Technology Demonstration of Sensor Applications to Direct Push Platforms and Monitoring and Operations

Contract # F41624-00-C8045

Technical Report for Field Test 5
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Submitted by:

Dakota Technologies, Inc.
2201-A 12th St. N.
Fargo, ND 58102
Phone: (701) 237-4908
Fax: (701) 237-4926

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Paul Jarski and Randy St. Germain

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14. ABSTRACT
Dakota Technologies, Inc. (DTI) demonstrated the REMPI systems applicability to measure soil gas concentrations from vapor sampling points installed by the AFCEE owned Geoprobe 66DT. In August 2003, Mr. Jerry Hansen of AFCEE coordinated the effort to mobilize equipment and personnel to Shaw Air Force Base in South Carolina. This site provided an excellent opportunity to gather field data and provide beneficial subsurface information to Parsons Environmental for delineating a jet fuel plume at Shaw AFB, SC. The work occurred in one phase, totaling 3 working days. A total of 24 points were implanted with subsequent measurements recorded for each point.

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REMPI, Soil Vapor Sampling, Aromatic Specific, BTEX, fuels, sensors, direct push

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Background

Dakota Technologies, Inc. (DTI) demonstrated the REMPI system's applicability to measure soil gas concentrations from vapor sampling points installed by the AFCEE owned Geoprobe 66DT. In August 2003, Jerry Hansen of AFCEE coordinated the effort to mobilize equipment and personnel to Shaw Air Force Base in South Carolina. This site provided an excellent opportunity to gather real field data and provide beneficial subsurface information to Parsons Environmental for delineating a jet fuel plume near Building 1610 at Shaw AFB, SC. The work occurred in one phase, totaling 3 working days. A total of 24 points were implanted with subsequent measurements recorded for each point.

Objectives

1. To test the REMPI instrument constructed for AFCEE under this BAA contract
2. To collect high quality and quantity data to characterize the extent of contamination from petroleum in the subsurface Shaw AFB, South Carolina

Sensors Tested

REMPI

Resonance enhanced multi photon ionization (REMPI) is an analytical method to detect low levels of compounds as a gas. The excitation wavelength determines what compounds are excited most efficiently. The detector in this case was designed to specifically detect benzene, toluene, ethylbenzene and xylenes (BTEX). In surface sampling mode a vacuum pump pulls air sample through the excitation cell. When target compound are present a voltage change is noted. Voltage is relative to concentration.

Site Activities

Fargo

DTI personnel prepared the REMPI system and support equipment for shipment to the Kansas City Army Corps of Engineers (COE) facility for transport to South Carolina. The COE prepared the Geoprobe 66DT track rig and packed the equipment on their transport vehicle. The equipment left ND on August 1, 2003.

Shaw AFB

DTI personnel arrived in Sumter, SC on Monday, August 11th at approximately 1:30 AM. Monday morning (Aug 11), DTI, COE, and Parsons personnel inspected the site and checked on the status of utility clearance. While the utility clearance details and probing locations were being determined, the REMPI system was unpacked and installed into a rental van. A calibration of the system was then performed to determine if the system was functioning properly. After successful completion of the calibration, DTI personnel returned to Sumter, SC to ascertain several components that would be required for performing headspace measurements on monitoring wells that would also be sampled.

Tuesday morning (Aug 12), sampling of the soil vapor points was started. At the first location the signal levels were much higher than anticipated which resulted in saturation of the detector. The system was then moved to the next location where again the signal was saturated. At this point it was determined that the vapors coming from the subsurface would have to be diluted

prior to introduction into the REMPI system. While these modifications were being made, arrangements for taking the system onto the flight line were finalized. At approximately 1:30 P.M., the REMPI system was taken onto the flight line to measure the concentrations at several monitoring wells. Each of these wells has free phase product that resulted in signal levels that were again off-scale. After completion of the monitoring well measurements the REMPI system required extensive clean-out and battery recharge before any other measurements could be made. This process required the rest of the afternoon.

Wednesday morning (August 13) a dilution apparatus was added to the system and measurements were started. The modifications were sufficient to bring the signal level on-scale at most of the vapor point locations. There were several areas where the signal levels were still off-scale but these were areas where the main contamination body was suspected. Twenty-seven vapor sampling points were successfully analyzed over the course of the day.

The evening of August 13 and the morning of the 14th were spent packing the REMPI system and support equipment for shipment back to the Kansas City COE facility. DTI personnel left Shaw the morning of August 14 to return to Fargo.

Data Collection

Soil Gas Collection Development

The standard method for withdrawing soil gas samples from a vapor point is to attach a ¼" polyethylene tube to the vapor point and lower it to depth. The vapor point is then screwed on to an expendable tip and the rods are withdrawn. The void space around the vapor point is then filled with sand and the rest of the hole is filled with either bentonite crumbles or bentonite slurry. The polyethylene tube is used to withdraw the soil vapors to the surface.

For our purposes the polyethylene tube is larger than required for collecting a soil gas sample. Also, there is some concern that at the lower flow rates that we typically use significant loss of analytes into the walls of the poly tube could occur. To alleviate these concerns, we developed a modified approach for collecting the soil gas samples. First, a 1/16" brass Swagelok ferrule was attached approximately 5 inches above the end of a 1/16" PEEK transfer line. A small piece of silicone tubing was then slid over the ferrule. The PEEK tube was lowered into the polyethylene tube until the ferrule mated with the top of the vapor point. Slight pressure was then applied to the tubing to firmly seat the ferrule in place, which formed a leak-free seal. A specially modified Swagelok ¼" to 1/16" reducing union was then used at ground surface to mate the polyethylene tubing to the PEEK tubing. In this way the PEEK tubing was isolated from the surface and polyethylene tubing so only a representative soil gas sample would be collected.

Standard Operating Procedure Development

Before beginning the work at Shaw AFB we conducted several experiments to develop a standard operating procedure (SOP) for the demonstration. Our main concern about sampling the soil vapor points was that if the soil formation were tight, a partial vacuum would form in the REMPI cell that would affect the subsequent measurement and could damage the vacuum pump used for drawing the sample. Therefore, we developed a two-pronged approach for calibrating the system and collecting the soil gas sample to alleviate these concerns. First, to calibrate the

instrument, the system would be configured such that the cell was held at atmospheric pressure (Figure 1). Since the makeup gas (carbon scrubbed ambient air) for this procedure is at atmospheric pressure, there is virtually no chance that a vacuum will develop in the cell or that the pump will be placed under undo load. Once the calibration had been performed, the system was reconfigured for reduced pressure operation (Figure 2). In this configuration, the orientation is such that most of the makeup gas is being drawn from the atmosphere so there is little chance that the pump will be damaged. While these two procedures are different it must be noted that the same flow of analyte gas is passing through the cell, which allows us to use the results of the calibration to normalize the soil vapor results. The full calibration and sampling point procedures are given below.

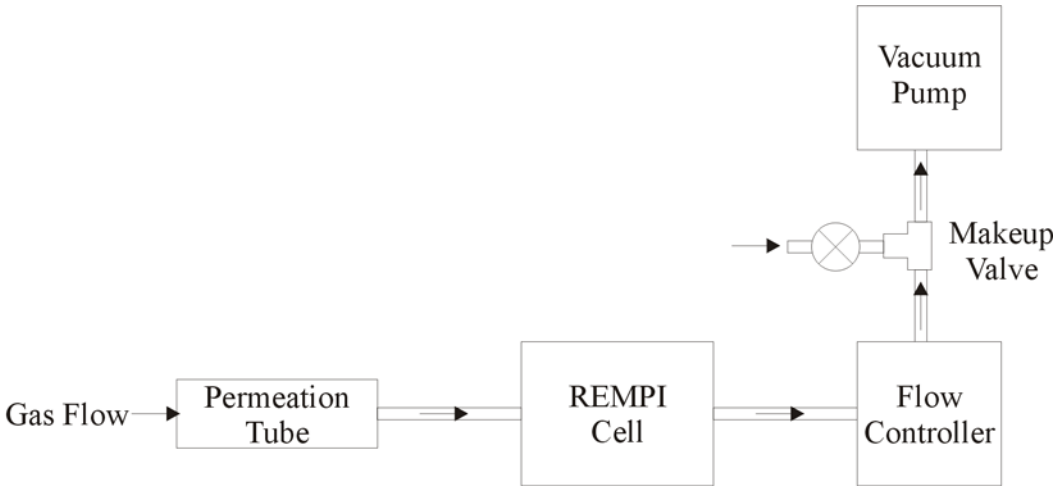


Figure 1. Atmospheric pressure arrangement

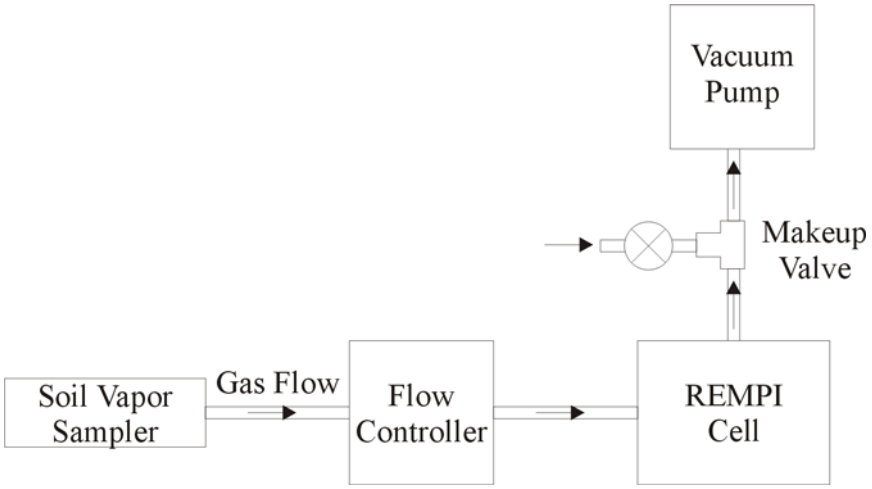


Figure 2. Reduced pressure arrangement

Calibration Procedure

1) Hook up cell using atmospheric pressure arrangement (Figure 1)
2) Measure laser energy (nominally set at 300 μJ)
3) Attach permeation tube holder with carbon scrubber
4) Collect baseline measurement for 2 minutes
5) Place permeation tube in holder
6) Record temperature of permeation tube
7) Collect permeation measurement @ 150 mL/min for 3 minutes
8) Save data as calibration file

Sampling Point Procedure

1) Hook up cell using Reduced pressure arrangement (Figure 2)
2) Attach carbon scrubber
3) Collect baseline for 2 minutes
4) Remove carbon scrubber
5) Attach 1/16" PEEK tubing to cell
6) Set flow rate for 75 mL/min
7) Wait until signal stabilizes and continue collection data for 3 minutes
8) Save data

Field Modifications

As previously mentioned the concentrations encountered during the demonstration initially saturated the REMPI system. To alleviate this problem, a modified gas handling system was assembled to dilute the soil gas sample. The dilution was accomplished by attaching two rotameters in parallel and diluting the analyte gas stream by a factor of 10. This dilution factor was sufficient to bring virtually all of the data points on scale.

Data Processing

Once DTI personnel were back in Fargo, the calibration logs were used to change the soil vapor logs from voltages to concentrations. For those logs where the soil gas was diluted, the resultant concentration was multiplied by an appropriate dilution factor. The TVH and REMPI concentrations are shown in tabular format in Table 1. The resulting soil gas concentrations

measured with the REMPI system were then plotted versus the total volatile hydrocarbon (TVH) measurements collected by Parsons personnel (Figure 3).

Table 1. REMPI and TVH concentrations at each monitoring point

Location	Diluted Concentration (ppb Tol. Equiv.)	Dilution Factor	Actual Concentration (ppb Tol. Equiv.)	TVH 1	TVH 2	Average TVH
MP1610_7	3.62	0.1	36.20	450	100	275
MP1610_1	319.77	0.1	3197.72	1000	1650	1325
MP1610_2	32.09	0.1	320.93	1700		1700
MP1610_19	134.87	0.1	1348.73	3350	5500	4425
MP1610_6	230.42	0.1	2304.22	2200	3200	2700
MP1610_13	27.04	0.1	270.44	700	100	400
MP1610_14	279.00	0.1	2789.99	6250	11000	8625
MP1610_17	41.45	0.1	414.52	3100		3100
MP1610_4	333.77	0.1	3337.65	8600	11000	9800
MP1610_8	10.22	0.1	102.23	1550	1750	1650
MP1610_18	49.82	0.1	498.18	2750	2800	2775
MP1610_5	287.27	0.1	2872.67	2250	11000	6625
MP1610_12	32.33	0.1	323.27	3450		3450
MP1610_11	269.21	0.1	2692.12	4050	4350	4200
MP1610_9	388.84	0.1	3888.45	5800	11000	8400
MP1610_10	62.72	0.1	627.21	1150	1000	1075
MP1610_15	33.28	0.1	332.76	740	150	445
MP1610_16	135.68	0.1	1356.77	3100	4350	3725
MP1610_20	2.26	0.1	22.57	250	210	230
MP1610_1_Shallow	0.56	1	0.56	160	100	130
MP1610_2_Shallow	4.15	1	4.15	3600	1000	2300
MP1610_3_Shallow	4.88	1	4.88	1400	1500	1450
MP1610_4_Shallow	2.56	1	2.56	1000	180	590
MP1610_14_Shallow	1.27	1	1.27	520	100	310
MW1610_7	>400	0.1	>4000	>11000		
MW1610_4	>400	0.1	>4000	>11000		
MW1610_5	>400	0.1	>4000	>11000		

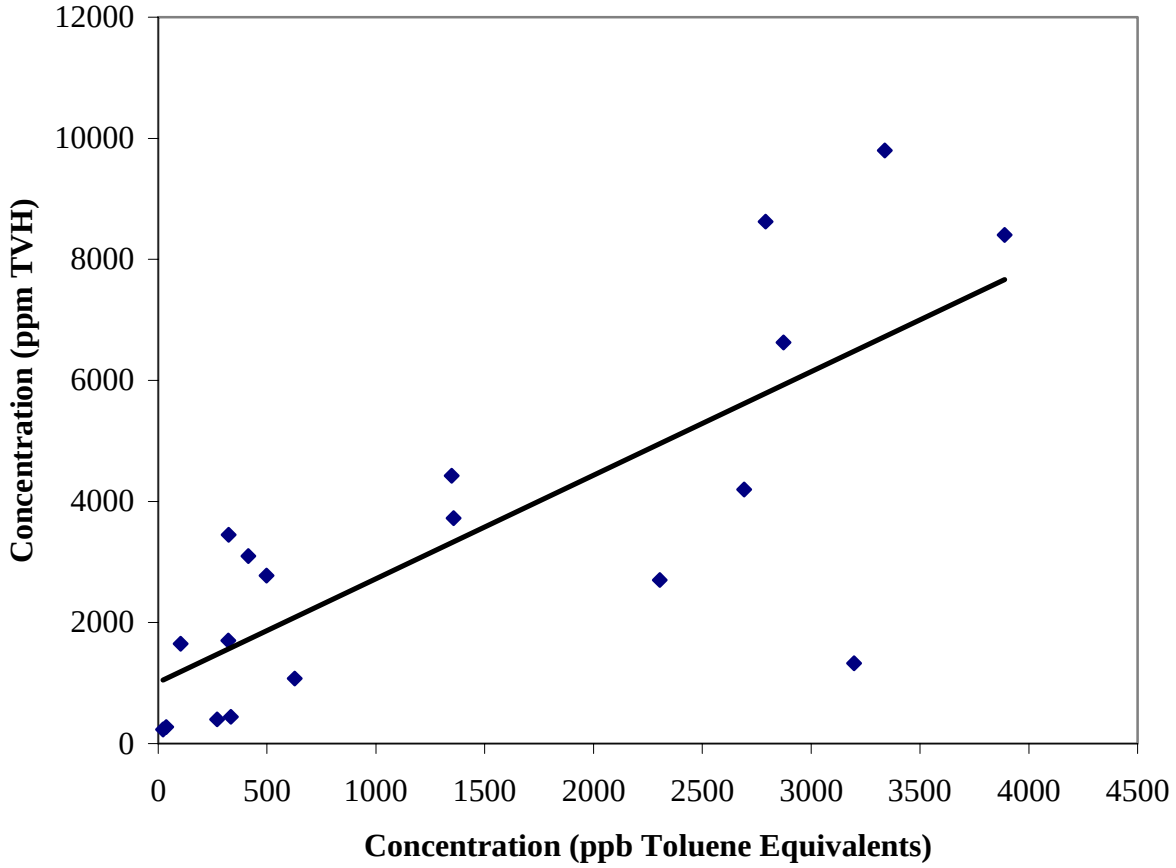


Figure 3. Correlation plot of REMPI versus TVH data

The correlation plot of the REMPI results with the TVH measurements looks quite good especially since the TVH data is measuring all volatiles while the REMPI system responds only to BTEX. The TVH numbers used for this correlation were found by averaging the two TVH measurements since some of these differed drastically. There was only one location (MP1610-1) where the REMPI results deviated substantially from the TVH measurements. It is unclear why the REMPI system noted very high concentrations while the TVH unit did not.

Upon completion of the REMPI data processing a contour plot of the area was drawn (Figure 4). A site map of the Building 1610 area is shown in Figure 5 for reference. An interesting feature of this plot is the low concentration area near monitoring points MP-1610-13, 17, 19, and 12. This area is currently the location of a remediation system where it is believed that most of the contamination has been removed. The contour plot clearly shows this area has been substantially impacted by the remedial efforts.

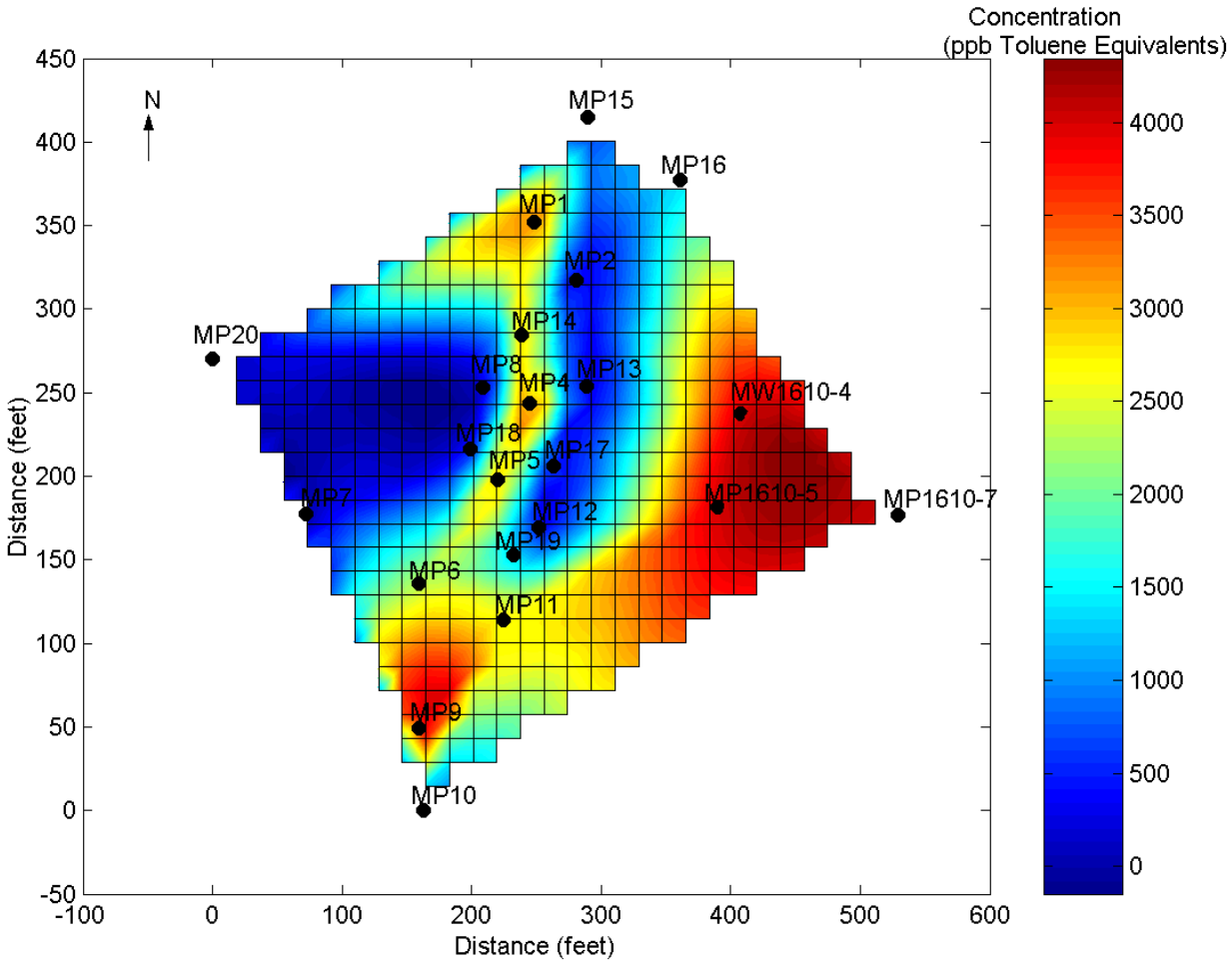


Figure 4. Contour Plot of Building 1610 site

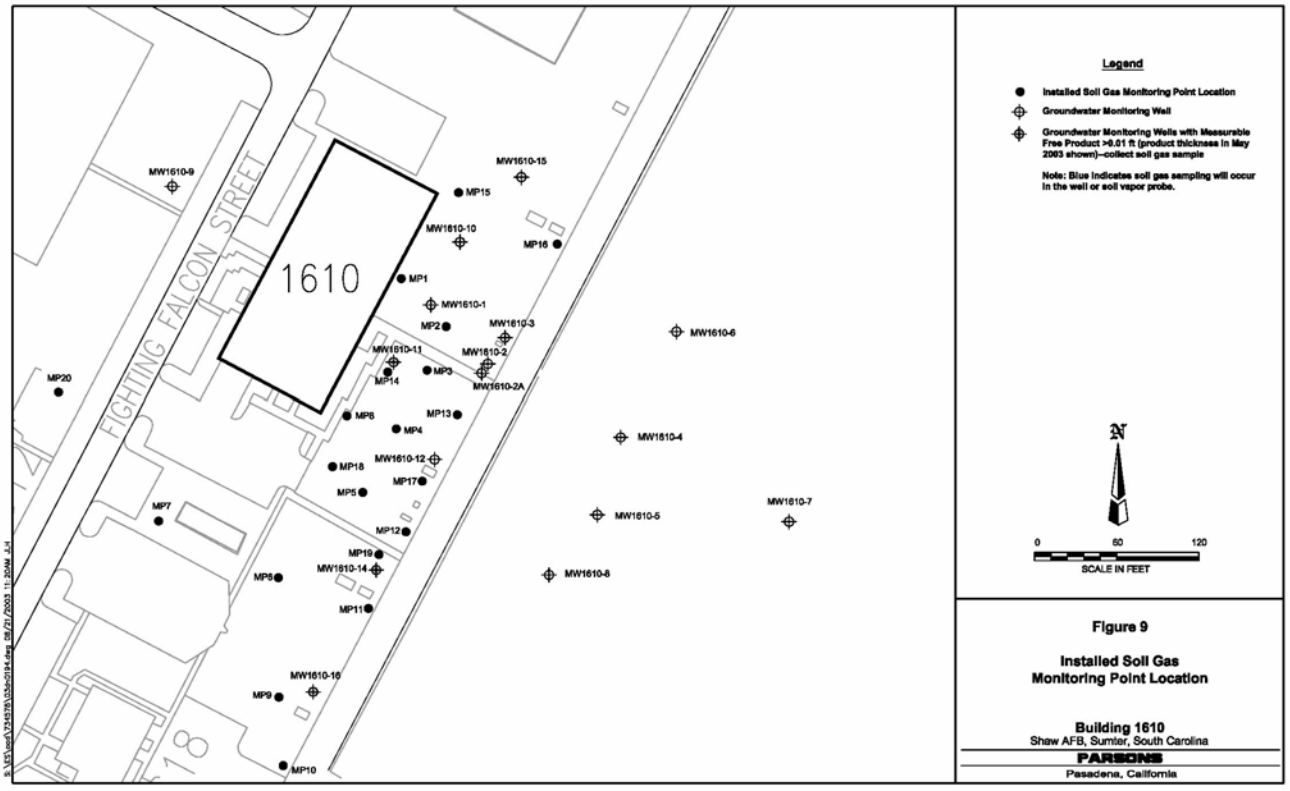


Figure 5. Building 1610 site map

Equipment Performance

The performance of the REMPI system was the primary focus of this work. In general the fieldwork was very successful, demonstrating that DTIs' REMPI system can be used in conjunction with soil vapor sampling points to produce quality data.

During the REMPI work the field team experienced a few problems with the hardware, but none halted the work. The following is a list of problems encountered and steps taken to resolve the problem.

Problem	Resolution
Saturated detector at several locations	Implemented dilution system to deal with high concentrations
UPS battery failed after complete discharge on flight line	Continuously ran generator during remainder of demonstration. Replaced UPS battery after demonstration
Carry over of contaminants in PEEK tubing	Replaced PEEK tubing 3 times
Unable to draw sample from MP1610-3	None

The REMPI system generally performed well throughout the fieldwork. The main problem area was dealing with the high concentrations that were encountered at this site. While the dilution setup worked well, a more user friendly arrangement would have been advantageous.

Recommendations

The gas handling system for the REMPI system could be improved to enhance user friendliness. While the manual rotameters currently used works, electronic flow controllers would provide much more precise adjustment capabilities.

A valve (or valves) should be incorporated to allow the user to switch between the calibration setup and sample collection setup. This would allow the user to switch the apparatus quickly without having to unswage and reswage several components.

The gas handling system should be modified to allow the user to quickly switch from the permeation tube to the carbon scrubbed air without having to manually insert the permeation tube.

An improved dilution system should also be developed. Since the REMPI system is very sensitive, diluting the sample may become a standard procedure. The dilution system may need to be a stand-alone apparatus since most of the interior of the current box is filled.

Modify UPS supplies so battery replacement is straightforward. The battery failure would not have been an issue if it were easily reachable during the demonstration. However, as currently designed, the generator was required to run the entire time after the battery failed.

Develop software to plot data in concentration. This will allow the users to immediately view the results in concentration rather than volts.

Appendix

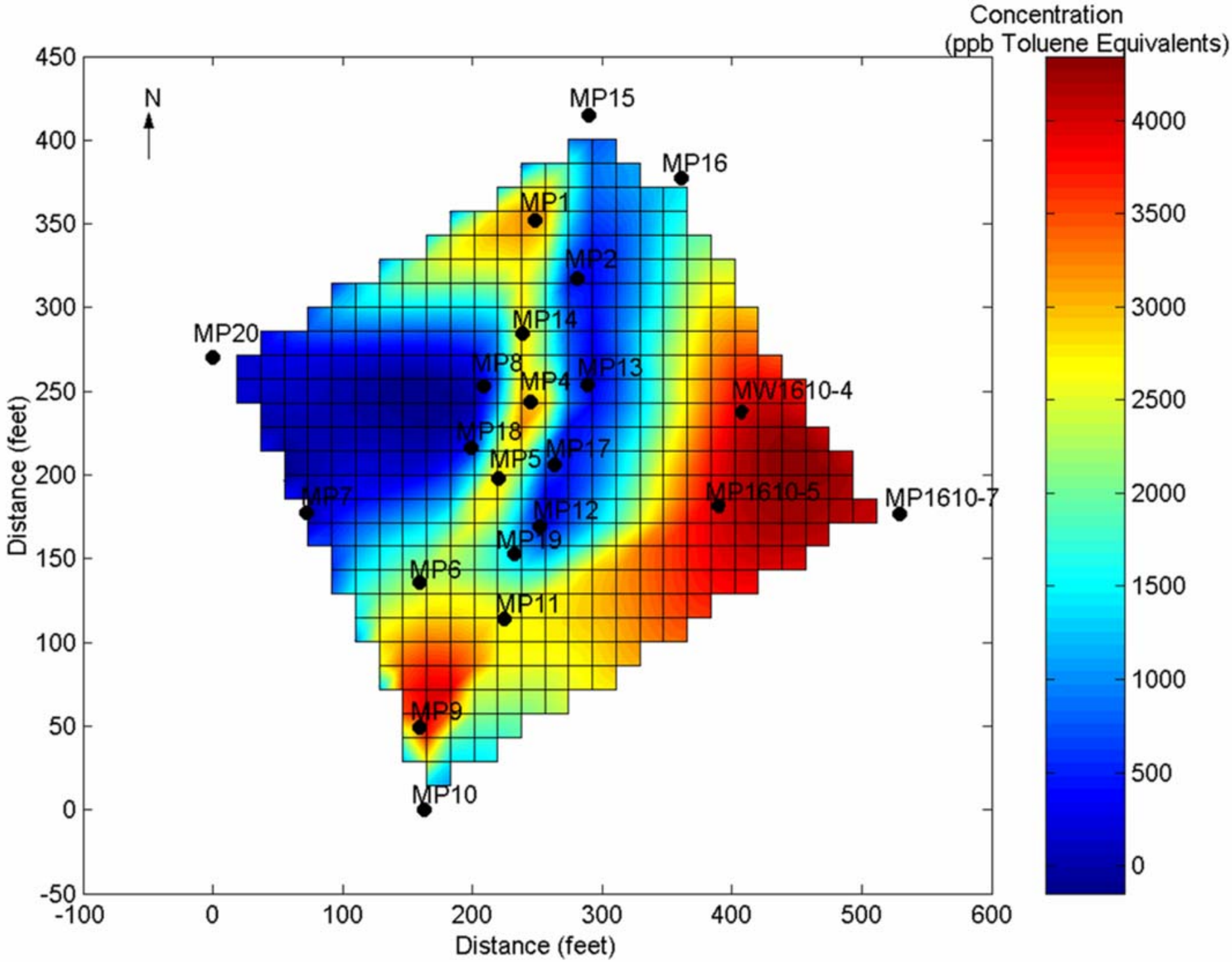
Appendix A is a compilation of data and maps for Shaw AFB, SC:

- Site maps of Shaw AFB
- Contour plot of concentration

Acknowledgements

Many people played a role in the successful completion of this field demonstration. Mr. Jerry Hansen of Brooks AFB, TX was the project manager for this work. Ms. Kathleen Older of Kansas City Corps of Engineers provided assistance with coordinating the field work and supplied a drill crew to operate the Geoprobe 66DT. Mr. Tom Dragoo and Mr. Cannon Silvers from Parsons provided planning, area maps, base access, and collected TVH measurements. Thank you to Mr. Raymond Mulholland from Shaw AFB for assistance with base access, flight line access and sponsorship on base.

APPENDIX A
Shaw AFB, SC


Concentration
(ppb Toluene Equivalents)
4000
3500
3000
2500
2000
1500
1000
500
0
N
MP15
MP16
MP1
MP2
MP14
MP20
MP8
MP4
MP13
MW1610-4
MP18
MP17
MP5
MP7
MP1610-5
MP1610-7
MP12
MP19
MP6
MP11
MP9
MP10
Distance (feet)
450
400
350
300
250
200
150
100
50
0
-50
-100
0
100
200
300
400
500
600
Distance (feet)

Legend

- Installed Soil Gas Monitoring Point Location
- Groundwater Monitoring Well
- Groundwater Monitoring Wells with Measurable Free Product >0.01 ft (product thickness in May 2003 shown)--collect soil gas sample

Note: Blue indicates soil gas sampling will occur in the well or soil vapor probe.

N

0 60 120

SCALE IN FEET

Figure 9

Installed Soil Gas Monitoring Point Location

Building 1610
Shaw AFB, Sumter, South Carolina

PARSONS
Pasadena, California

S:\ES\ccd\734578\035dn0194.dwg 08/21/2003 11:20AM JLH