FIELD COMPARISON OF DIRECT PUSH PREPACKED SCREEN WELLS TO PAIRED HSA 2" PVC WELLS

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INTRODUCTION

Geoprobe® Systems has developed the capability to install RCRA quality monitoring wells by direct push (DP) methods. This involves the use of prepacked well screens (1.5 inch OD by 0.5 inch ID by 36 inch length) that are installed through the bore of large diameter probe rods (2.125 inch OD by 1.5 inch ID) after they are driven to depth. New grouting capabilities enable placement of 20% to 30% bentonite slurries or neat cement grouts by the bottom-up side-port tremie method in small diameter DP bore holes. This capability assures the integrity of the well and protects groundwater quality.

This paper compares water quality parameters (pH, specific conductance, turbidity), water levels, and chlorinated volatile organic compound (X-VOC) analytical results from paired prepacked screen DP wells and conventional hollow stem auger (HSA) installed wells The paired wells were sampled over a ten month period. Good correlation of the measured parameters was observed during this time period. The time efficient, low cost installation of the DP wells, and elimination of contaminated drill cuttings makes these DP wells an attractive alternative to conventional water quality monitoring wells.

STUDY AREA BACKGROUND

Chloroform(CCl_3), carbon tetrachloride (CCl_4), trichloroethene (TCE), and tetrachloroethene (PCE) were detected in monitoring wells during the course of investigating leaking underground storage tank (LUST) facilities. A separate investigation was initiated by the Kansas Department of Health and Environment (KDHE) to determine possible sources for these contaminants. The study area encompasses a portion of an old urban industrial district that is a mix of industrial, commercial, and residential sections.

The study area is situated in the Smoky Hills Valley of the GreatPlains (Kansas Geological Survey [KGS] 1949). The alluvial deposits in the Smoky Hills Valley are of recent Pleistocene age (KGS 1981); and the Wellington Formation of Permian age (KGS 1949) forms the shale bedrock beneath the alluvium. The alluvial deposits of the valley consist of interbedded silts, clays, sands, and gravels. The upper 8 to 45 feet of consist of silt, silty clay, and fine sands. The lower alluvial deposits are granitic sands and gravels ranging from 5 feet to 70 feet thick. These sand and gravel deposits compose the primary aquifer for the local municipality (KGS 1949). The underlying shale forms an areally extensive aquitard.

PROCEDURES AND METHODS

Well Installation

HSA Wells for this study were selected from two adjacent sites [North Site (SN) and South Facility (FS)]. Locations of the wells are shown on Figure 1. The HSA wells were installed before the collocated DP wells. The locations of the monitoring wells at the North Site were selected by KDHE and Tetra Tech EM (TT EM) based on previous investigations to determine possible sources of the X-VOC contaminants present in the groundwater (KDHE 1996). Direct push electrical conductivity logs and split spoon samples were correlated and used to assist in determining the vertical placement of the well screens. Access, utility locations, and surface conditions in the urban area usually controlled how closely the prepacked wells could be placed to the existing HSA wells. Lateral spacing between the paired wells varied from approximately four feet to twenty feet. An effort was made to keep the length and depth of the screen intervals similar. Where an HSA installed well had a 10 foot screen set 30 to 40 feet below ground surface (bgs) the paired DP well was installed with 9 feet of screen at 31 to 40 feet bgs.

The HSA monitoring wells were constructed of 2-inch, schedule-40, polyvinyl chloride (PVC) casing and screen using flush-threaded joints. The screen slots were

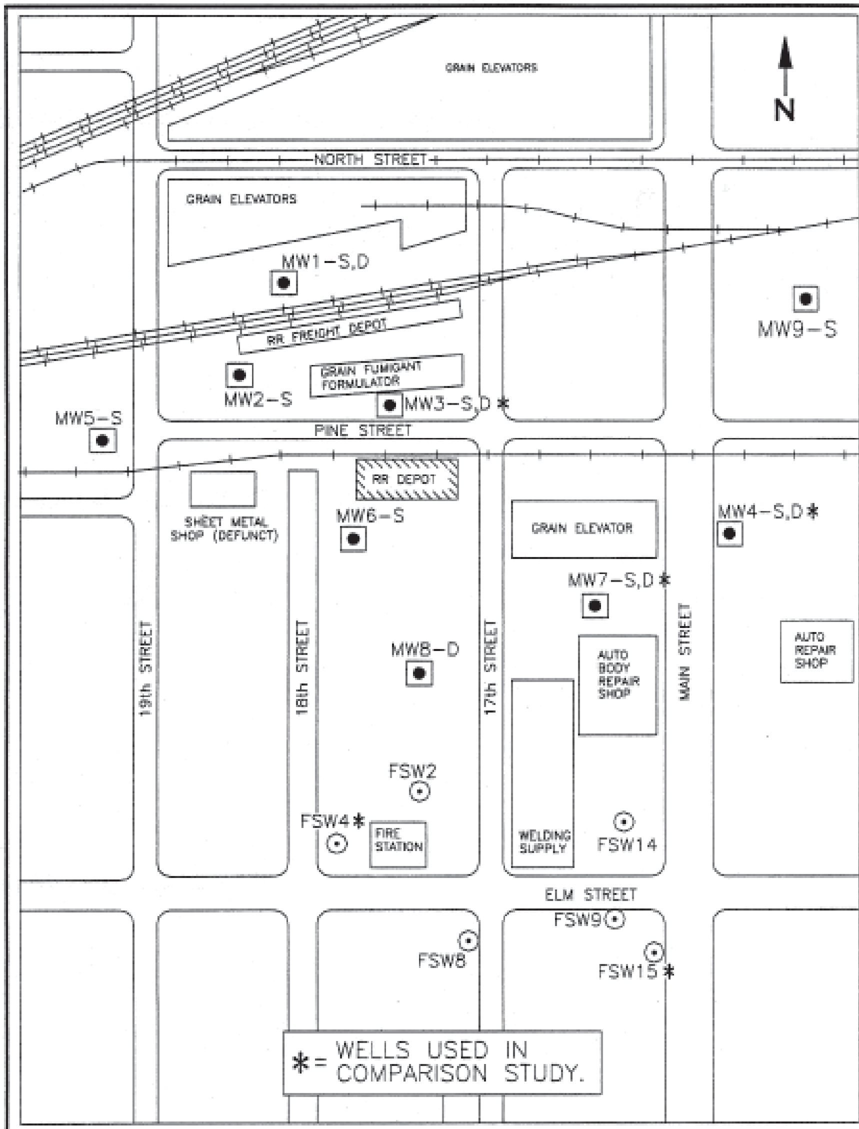

Figure 1
Site Map with Well Locations

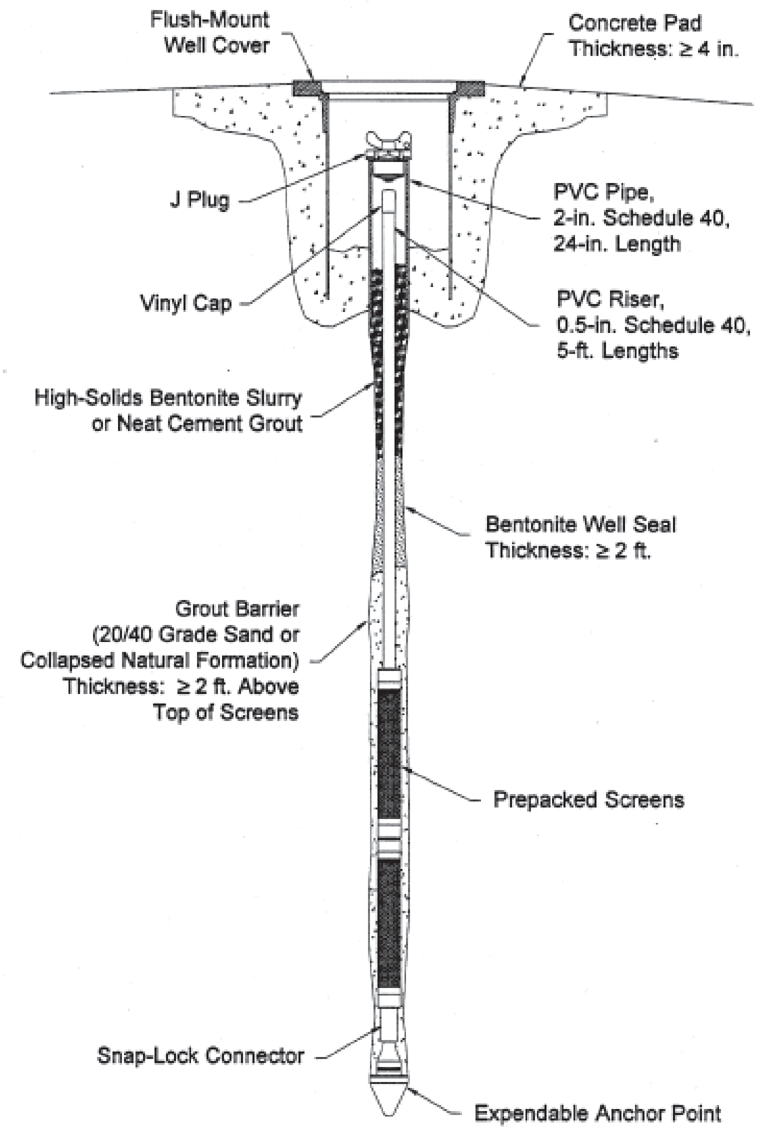

Figure 2
A Geoprobe Prepacked Screen Monitoring Well

0.02-inch wide. Each of the well screens had a 4.5-inch PVC plug at the bottom. At the North Site a polyester mesh filter sock was secured over the outside of the well screens with stainless-steel hose clamps to reduce the infiltration of silt and other fines into the well. A coarse silica sand (12 to 25 mesh) filter pack was extended a minimum of 2 feet above the screened interval on each well. The filter pack was gravity installed by pouring sand through the augers (8.25" OD by 4.25" ID) as they were slowly raised. The depth to sand was checked continuously with a weighted tape to verify that bridging did not occur (KDHE 1996).

A bentonite slurry was tremied into each well and extended to a depth of 2 feet bgs for each well. The monitoring wells were completed with a flush-mount, protective cover surrounded by a 2-foot-square concrete pad. All wells had locking PVC caps with expandable rubber seals. The HSA well construction methods used for this project meet the basic state (KDHE 1989), RCRA (EPA 1986, 1992) and ASTM Method D 5092 requirements for a water quality monitoring well.

The prepacked screens (Geoprobe® Part No. GW-2010) are constructed in three foot length sections which have an outside diameter of about 1.5-inches and an inside diameter of 0.5 inches. The inner component of the prepacked screens consists of 0.5 inch Schedule 80 PVC with 0.01 inch slots. The outer component of the screen is stainless steel wire mesh with a pore size of 0.011 inches. The screens are prepacked with 20/40 grade silica sand (KEI 1996). The DP wells were constructed by first advancing 2.125 inch OD by 1.5 inch ID probe rods with a hydraulic percussion probing machine. Once the probe rods were set at depth, prepacked screens were lowered through the bore of the rods as PVC riser was added to the well assembly. The prepacked screens were attached to an expendable anchor point by a locking connector. After the screens were locked onto the anchor point the rods were retracted just above the top of the screens. Then, either natural formation collapse or gravity installation of 20/40 grade sand through the rod annulus was used to construct the sand barrier above the screens. This sand barrier was extended a minimum of two feet above the screens to prevent the intrusion of annular sealants (bentonite/grouts) into the screened interval. After the sand barrier was in place a high pressure grout pump (Geoprobe Model GS-1000) was used to install the bentonite seal and grout by the bottom up side port tremie method (KEI 1996). Conventional flush mount protection was installed with a minimum two foot diameter well apron of concrete. A schematic of the completed prepacked screen well installation is provided in Figure 2. The direct push prepacked screen well construction methods used for this project meet the basic state (KDHE 1989), RCRA (EPA 1986, 1992) and ASTM Method D 5092 requirements for a water quality monitoring well. The primary difference being the smaller diameter of the DP wells and the direct push method of installation.

Well Development

The HSA monitoring wells at the North Site were surged using an 8-foot, stainless-steel bailer. Additionally, an Enviro-Tech® ES-40 or ES-60 impeller pump was used for clearing up the silt in the wells. Although they could achieve pumping rates of only 1 gpm, the ES-40 and ES-60 pumps could be lowered to the bottom of the wells, where they removed the majority of the silt. The wells at the South Facility were developed with a 1.5"OD by 36" long poly bailer. During HSA well development at the North Site, the water quality parameters were monitored and were required to stabilize within plus or minus 10 percent. No documentation was available on field parameters during development of the HSA wells at the South Facility.

The DP wells were developed with a tubing check valve system (Geoprobe® Part No. GW-42). A stainless steel check valve and check ball are inserted into the lower end of 0.375 inch OD by 0.25 inch ID polyethylene tubing and lowered into the well screen. The tubing is manually oscillated up and down at the surface to purge the well. One gallon of water was purged in five to ten minutes from the prepacked screen wells using this method. A volume of ten to fifteen gallons was purged from each well during the development process. This was in excess of three well volumes. The pH, specific conductance, and temperature were monitored during the development process and stabilized within 10% between three consecutive readings.

Measurement of Field Parameters

During the presample purging process temperature, pH, specific conductance, and turbidity were measured in the paired wells. Variation of less than 10% was obtained for all of the water quality parameters except turbidity. Turbidity did vary by more than 10% in some of the DP wells. Instruments used to measure the water quality parameters include : Cole Parmer Model 3900-50 pH meter, Oakton Model WD-35607-00 conductivity meter, and Cole Parmer Model 8391-50 turbidity meter. All calibrations and measurements of field parameters were made following the manufacturers recommendations. The water levels were measured with a Geoprobe Model GW-1200 water level indicator.

Well Sampling Procedures

Before samples were collected each well was purged a minimum of three well volumes. Well volumes were calculated including the filter pack volume, assuming a porosity of 30% for the filter pack material. The HSA wells were purged with an Enviro-Tech® model ES-60 or ES-40 impeller pump. The prepacked screen wells were purged using the tubing check valve system. Samples were collected from both the HSA well and the DP well using the tubing check valve system as a consistent sampling method. Fresh sample was drained directly from the tubing into the 40ml VOA vials, preserved, and submitted to the lab for analysis.

Analytical Procedures

The groundwater samples for this study were analyzed with a Hewlett Packard model 5890 Series II gas chromatograph (GC) using heated headspace methods with manual injection. The GC was factory equipped with an electron capture detector (ECD). A J&W Scientific 30 meter by 0.53mm DB™-624 megabore capillary column (PN 122-1334) was used for analyte separation on all of the analyses. The ECD was used to quantitate the X-VOCs. The temperature ramp for the GC oven and gas flow rates were optimized to obtain analyte separation and accurate identification. The GC system was calibrated for each analyte using a three point calibration curve. Analytical standards were prepared from commercially available stock standards purchased from ULTRA Scientific or AccuStandard, Inc. Analytical quality control consisted of the preparation and analysis of analytical duplicates, matrix spikes and matrix spike duplicates. As further verification of the headspace method one round of split samples were submitted to an independent lab for purge and trap GC-MS analysis. Linear regression of the 38 positive detects from both the purge and trap GC-MS and the headspace GC-ECD method resulted in a correlation coefficient (r^2) of 0.991, slope of 1.064, and Y-intercept of -1.192.

COMPARISON OF FIELD PARAMETERS AND X-VOC DATA BETWEEN HSA WELLS AND PAIRED DP PREPACKED SCREEN WELLS

Five HSA well locations were selected to install paired prepacked screened wells for comparison. At the three North Site locations nested (shallow and deep) HSA wells had been installed to look at the vertical distribution of contaminants. This resulted in two sets of paired wells at these three locations and a total of eight pairs of wells for comparison (Figure 1). Data collected from the paired wells is graphed and discussed in the following sections. Each point on a graph represents a set of paired data from a set of paired wells. Once the data was collected and plotted linear regression analysis was performed to quantitate the correlation between the data sets. Correlation coefficients (r^2) were calculated for each data set. Any nondetect data used in the linear regression analysis was calculated as one half of the method detection limit for that analyte.

Field Parameters

The initial measurement made during each sampling event was to determine the water level in each well. The resulting set of 80 paired water level measurements (Figure 3) has a correlation coefficient (r^2) of 0.998 and slope of 0.995 indicating a very good agreement for measurement of water levels between the paired wells.

During presample purging on several occasions pH, specific conductance, and turbidity measurements were made at increments approximately equal to 1, 2, and 3 well volumes for the paired wells. The last measurement made during each purging event for pH and specific conductance for the paired wells is plotted on Figures 4 and 5, respectively. The correlation coefficients (0.968, 0.989) and slopes of the regression lines (1.034, 1.061) for pH and specific conductance respectively, indicate that the paired HSA and prepacked screen wells are producing groundwater of essentially the same quality.

EPA RCRA guidance (EPA 1986) suggests a turbidity of 5 NTU (nephelometric turbidity units) as an acceptable level for water quality samples. Recent research (EPA 1996) has shown that some analytes, especially metals, are strongly affected by elevated turbidity levels in groundwater samples and recommends that low flow purging techniques should be used for water quality sampling. Additional research (Paul and Puls, 1997) has shown that turbidity has minimal effect on the concentration of at least some of the chlorinated VOCs. Some investigations (Ryan and Gschwend 1990, Gounaris et al. 1993) have also found that the natural turbidity levels in groundwater may noticeably exceed the 5 NTU level targeted by the EPA RCRA guidance.

The results of the turbidity measurements for the paired wells in this study are plotted in Figure 6. The turbidity observed in many measurements of the DP wells is higher than the paired HSA wells. (The values plotted above 200 NTU on the graph are >200 NTU values.) Initially, the small diameter DP wells were purged with the tubing check valve system at a rate of about one gallon of water in six to eight minutes. Some of the DPwells were able to provide <50 NTU water but, the rapid oscillation of the tubing check valve at this purge rate appeared to surge some of the wells. When a low flow purge rate (100 to 200 ml/min) was used most of the prepacked screen wells yielded water with turbidity less than 50 NTU and some of the wells produced water samples with turbidity less than 10 NTU. Also note that the HSA wells at the North Site were equipped with fabric silt socks to help achieve low turbidity in the wells. As Figure 11 shows, when some of the HSA wells were purged with bailers the turbidity levels in the ground water were noticeably higher.

X-VOC Data

A summary of the linear regression analysis for the X-VOC data based on well pairs is given in Table 1. The well pairs with the highest correlation coefficients are SN07S and FS15. Figures 7 and 8 show the plotted results from the paired wells at SN07S and FS15. Four different X-VOCs were detected in each well at concentrations from less than 5 µg/l to over 60 µg/l. The calculated regression

FIGURE 3
Water Levels

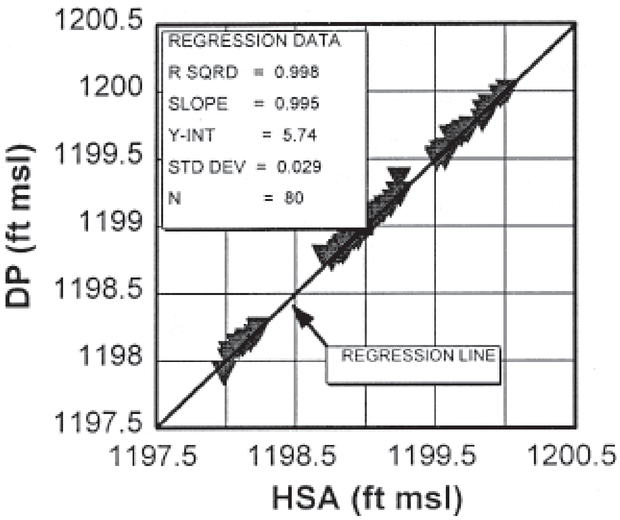

FIGURE 4
pH Data

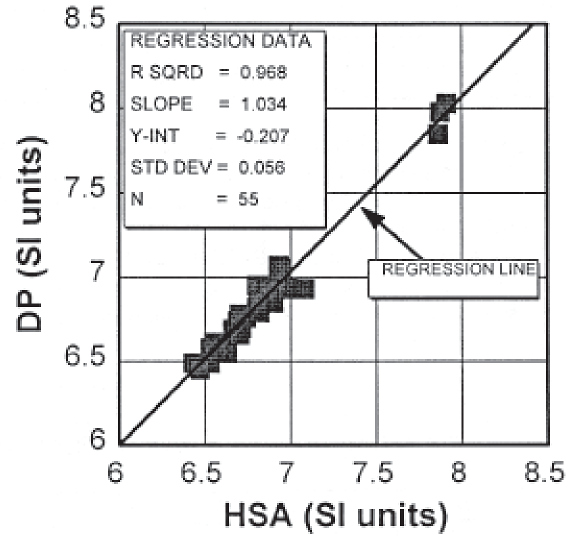

FIGURE 5
Conductance

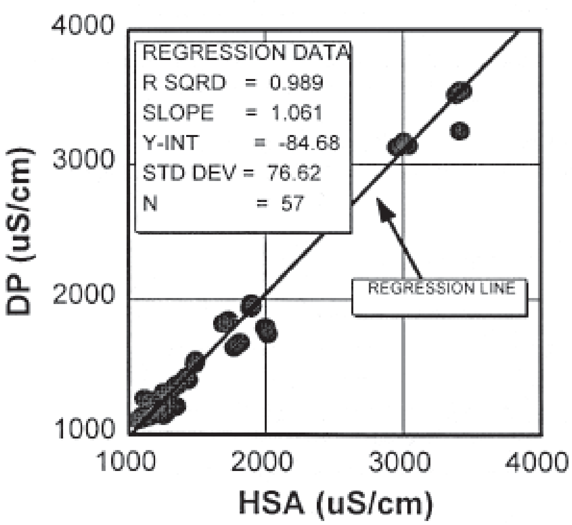

FIGURE 6
Turbidity

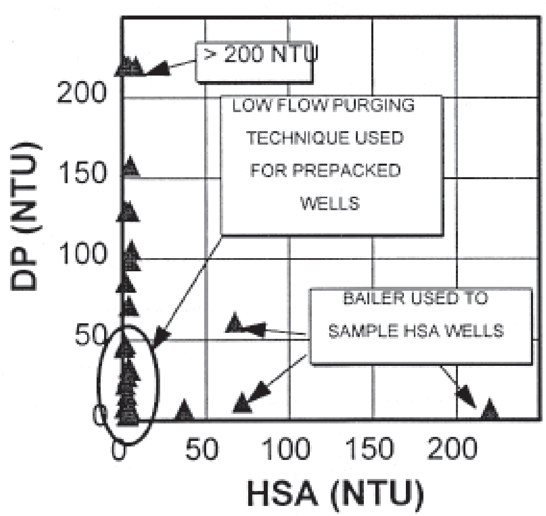

TABLE 1
SUMMARY OF X-VOC LINEAR REGRESSION ANALYSIS BY PAIRED WELLS

Well Location	R SQRD[1]	Slope	Y-Intcpt	Std. Dev.	N[2]
SN03S	0.631	0.892	13.96	49.73	9
SN03D	0.746	0.889	1.100	1.325	9
SN04S[3]	0.629	0.433	0.664	1.052	14
SN04D[4]	0.149	0.557	1.719	3.194	12
SN07S	0.907	0.926	1.741	5.063	23
SN07D[5]	1	1	0	0	*
FS04[6]	0.469	1.065	-7.1	4.435	5
FS15	0.952	1.084	-1.307	4.17	15

Notes :

1- Correlation coefficient (r^2) calculated by linear regression.
2 - N is the number of paired data in which one or both of the results were above the detection limit. Regression data reported based on results in which one or both results for the paired samples were above detection limit only.
3 - All results less than 15 ppb.
4 - All results less than 10 ppb. HSA well 10 ft screen, DP well 15 ft screen.
5* - All results nondetect.
6 - HSA well about 10% closer to contaminant source.

TABLE 2
SUMMARY OF X-VOC LINEAR REGRESSION ANALYSIS BY ANALYTE

Analyte	MDL	R SQRD	Slope	Y- Int.	Std. Dev.	N[1]
1,1-DCE	2.5	0.718	1.002	-3.486	10.19	11
1,1-DCA[2]	6.3	-	1	0.663	-	2
CCl_3	1.0	0.817	1.369	0.258	38.95	8
1,1,1-TCA	1.0	0.929	0.993	-0.824	5.307	6
CCl_4	0.5	0.966	0.796	0.942	7.519	24
1,2-DCA	5.0	0.538	0.551	4.856	4.494	16
TCE[2]	2.5	-	1.167	0	-	1
PCE	0.5	0.911	0.911	3.152	6.595	11
All Positive Detects[3]	**na**	**0.818**	**0.983**	**-0.185**	**16.34**	**78**
All Results[4]	**na**	**0.859**	**0.981**	**0.005**	**6.879**	**432**

Notes:
1 - N is the number of data pairs with positive detects. Only these data pairs used to calculate linear regression parameters.
2 - Only one or two positive detects for these analytes. Slope and intercept calculated through positive detect point(s) and nondetect point.
3 - Linear regression parameters calculated for all analytes based only on data pairs with positive detects.
4 - Linear regression parameters calculated for all analytes based on all data pairs, both with positive detects and nondetects.

TABLE 3
UNIVARIATE STATISTICS OF X-VOC DATA

Well Type	Mean	Variance	Std. Dev.	N
HSA	24.36	1227	35.03	78 [1]
DP	23.76	1449	38.07	78
HSA	5.648	299.4	17.30	432 [2]
DP	5.546	335.2	18.31	432

Notes:

1 - Statistics calculated based on data points with values above the detection limit.
2 - Statistics calculated based on all X-VOC data, including nondetects calculated as 1/2 detection limit.

parameters indicate a very good correlation between the paired DP well and HSA well.

The well pairs with the lowest correlation coefficients are SN04D and FS04. Most of the analyte concentrations observed at these wells were all below 10 µg/l to 15 µg/l, approaching the method detection limit for all of the analytes. At low concentrations a slight variation will indicate a poor correlation between the wells.

A linear regression analysis was also conducted by analyte (Table 2). The regression data is based only on the results with positive detects (with the exception of the last row). Three analytes (1,1,1-TCA, CCl_4, and PCE) have correlation coefficients greater than 0.9 for the results above the detection limit. The results of these analytes indicate a good correlation between the sets of paired wells. The lowest correlation coefficients of the analytes monitored (1,1-DCE and 1,2-DCA) may reflect that these analyte concentrations were close to their detection limits. Also, these dichlorinated compounds are two of the most volatile compounds monitored for in the study. Their higher volatility increases their susceptibility to loss of mass during sample collection, sample preparation, and analysis procedures.

Figure 9 is a summary plot of all of the positive detects for each of the analytes from the paired wells in the study. The study resulted in a total of 432 pairs of X-VOC data points. There were 78 pairs of data points with positive detects. The regression data provided in Table 2 based on all of the results with positive detects gave a correlation coefficient (r^2 = 0.818), slope, intercept, and standard deviation that suggests a good correlation between the paired wells. When the nondetect data pairs are included in the regression analysis the correlation coefficient is 0.859 (nondetects calculated as one half of the method detection limit).

As another way to compare the data sets from the DP wells to the HSA wells the univariate statistics (mean, variance, and standard deviation) were calculated for each of the data sets (Table 3). These parameters were first calculated for only the data pairs with positive detects (N = 78) and then for the entire data set (N =432) where nondetects were calculated as one half of the method detection limit in the regression analysis. These parameters are very similar for the X-VOC data from both types of well construction, again indicating the DP wells can provide data equivalent to that obtained from conventional HSA wells.

Finally, a Z-test was run on the X-VOC data from the paired wells to determine if there was any significant statistical difference between the data sets for the HSA and DP wells. The Null Hypothesis tested was :

Null Hypothesis (H_o) : There is no difference between the means of the samples collected from the DP wells and HSA Wells. That is :
H_o : $\mu 1 - \mu 2 = 0$
Calculated Z-statistic : 0.102203
Rejection Region : 95% Confidence Interval : $z > 1.645$ or $z < -1.645$

Since the calculated z-statistic is not in the rejection region the null hypothesis is accepted. This indicates that the means of the two data sets are statistically equivalent with 95% confidence.

DISCUSSION AND CONCLUSIONS

Obtaining a true paired well is more difficult than initially anticipated. Not only are the usual problems of obtaining access and utility clearances involved but there is real field variation. Early in the project a paired DP well was set about 10 feet south of the HSA well at the SN03 location. After the first couple of rounds of sampling it was obvious that the DP well was yielding samples with contaminants almost an order of magnitude below that in the paired HSA well. The HSA well at SN03 is set about 10 feet south of a loading dock, one of the probable source areas for CCl_4. Later, another DP well was set on the north side of the HSA well closer to the loading dock. This new DP well provided samples with almost the same concentrations of contaminants as the paired HSA well. These results reflect the rapid change in contaminant concentration near the source.

The ability to install 20% to 30% bentonite slurries or neat cement grouts by the bottom up side port tremie method in the small diameter DP wells is important. This enables these small diameter wells to be constructed with a high integrity annular seal as done for larger diameter conventional wells. The integrity of the annular seals was demonstrated at two of the paired well locations. At both the SN03 (probable source) and SN07 locations the shallow wells were contaminated with CCl_4 and CCl_3 (density > water). The deep well screens at these two locations were set below a silt-clay layer (aquitard). Both deep wells (HSA and DP) at the two locations were nondetect for the contaminants observed in the shallow zone, indicating a high integrity annular seal.

A linear regression analysis was conducted on the field parameters (water levels, pH, specific conductance, and turbidity) and several X-VOC compounds (1,1-DCE, CCl_3, 1,1,1-TCA, CCl_4, TCE, and PCE). This statistical analysis revealed that the DP wells provide essentially identical water level measurements and the pH and specific conductance observed are equivalent to the paired HSA wells. Many of the DP wells did yield samples with higher turbidity, but low flow purging significantly lowered the turbidity in most of the DP wells. Correlation of the X-

VOC data was good between most of the wells with several of the analytes having high correlation coefficients ($r^2 > 0.9$). The lowest correlation coefficients were observed for the more volatile dichlorinated compounds when the concentrations were near the analyte detection limits (< 15 µg/l). A correlation coefficient (r^2)of 0.818 was obtained from linear regression of all of the positive detect X-VOC results. A z-test was conducted on the X-VOC data set to determine if a significant difference existed between the mean of the DP well data and the HSA well data. This test concluded that there was no significant difference between the sample means at the 95% confidence interval. All of this information indicates that the DP wells can provide equivalent water quality samples to conventional HSA wells.

There are several benefits to installing DP wells for long term water quality monitoring during environmental investigations or remedial actions. One of the most obvious is that no potentially contaminated drill cuttings are generated. This eliminates the cost and need to handle, store, analyze, and dispose of these materials. No drill cuttings also reduces hazard exposure. Mobilization for and installation of the DP wells is relatively quick and the development and purge water generated is about one tenth that for conventional wells. The grouting capabilities allow for construction of a RCRA quality DP well that is protective of the groundwater, and as this study shows, provides representative water quality samples.

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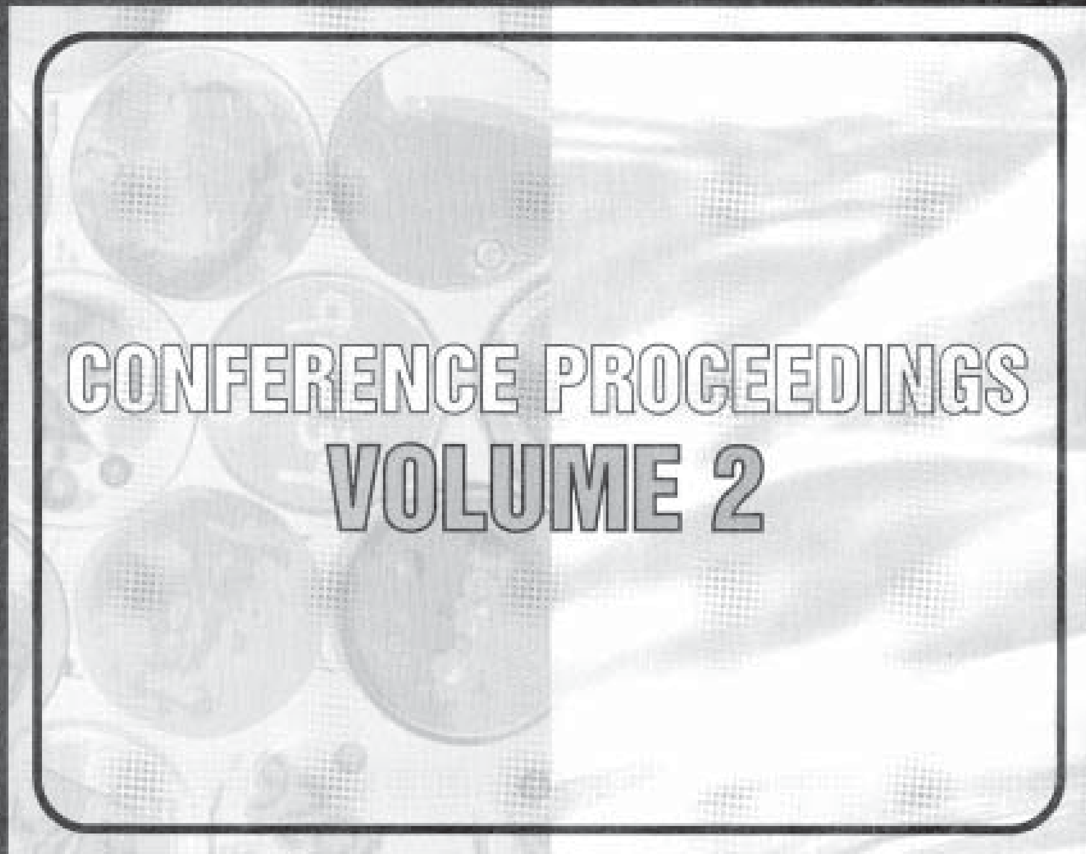

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