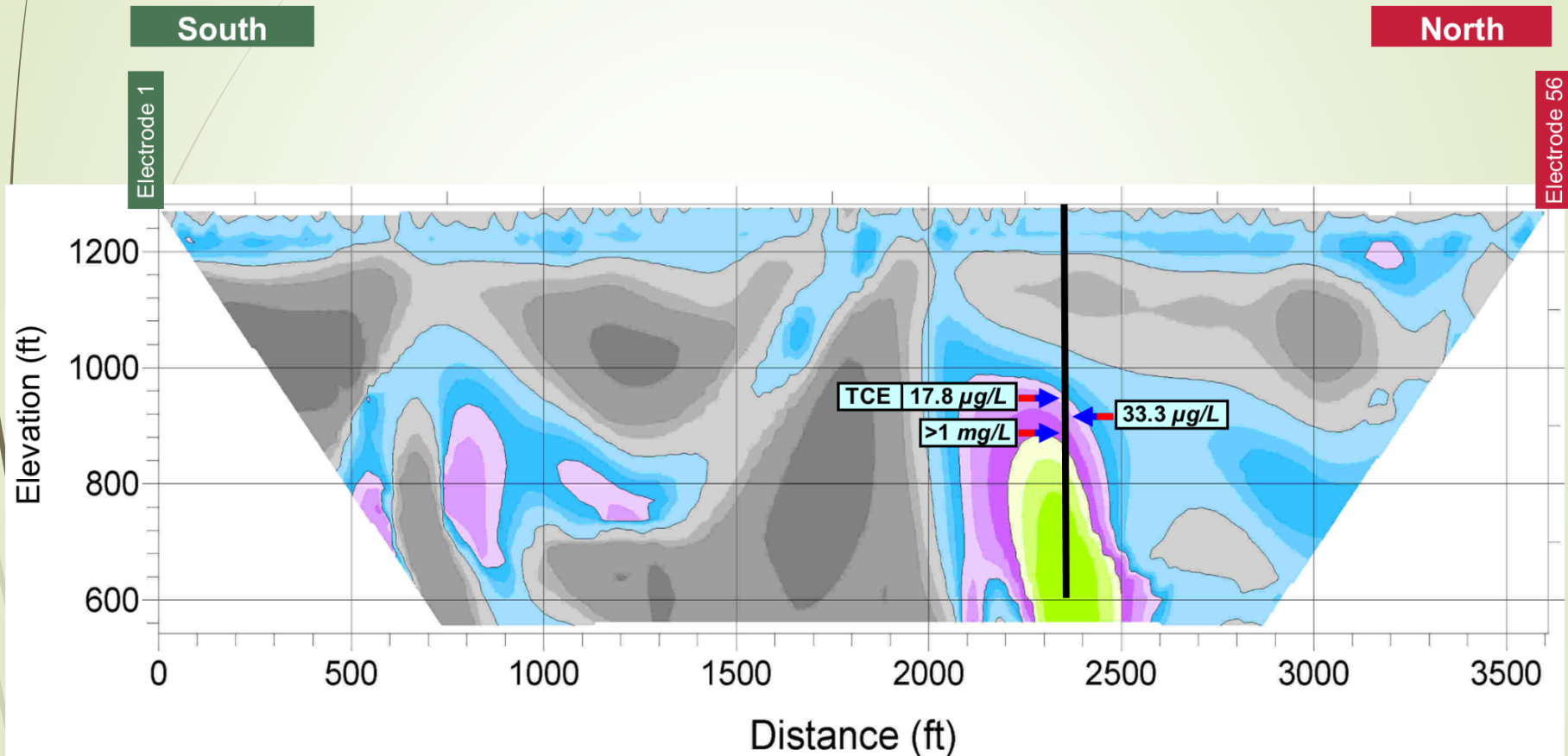
- Expand evaluations off Facility
 - Conducted at locations up to 2 miles away from the Facility
 - Utilized same electrode spacings as Phase Three (6 to 20-meter)
 - Advanced more than 5 miles of additional lines
 - Focus target areas on public right-of-way
- Identified highly conductive features in both the shallow and regional aquifers



Confirmatory Drilling

- Initial focus on regional aquifer
- Selected highly conductive feature inferred to be within regional NE trending fault structure proximal to the Facility
 - Depth to competent rock > 100 ft bgs
 - Air rotary drilling used to advance core hole to 700 ft bgs
 - Conductor casings set to isolate shallow and deep aquifers
- Straddle packers used to sample from nine discrete 20-foot sections of the open borehole in the regional aquifer
- VOC results consistent with the highly conductive feature (> 1 mg/L)
- Integrated data into RockWorks® Model 3D visualization
- Confirmatory drilling of the shallow aquifer is on-going

Phase Three (720 ft bgs Image)



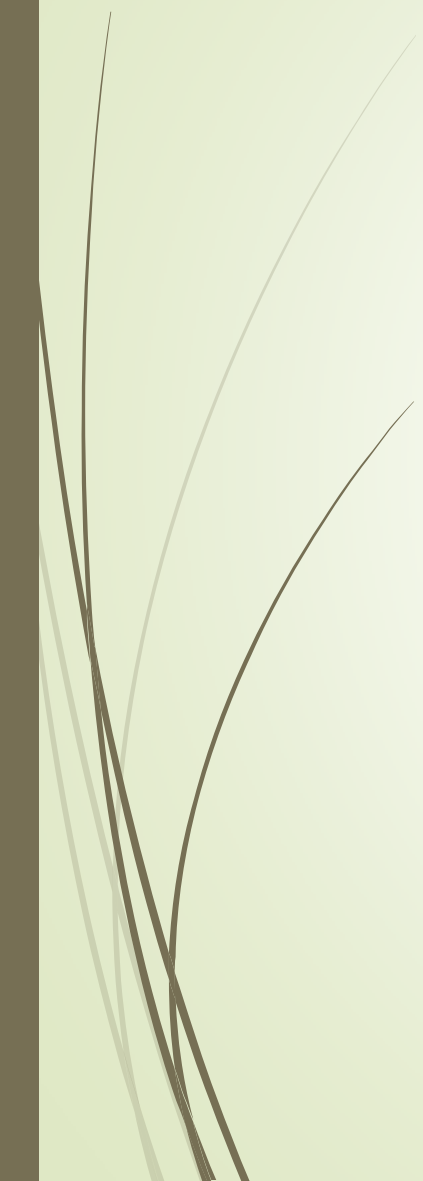


Why Are Features Conductive?

- Remains in evaluation
- Dissolved metals and other inorganic results do not suggest a source
- Geologic materials observed (limestone and dolomite) do not suggest a source
- Groundwater ORP data suggest reducing conditions in some intervals of VOC impacts
 - Highly conductive signature in bedrock may be associated with biofilm structure

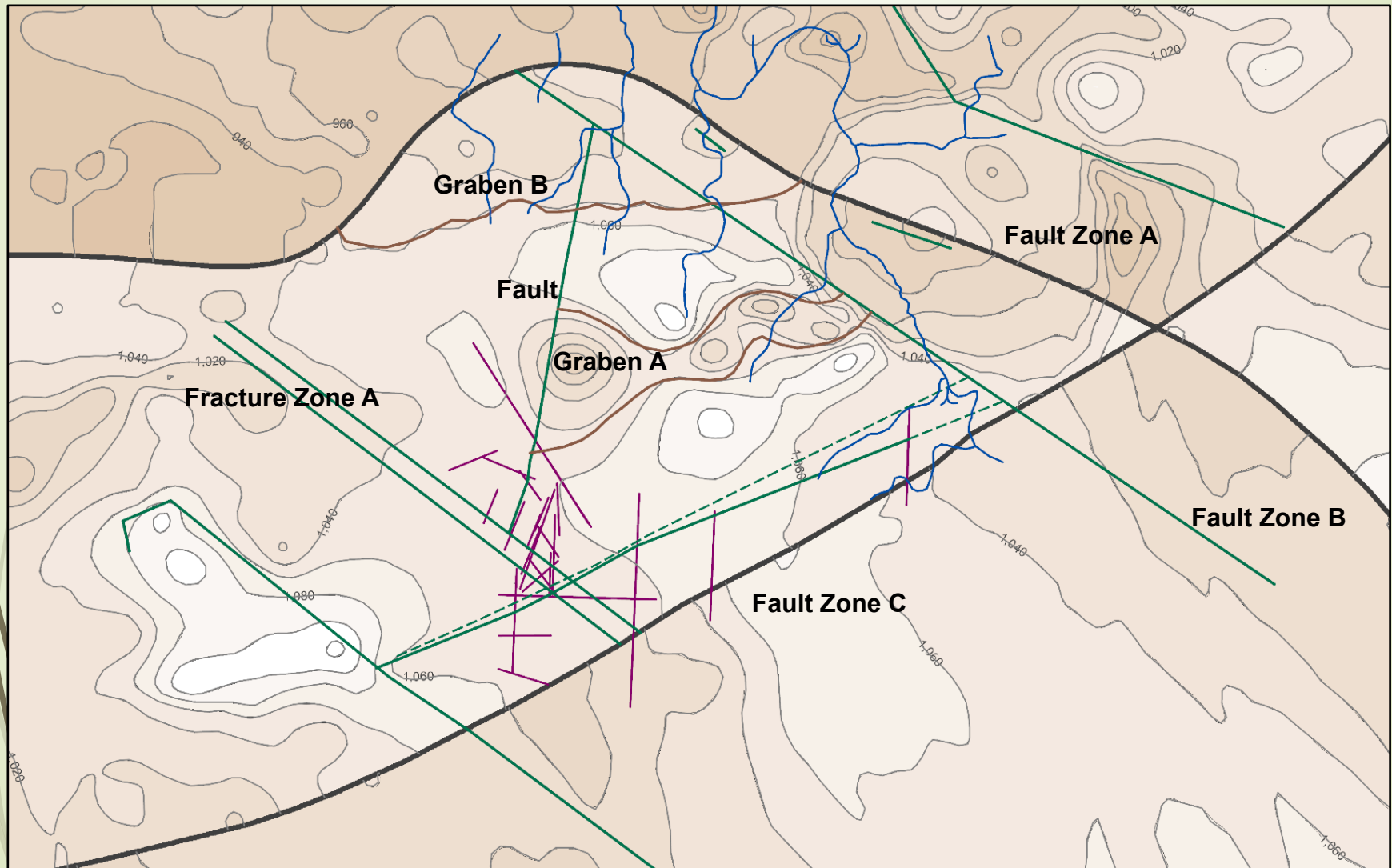


Data Integration



- Reviewed and integrated Site and regional geological and well data on faults, fractures, and aquitard topography
- Refined geologic structure interpretations based upon aquitard topography, geophysics results, and confirmatory drilling data
- Integrated additional information such as anion and cation geochemistry and tracer studies done by others

Regional Conceptual Model





Conclusions

- Aestus GeoTrax Survey™ has proven to be a highly useful technology to collect subsurface data on a regional scale
- The results are accurate in both a lateral and vertical scale, extending to depths > 700 ft bgs
- The Aestus GeoTrax Survey™ data, coupled with confirmatory drilling results and complete data integration, provides a representative CSM for contaminant transport and fate in a complex hydrogeologic setting
- Collaboration between Aestus, LLC and Stantec to collect, integrate, and interpret data in a phased approach while expanding the work area and investigation depth key to successful CSM development



Questions?

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Thank you for your attendance

