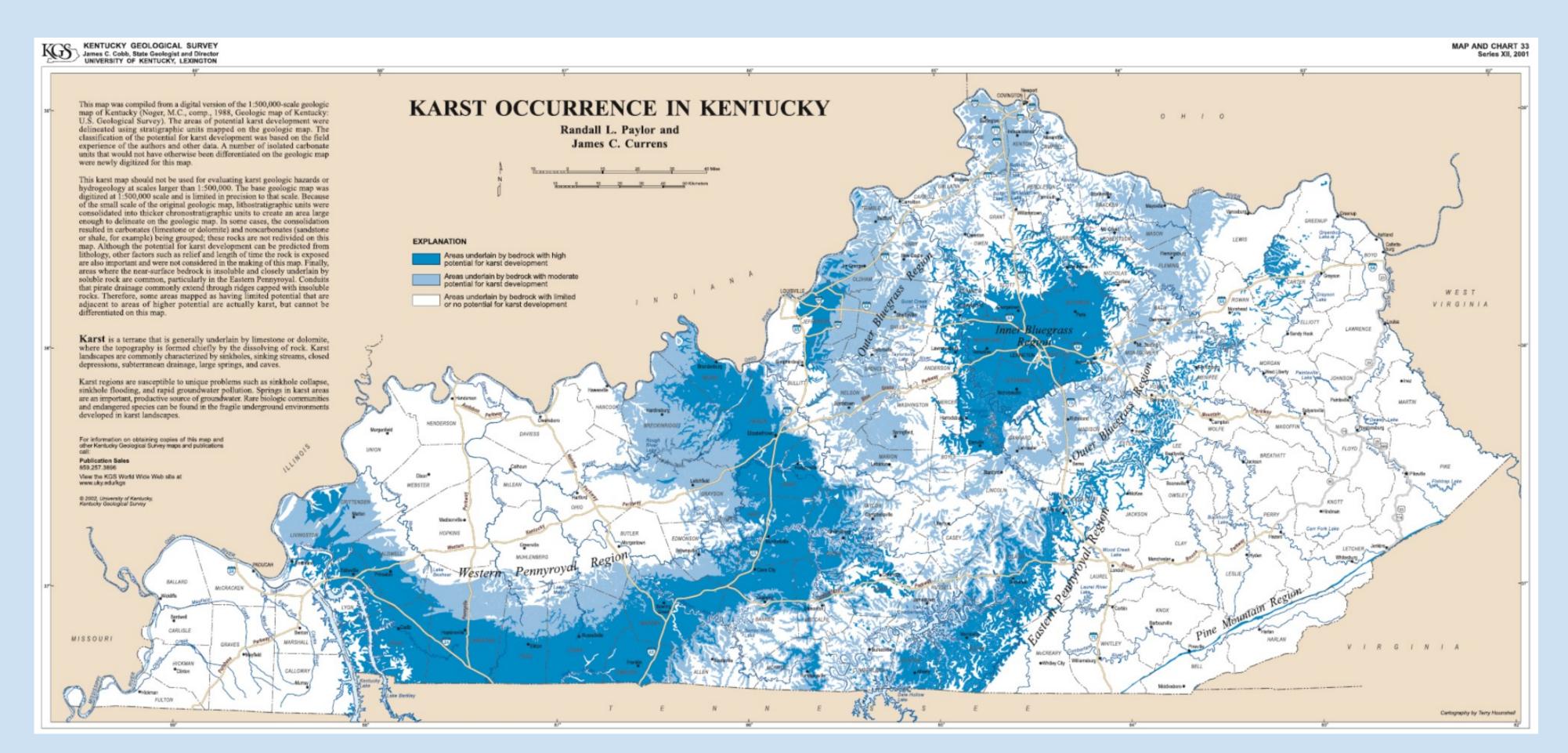
Underground Storage Tanks in Carbonate Bedrock Settings

The Kentucky Underground Storage Tank (UST) Branch has found that the use of surface geophysical methods to support conceptual site model development at UST sites in carbonate bedrock areas improves bedrock monitoring well placement. Approximately 55 percent of near-surface bedrock in Kentucky is limestone or dolomite (Currens, 2002) and the depth to bedrock in some carbonate bedrock areas is shallow (<15 feet below grade). UST systems installed in shallow bedrock areas are often constructed on or in bedrock; therefore, UST releases have impacted bedrock.

Selecting locations for bedrock monitoring wells to support identification of contaminant mass and distribution in carbonate bedrock settings can be difficult. Bedrock monitoring wells have been installed at Kentucky UST sites using topographic maps, observation of physical features, review of nearby UST sites, and published geologic reports. As measured against a goal of selecting well locations to efficiently determine impact status, these efforts have been hit and miss.

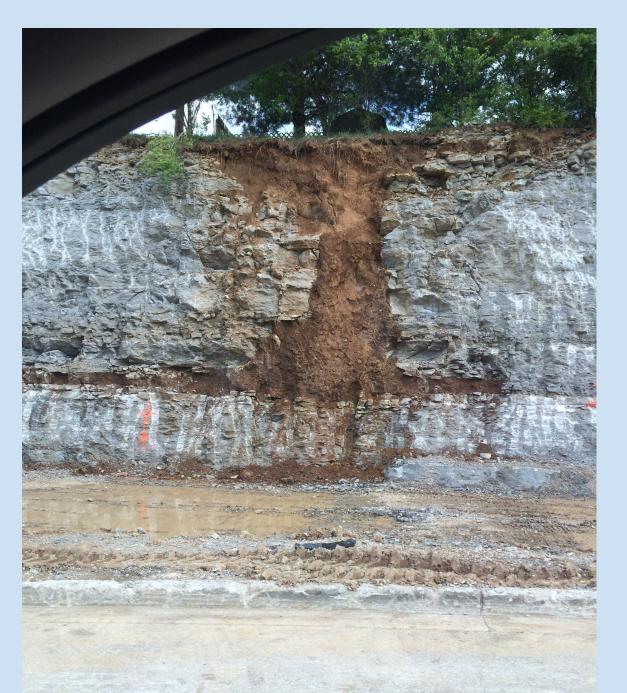
To improve bedrock monitoring well placement the UST Branch has employed two-dimensional electrical resistivity imaging (2-D ERI) to characterize the topography of the bedrock surface and identify soil-filled or water-filled voids, weathering zones, and fractures at a number of sites. 2-D ERI can be performed at many UST sites in 2 to 3 days.





Images of Inner Bluegrass Karst Georgetown and Lexington



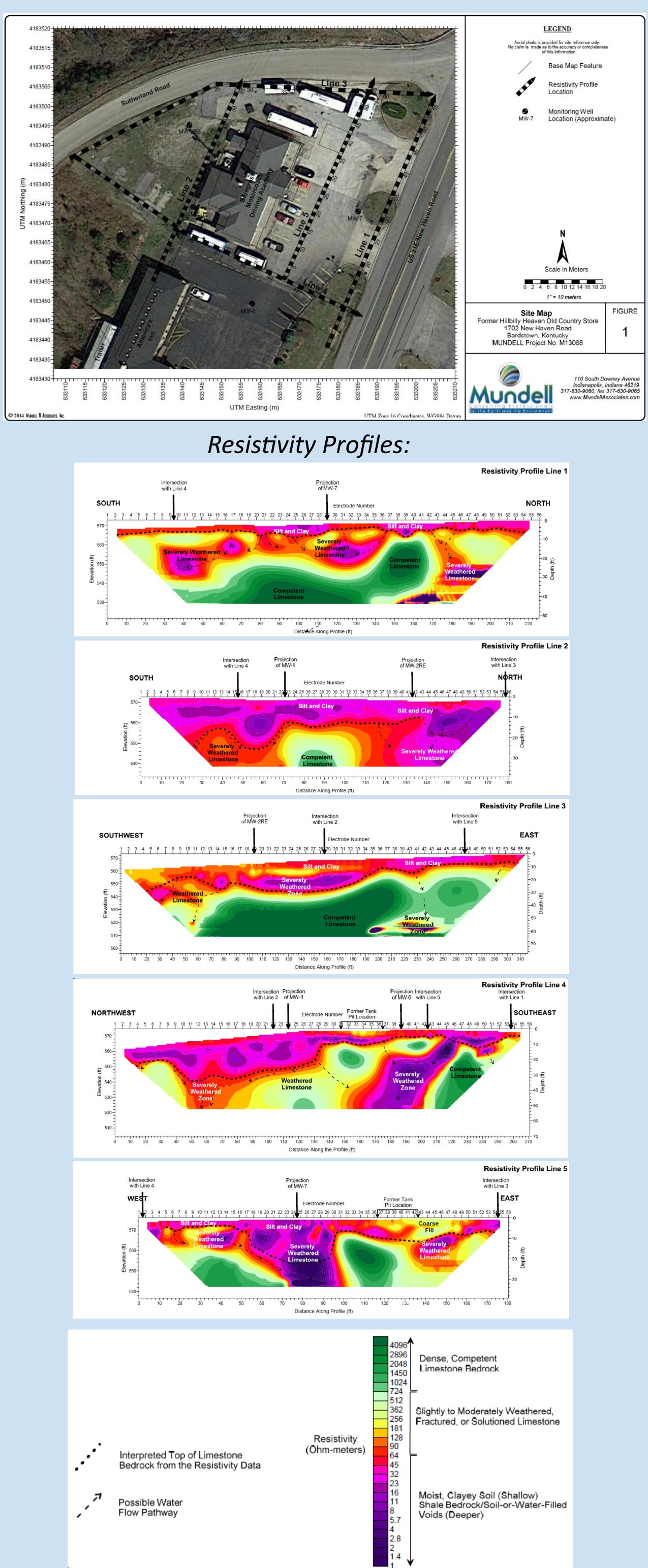




Lessons Learned: Using Surface Geophysics to Select Bedrock Monitoring Well Locations at UST Sites in Carbonate Bedrock Settings in Kentucky

Brad Highley, P.G. — Kentucky UST Branch

2-D ELECTRICAL RESISTIVITY IMAGING RESULTS and GEOPHYSICAL INTERPRETATION — BARDSTOWN SITE

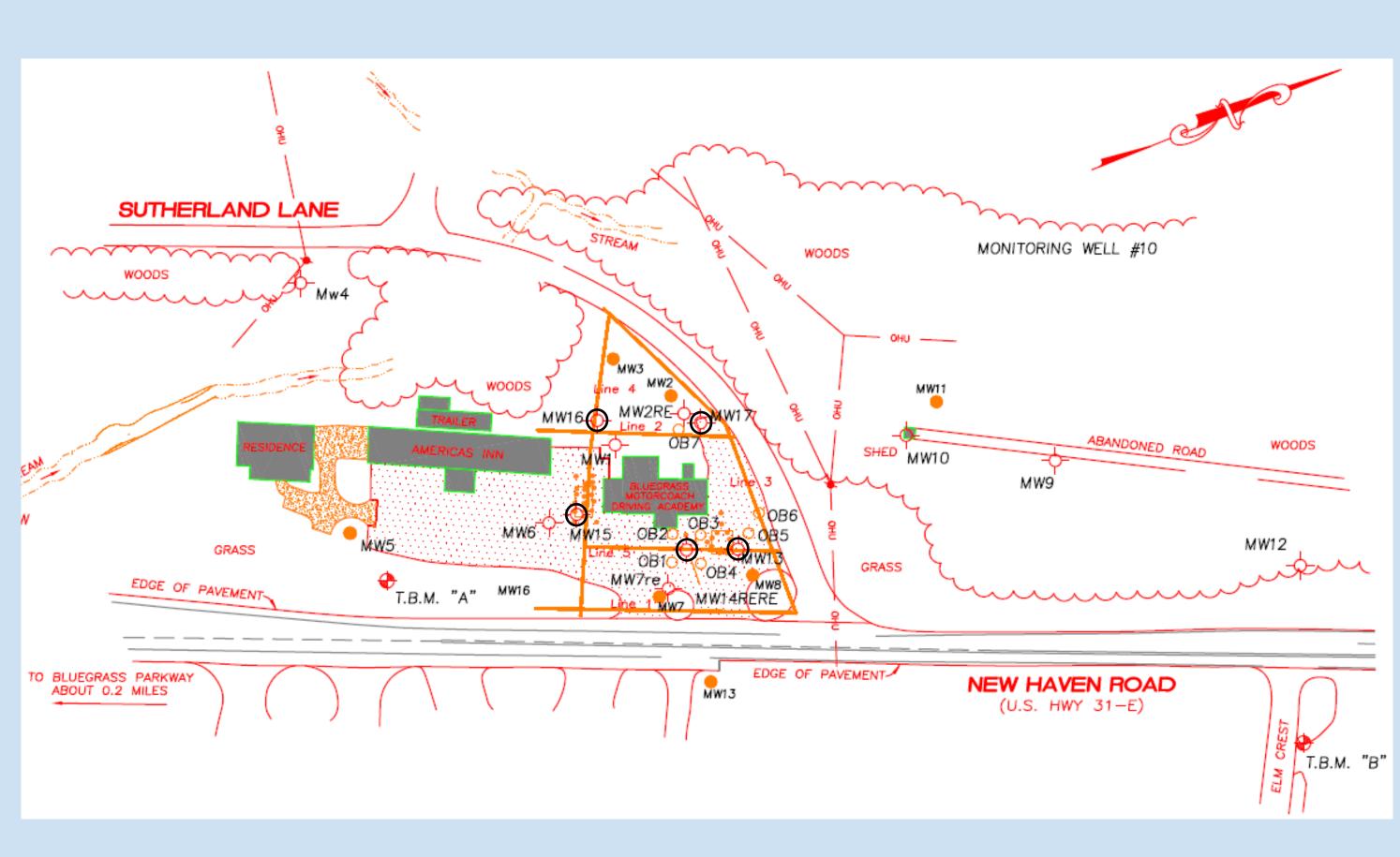




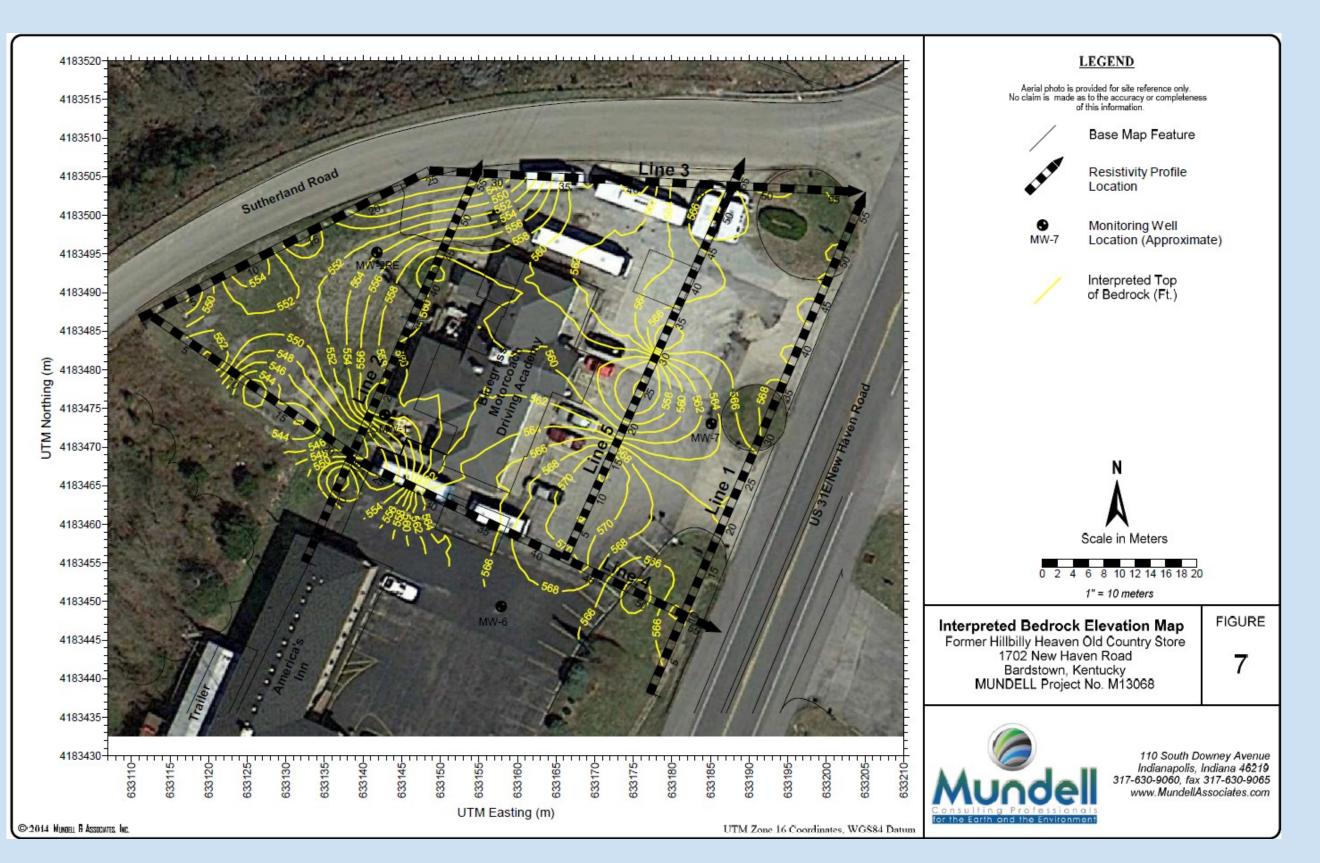
UST systems were removed in 1986 and 2005 from this property in Bardstown, Kentucky. (Recently, a motor coach driving school has operated at this property.) Benzene was confirmed in groundwater in bedrock in 1996 during Phase II Environmental Site Assessment activities. Kentucky Geological Survey maps indicate that bedrock units outcropping in vicinity of this site are the Louisville Limestone, Waldron Shale, and Laurel Dolomite. Pump-and-treat and dual-phase extraction technologies were used as a corrective action approach for a number of years. Some contamination reduction was noted after the remediation work but the reduction was insufficient to support site closure.

2-D ERI field work was performed in December 2013. Upon reviewing the geophysical report, the UST Branch worked with the consultant and directed the installation of bedrock wells in locations where resistivity profiles and vertical slice maps indicated possible weathered and fractured areas. 5 bedrock wells were installed to confirm the electrical resistivity results and geophysical interpretation (see circled locations on the map below).

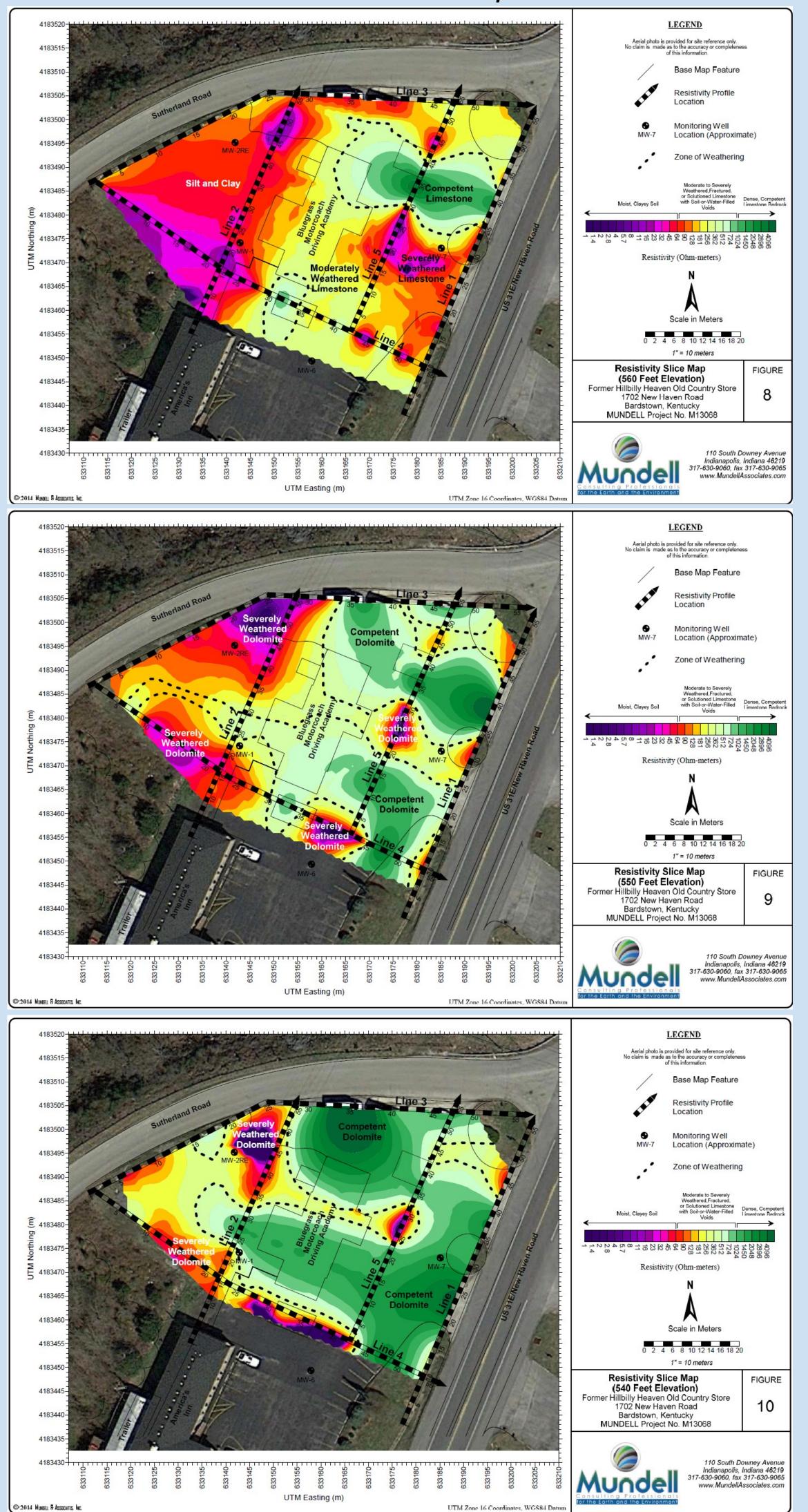
Benzene in groundwater above MCLs was confirmed in each of the newlyinstalled bedrock wells. Analytical results from one of the new wells showed Benzene in groundwater at 23.1 mg/L, the highest Benzene concentration observed historically. As a result of the geophysical work and installation of new bedrock monitoring wells, focus at the site has moved from characterization to remediation.



2018 National Tanks Conference — Louisville, Kentucky



Vertical Slice Maps:



TYPICAL ELECTRICAL RESISTIVITY EQUIPMENT USED FOR DATA COLLECTION AT SITES IN KY





TABLE OF COSTS FOR SURFACE GEOPHYSICS

This table shows the costs of using 2-D ERI and other geophysical techniques to characterize the bedrock surface and deeper at 7 sites. Costs of the geophysics work will vary based on mobilization distance, size of site, number and length of lines, number of techniques used, target depth, etc.

Costs of Using Surface Geophysics Techniques at Kentucky Sites					
Type of Facility	Location	Karst Region	Geophysics Scope of Work	Estimated Time to Complete	Costs
service station	Nelson Co.	Outer Bluegrass Region	5 resistivity profiles	2 days*	\$ 9,400.00
truck stop	Madison Co.	Inner Bluegrass Region	5 resistivity profiles	2 days**	\$ 5,600.00
service station	Rockcastle Co.	Eastern Pennyroyal Region	5 resistivity profiles, electromagnetic terrain conductivity, & GPR	2 days*	\$ 16,800.00
service station	Scott Co.	Inner Bluegrass Region	3 resistivity profiles, electromagnetic terrain conductivity, GPR, & refraction microtremor shear wave profiling	2 days*	\$ 14,580.00
service station	Jefferson Co.	Outer Bluegrass Region	5 resistivity profiles, electromagnetic terrain conductivity, & GPR	2 days*	\$ 13,200.00
service station	Oldham Co.	Outer Bluegrass Region	5 resistivity profiles	2 days*	\$ 9,500.00
convenience store	Gallatin Co.	Outer Bluegrass Region	7 resistivity profiles, electromagnetic terrain conductivity, & GPR	2.5 days*	\$ 15,400.00

*Includes cost of mobilization, field work, per diem, data analysis, a report, etc., for the geophysics contractor. Does not include costs of primary contractor oversight, mobilization, etc **This was part of a larger scope of work that included bedrock boreholes, downhole geophysics, etc., so the \$5,600 amount does not include mobilization, per diem, a report, etc

LESSONS LEARNED

Lessons learned: inadequate subsurface assessment can lead to incomplete remediation, increased costs, and longer time to site closure. The 2-D ERI method (plus other geophysical techniques) may locate bedrock features and help in understanding contamination distribution in bedrock. Based on the results of several surface geophysics studies and subsequent monitoring well installations, of which the Bardstown site is an example, the Kentucky UST Branch supports the use of surface geophysics in the site assessment process.

LITERATURE CITED

Kentucky is Karst Country! What You Should Know about Sinkholes and Springs by James C. Currens, 2002, Kentucky Geological Survey Information Circular 4, Series XII.

ACKNOWLEDGEMENTS

Subsurface assessment activities at the former UST facility in Bardstown were performed by the consultant, Chase Environmental Group, Inc., of Louisville, KY, and surface geophysics and subsurface geophysical characterization were performed by the geophysics contractor, Mundell & Associates , Inc., of Indianapolis, IN.







