High Resolution TarGOST/ CPT Characterization of DNAPL and Evaluation of Remediation Trenches using MVS

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ABSTRACT: Subsurface impacts at a former Manufactured Gas Plant (MGP) Site include coal tar dense nonaqueous phase liquid (DNAPL). Stratigraphy and DNAPL plumes were characterized by 68 conventional soil borings, 67 high-resolution Tar-specific Green Optical Screening Tool (TarGOST®) probings, and 21 cone penetrometer test (CPT) probings. Observations from borings and TarGOST® data indicated DNAPL presence was widespread, but variable and discontinuous. CPT probes provided high-resolution information on the complex stratigraphy. The selected remedy includes trenching and constructing subsurface galleries for passive collection of DNAPL. Given the complex three-dimensional distribution of DNAPL plumes, development of a methodology to quantitatively evaluate numerous prospective locations of trenches to optimize potential DNAPL recovery was a critical objective. The Mining Visualization System (MVS) Software by C Tech Corporation was chosen to develop a quantitative, visually-guided methodology. Prospective trench geometries were visually drawn, with simultaneous calculations of volumes of DNAPL-impacted soil within ten feet of the trench centerlines, and the surface area of plumes along trench centerlines. This methodology allowed rapid testing and ranking of many complex prospective trench lines, and selection of those intercepting the largest DNAPL volumes. Four trenches were constructed in October and November 2011, with subsequent DNAPL recovery demonstrating the method's validity.

INTRODUCTION

Coal gasification operations took place at the six-acre Aberdeen, South Dakota Former Manufactured Gas Plant (MGP) Site from 1888 until 1948. Subsurface impacts include coal tar in the form of dense nonaqueous phase liquid (DNAPL). Methods used to characterize the DNAPL plumes and stratigraphy consisted of conventional drilling/probing at 68 soil boring locations, high-resolution laser-induced-fluorescence (LIF) data collection using the Tar-specific Green Optical Screening Tool (TarGOST®) at 67 locations, and cone penetrometer test (CPT) probing at 21 locations. Locations of the soil borings, CPT probings, and TarGOST probings are shown in Figure 1.

METHODOLOGY

The abundance of high-resolution data offered both the opportunity for extremely detailed analysis, and a significant challenge for development of a trench evaluation methodology that would utilize and honor all the data. The Mining Visualization System (MVS) Software by C Tech Corporation was chosen to perform these tasks. Initially, MVS was used to visualize stratigraphy using CPT data and derived soil classifications.

LEGEND:

- CPT LOCATIONS
- TarGOST LOCATIONS
- SOIL BORING/MONITORING WELL LOCATIONS
- TarGOST CHARACTERIZATION AREAS

0   200   400 Feet

GRAPHIC SCALE

NORTHWESTERN ENERGY
ABERDEEN, SOUTH DAKOTA
FORMER MANUFACTURED GAS PLANT SITE

CPT, TarGOST, and Soil Boring Test Locations

ARCADIS
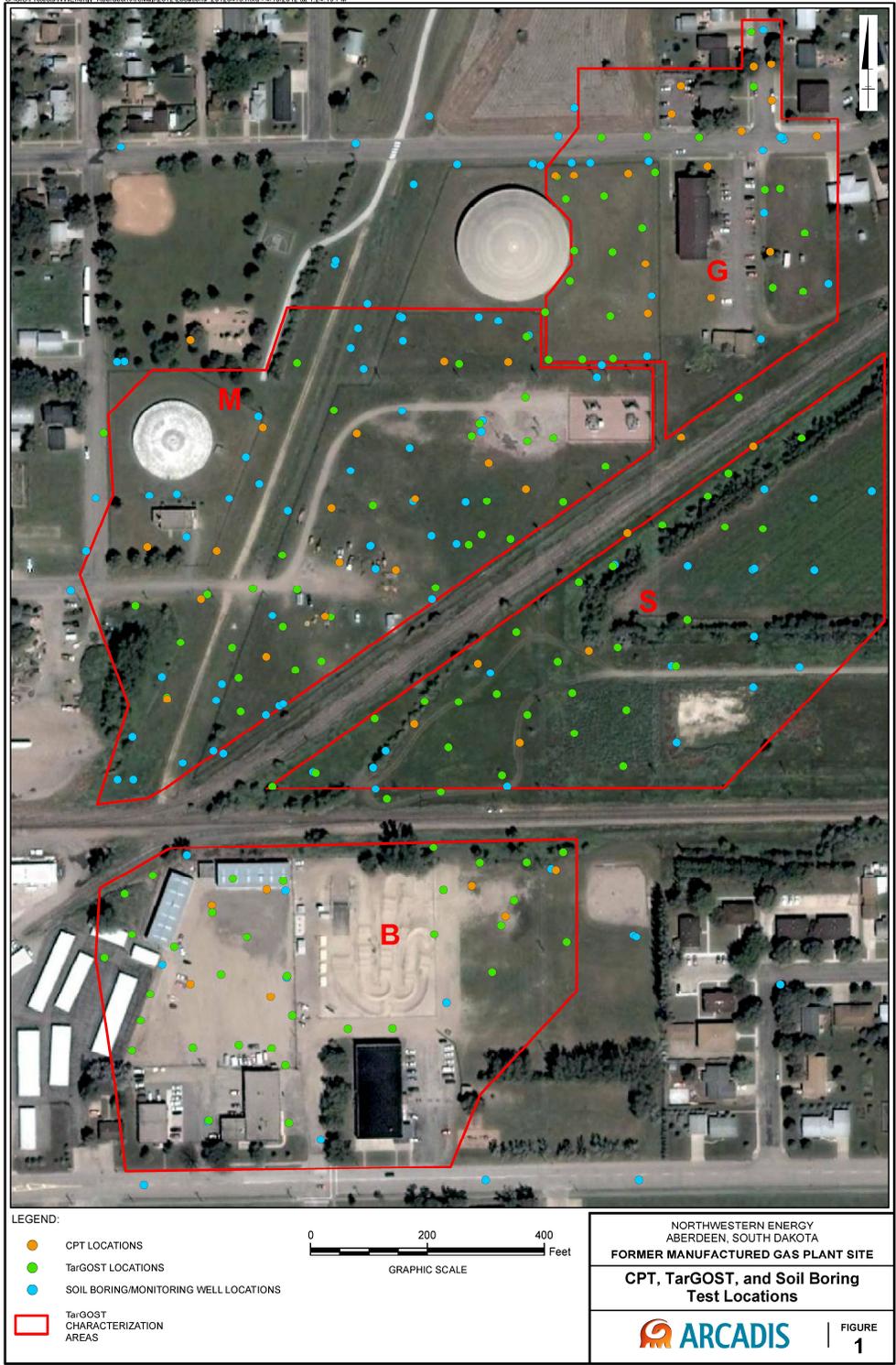
FIGURE
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FIGURE 1. CPT, TarGOST, and Soil Boring Test Locations.

CPT Characterization. CPT probes provided high-resolution information on cone resistance, friction ratio, and porewater pressure. Data collected at 1-centimeter intervals allow constructing profiles as shown in Figure 2. CPT data were used with the normalized soil behavior charts of Robertson (1990), which use CPT parameters normalized in terms of effective stress, to develop a high resolution subsurface soil stratigraphic model. Figure 2 shows CPT based soil stratigraphy at the discrete probing locations. The site soils included lacustrine clays/silty clays over deltaic sandy silt/ silty sands, which in turn overly glacial till. The top surface of the glacial till unit is shown in Figure 2. The low permeability glacial till layer is thought to retard the downward migration of DNAPL.
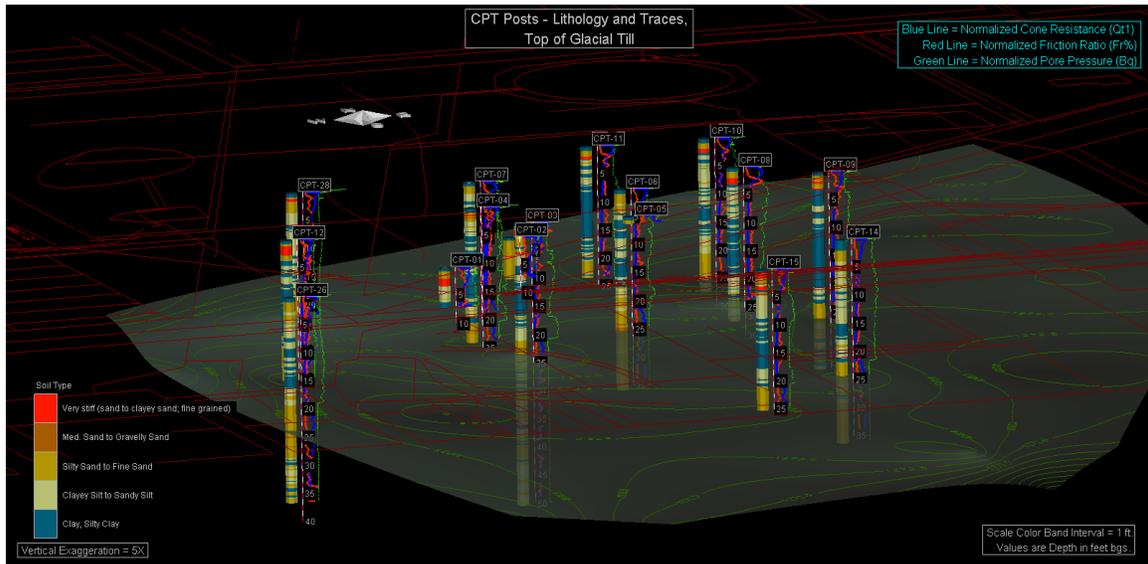

FIGURE 2. CPT soil stratigraphy with profiles of cone resistance, friction ratio, and porewater pressure.
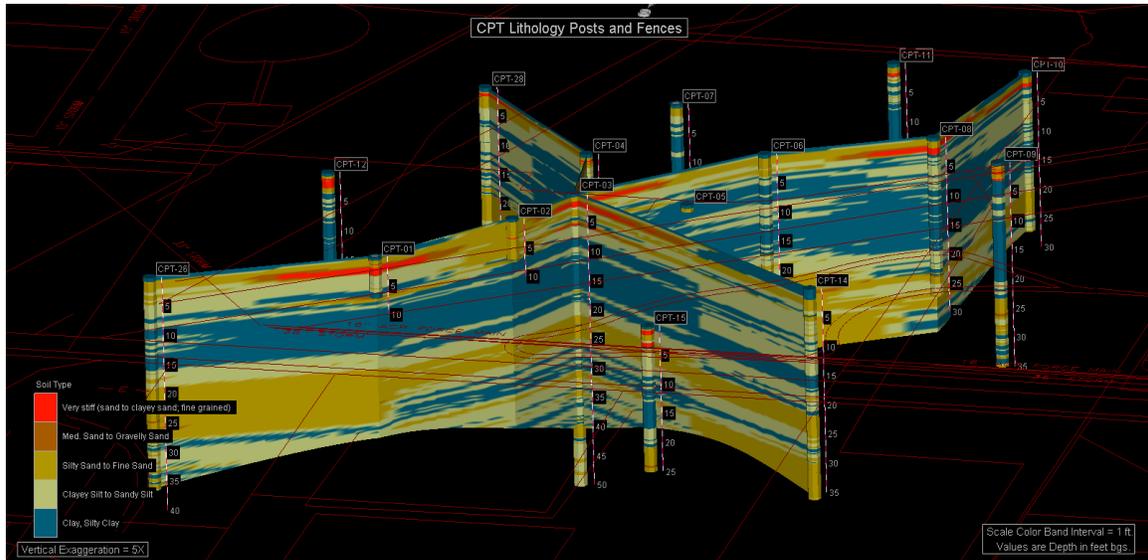

FIGURE 3. CPT stratigraphic profiles.

Figure 3 illustrates stratigraphic profiles based on kriging between the CPT probe locations. Comparison of lithologies shown in the data posts with the surrounding fences illustrates that the kriged fences honor the CPT data very well. Any desired fence line(s) can be easily generated from the model.

TarGOST® Characterization. TarGOST® data were subsequently visualized and kriged in combination with the dataset of observed DNAPL in borings to allow the distribution of NAPL bodies to be understood.
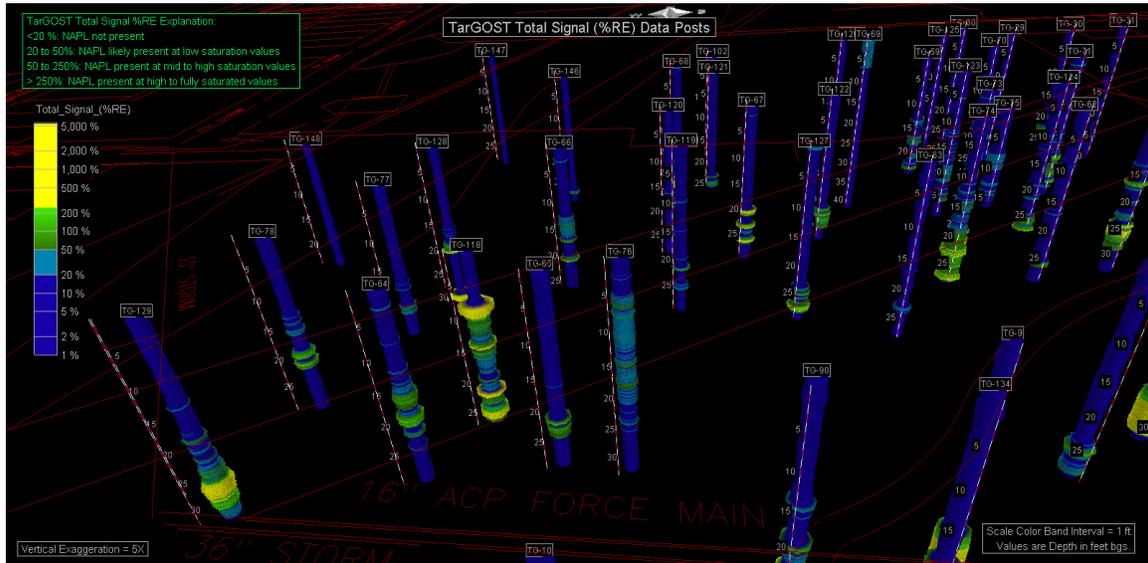
FIGURE 4. TarGOST® data posts.

The TarGOST instrumentation collects data at intervals from approximately 0.02 to 0.05-foot intervals, resulting in a dataset of 37,777 rows for this investigation. Every data point is included in the data posts as shown in Figure 4. The data are color-coded and increase in diameter as the total percent reflectance (%RE) signal increases, allowing DNAPL presence to be easily seen.
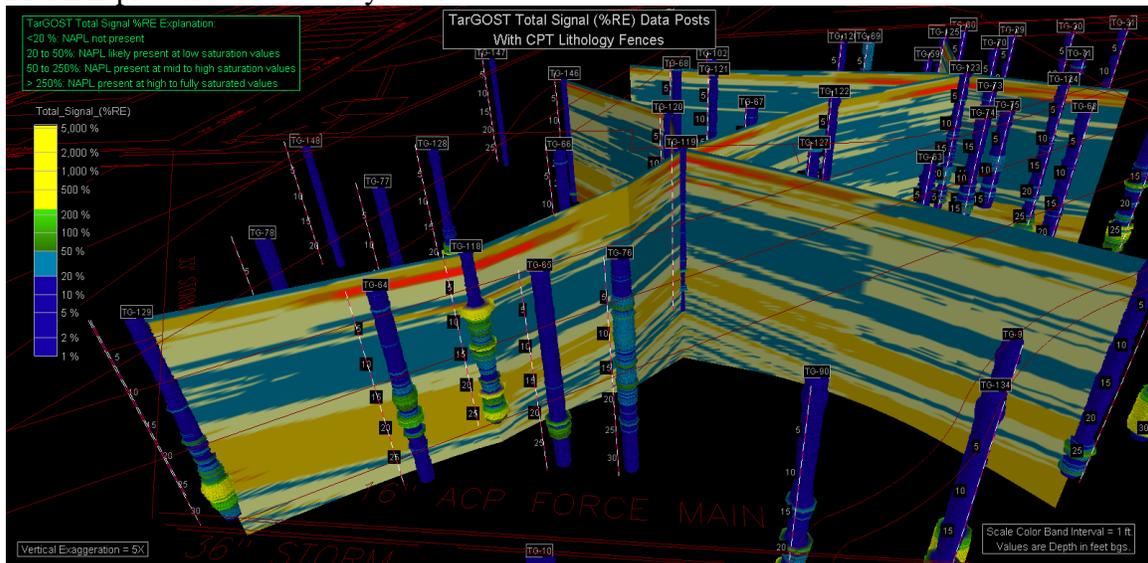
FIGURE 5. Combination of TarGOST® data posts with CPT lithologic fences.

Figure 5 combines TarGOST® data posts with CPT lithologic fences. This figure illustrates how the lithologic control of the DNAPL distribution may be evaluated by combining the two data sources.
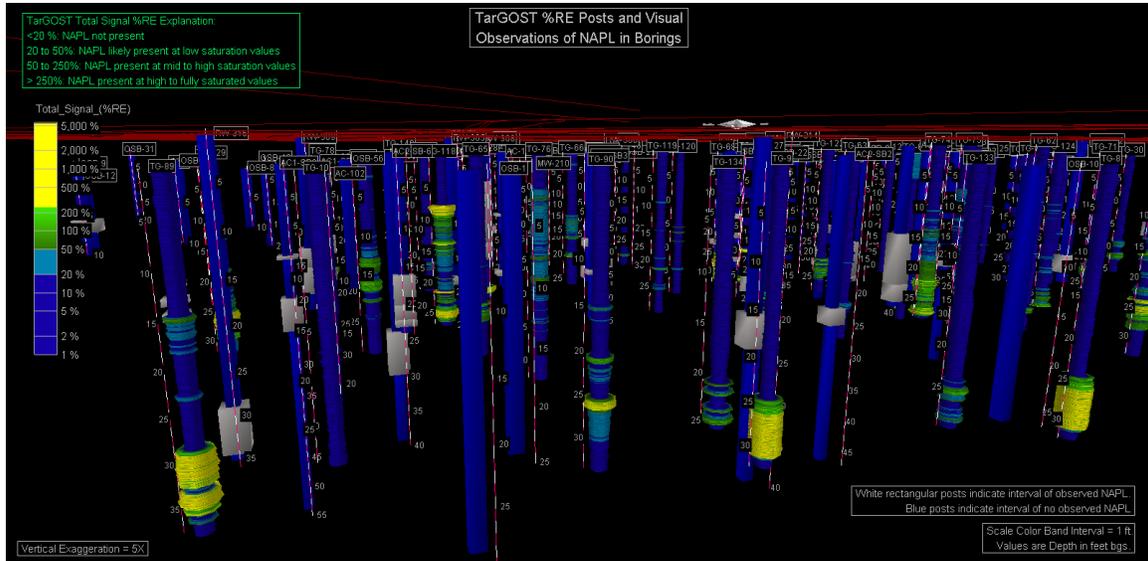

FIGURE 6. TarGOST data posts and visual observations of DNAPL in soil borings.

TarGOST® data posts and visual observations of DNAPL are combined in Figure 6. The intervals in which DNAPL was observed appear as white rectangular prisms. Note that the depth scales along each boring allow impacted intervals to be easily assessed.

Observations from borings and TarGOST® data indicated DNAPL presence was widespread, but extremely variable and discontinuous, both laterally and vertically to depths of approximately 35 feet. The data were combined to krig DNAPL plumes as illustrated in Figure 7.
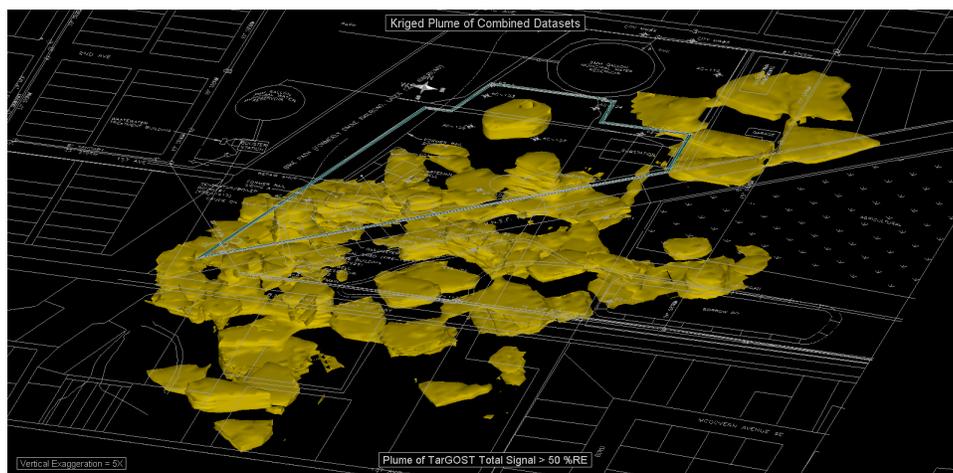

FIGURE 7. The plume of DNAPL kriged from the combination of TarGOST® data and visual observations.

Trenchline Evaluation. The selected remedy consists of trenching and constructing subsurface galleries for passive collection of drainable DNAPL. The trenching machine, operated by DeWind Dewatering, Inc. of Zeeland, Michigan, is shown in Figure 8. Given the significant costs associated with mobilization and operation of this machine, it is evident why the methodology developed to quickly evaluate and rank potential recovery from various trench configurations was desirable.

FIGURE 8. The trenching machine.

As a preliminary evaluation of trench line location evaluation, both northing and easting sectional slices were generated across the plumes. The axes along the slices allowed the lateral extents, thicknesses, and depths of DNAPL bodies to be measured.

Prospective trench geometries were visually drawn across the thickest and most laterally extensive DNAPL bodies. The yellow band shown in Figure 9 indicates a 10-foot band on either side of the trench centerline. The model then calculates the DNAPL saturated soil volume within the 20-foot width, and the cross-sectional area of DNAPL saturated soil along the fence line. This allows rapid evaluation and ranking of any alternative trench configurations under consideration by the project team.
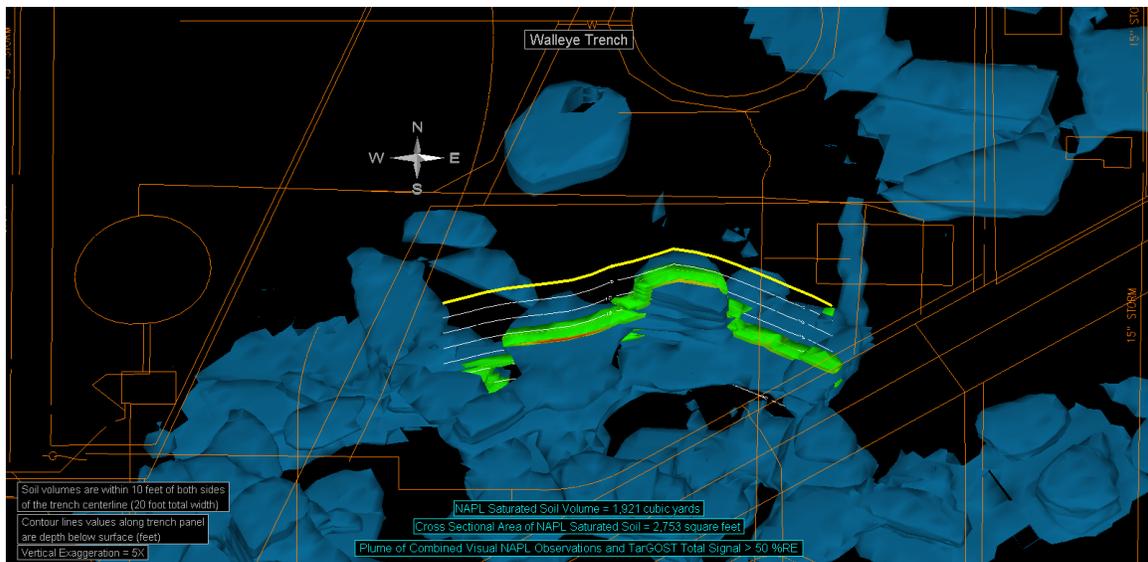
FIGURE 9. Illustration of a potential trench configuration designated "Walleye".

Geologic cross-sections were cut along the trench lines to view the influence of stratigraphy on the distribution of the DNAPL plumes. Figure 10 illustrates the geologic cross section with the DNAPL plume for the Walleye trench.
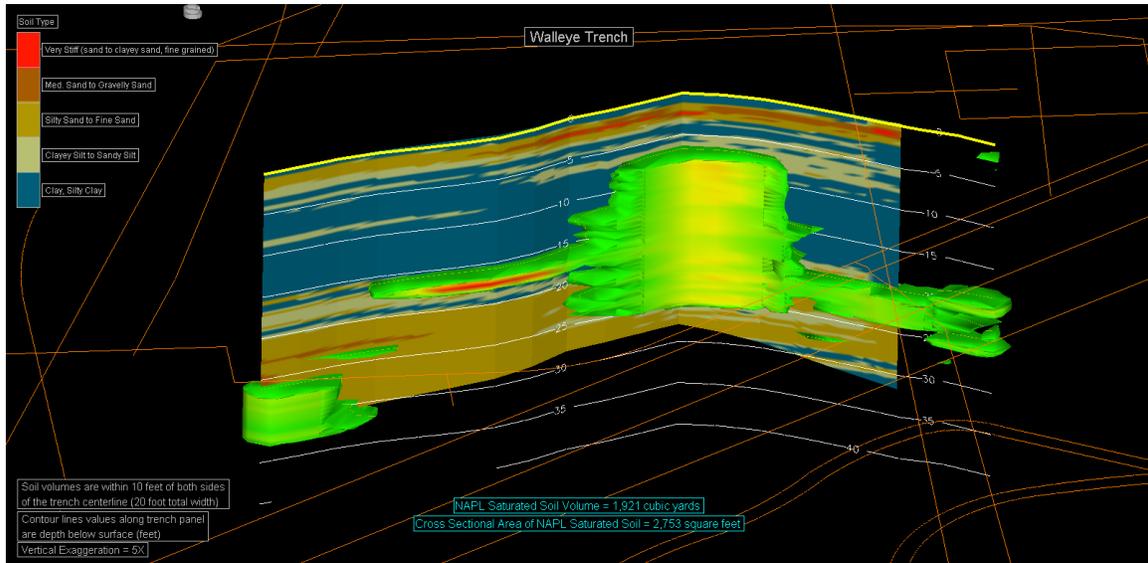

FIGURE 10. View of the Walleye Trench showing the DNAPL plume along the lithologic fence kriged from the CPT data.

The isolines of depth illustrated in Figure 10 allow the thickness and vertical distributions of DNAPL bodies to be quantified. This integration of embedded tools allowed the team to rapidly test many complex prospective trench lines, and select lines that avoided utilities and curved as needed to intercept the largest volumes of DNAPL.

Evaluations of numerous trench line alternatives resulted in the selection of the four trenches shown in Figure 11 for field implementation. The trenches are designated "Pheasant", "Rushmore", "Coyote", and "Walleye" in honor of South Dakota state symbols.
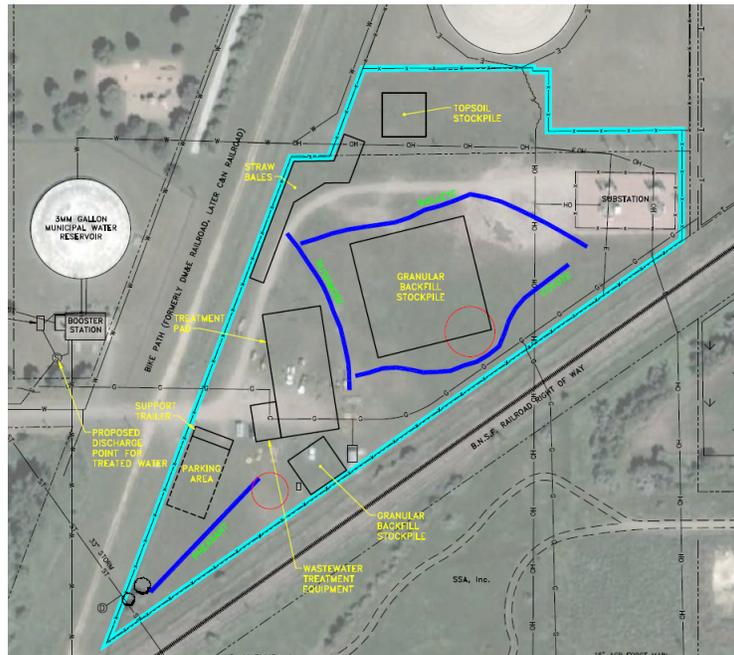

FIGURE 11. Selected Trenchlines

RESULTS. The trenches were installed from October 21, 2011 to November 19, 2011. To date, only passive collection of DNAPL has been performed. Table 1 presents the thicknesses of DNAPL measured in the trenches, and Table 2 shows the calculated volumes under the passive conditions.

Table 1: Thickness of Recovered Coal Tar DNAPL (Feet)

Collection Gallery	11-15-2011	11-18-2011	11-30-2011	1-23-2012
Coyote	0.45	0.47	0.50	0.50
Pheasant	0.93	0.97	1.14	1.90
Rushmore	1.21	1.75	1.88	2.31
Walleye-West	0.63	0.72	0.86	1.25
Walleye-East	0.00	0.08	0.09	0.30

Table 2: Estimated Volume of Recovered Coal Tar Fluid (Gallons)

Collection Gallery	11-15-2011	11-18-2011	11-30-2011	1-23-2012
Coyote	20	22	25	25
Pheasant	15	17	23	64
Rushmore	146	305	352	532
Walleye-West	40	52	74	156
Walleye-East	0	1	1	9
Total	221	396	475	785

CONCLUSIONS

The abundance of high-resolution data offered both the opportunity for extremely detailed analysis, and a significant challenge for development of a trench evaluation methodology that would utilize and honor all the data. The MVS Software by C Tech Corporation was successfully used to perform these tasks, with 4 trench configurations selected for field implementation. Since the trenches were installed in October and November, 2011, the relatively rapid rate of initial accumulation of coal tar DNAPL within the collection galleries suggests recovery of acceptable volumes of coal tar fluids will be possible.

In 2012, pump testing and infrastructure design required for extraction of accumulated coal tar DNAPL from the collection gallery sumps will be initiated.

ACKNOWLEDGEMENTS

REFERENCES

Robertson, P.K. 1990. Soil classification using the cone penetration test. Canadian Geotechnical Journal, 27 (1), 151-8.