

# Field Comparison of Micropurging vs. Traditional Ground Water Sampling

by Peter M. Kearl, Nic E. Korte, Mike Stites, and Joe Baker

## Abstract

**M**icropurge sampling of ground water wells has been suggested as a possible replacement to traditional purge and sample methods. To compare methods, duplicate ground water samples were collected at two field sites using traditional and micropurge methods. Samples were analyzed for selected organic and inorganic constituents, and the results were compared statistically. Analysis of the data using the nonparametric sign test indicates that within a 95 percent confidence interval, there was no significant difference between the two methods for the site contaminants and the majority of analytes. These analytical results were supported by visual observations with the colloidal borescope, which demonstrated impacts on the flow system in the well when using traditional sampling methods. Under selected circumstances, the results suggest replacing traditional sampling with micropurging based on reliability, cost, and waste minimization.

## Introduction

Traditional sampling practices for ground water monitoring wells commonly consist of purging three or more well volumes prior to sample collection. Purging and sampling are conducted at various flow rates, and the resultant water samples are usually filtered. Samples are commonly collected using bailers, submersible pumps, or bladder pumps. The rationale for purging wells is to remove stagnant water from the wellbore in order to permit representative water from the surrounding porous medium to enter the well. This approach is based on sampling studies that show pH and conductivity stabilize after three to five wellbore volumes are removed (Scalf et al. 1981; Barcelona et al. 1985; Hardy et al. 1989).

The alternative sampling approach using micropurging is based on the premise that stagnant water in the well casing does not completely mix with ground water flowing through the screen. Using tracer experiments, Robin and Gillham (1987) showed that ground water moves through the screened portion of a well with little interaction or mixing with stagnant water in the overlying well casing. Similar studies by Powell and Puls (1993) supported this observation. These studies suggest that flow in the well screen is horizontal and laminar. Using the colloidal borescope, these results were corroborated by visual observations of particles that are being advected by the ground water (Kearl et al. 1992). These studies

suggest that water samples taken directly from the screened interval are representative of ground water in the surrounding formation and that purging several well volumes prior to sample collection is unnecessary.

Dedicated pumping systems are not a requirement of traditional sampling practices, though they are used at some field sites. Pumps are most often inserted into a monitoring well immediately prior to sampling. Using the colloidal borescope, Kearn et al. (1992) visually observed the impact of inserting a sampling device into a well. Significant increases in particle size and numbers have been observed during the insertion of the instrument into the well as shown in Figure 1a. These effects tend to decrease with time (Figure 1b), showing that insertion of a sampling device and subsequent pumping would yield water samples containing colloids and particles that do not represent ambient ground water flow conditions. Significant disturbance resulting from the insertion of a sampling device was also observed using turbidity measurements by Puls et al. (1992). The presence of these particles affects the analytical results for the sample, whether the water is filtered or not. Furthermore, current sampling practices do not differentiate between chemical species dissolved in the ground water and those sorbed to mobile particles that are being transported by the ground water. The borescope has observed mobile particles in the 1 to 10  $\mu\text{m}$  size at several field sites. Nevertheless, with traditional sampling practices, a 0.45- $\mu\text{m}$  filter is used to remove larger particles with no consideration of their potential mobility. Puls and Barcelona (1989) reported that the use of a 0.45- $\mu\text{m}$  filter was not useful, appropriate, or reproducible in providing information on metals mobility in ground water systems, and that it was not appropriate for determining truly dissolved constituents in ground water.

Consequently, it has been suggested that consideration be given to modifying traditional sampling procedures in order to obtain representative samples of the total mobile pollutant load of both dissolved and sorbed species. It was recommended that samples be collected at low rates, such as 100 mL/min, using a dedicated sampling pump to prevent disturbing the well. Ambient ground water in-flow would be sufficient to supply water to the pump preventing mixing with stagnant water from the well casing. To this end, the technique of micropurging using dedicated pumps and low volume pumping (100 mL/min) was proposed (Kearn et al. 1992). Only the sample tubing and pump are purged. The purging of three or more wellbore volumes associated with conventional sampling is eliminated, as are the large volumes of purge water requiring disposal. It should be noted that purge water is a particular problem at many Department of Energy sites. Where there are a large number of wells and/or mixed waste is suspected, the costs associated with storing, testing, and disposing of purge water are considerable (e.g., \$100,000 per year at Oak Ridge National Laboratory). Shanklin et al. (1993) reported that micropurging would reduce annual sampling costs by \$115,000 by eliminating rinsate samples and decontamination of sampling equipment.



Figure 1a. Particles resulting from inserting a pump into a monitoring well (magnified 140 times).



Figure 1b. Same view one hour later showing the decrease in particle size and number.

If quantifying the total mobile pollutant load is the investigation goal, it is recommended that water samples not be filtered. By using low pumping rates, only particles that are being advected by the ground water flow are sampled. Observations with the colloidal borescope show that high flow rates mobilize additional particles that are normally immobile under ambient flow conditions. Sampling at low flow rates without filtering allows the quantification of the total mobile pollutant load. In other words, both the contamination that is moving in the dissolved phase and contamination that is sorbed to mobile particles are being measured. This approach for sampling colloids and metals has also been recommended by Puls and Powell (1992) and Backhus et al. (1993).

This paper presents the results of sampling studies to compare water chemistry results from traditional and micropurge sampling methods. Comparative sampling was conducted using both micropurging and traditional techniques at a field site near Kansas City, Missouri. Repetitive micropurge sampling and visual observations utilizing the colloidal borescope were also performed at a site near Paducah, Kentucky.

## Methods

Comparing different sampling techniques for obtaining ground water samples in the field is difficult. A contaminant plume will contain widely varying concentrations due to aquifer heterogeneities or input from different sources (Keely and Boateng 1987; Kaplan et al. 1991; Robbins and Martin-Hayden 1991). Barcelona et al. (1989) demonstrated that natural variability within a ground water system over time can exceed the variability introduced by sampling and analysis procedures. Significant temporal variations in water quality have also been documented by Clark and Baxter (1989), who showed order of magnitude variations in organic pollutant levels from samples taken over a four-hour pumping period. Stable analytes such as calcium, sodium, and chloride show differences as high as a factor of two between water samples taken in the same vicinity at the same time (Huntzinger and Stullken 1988). Consequently, it is important to consider natural variability when comparing sampling variability.

Two field sites were selected for comparison of the traditional and micropurge sampling techniques. A site near Kansas City, Missouri, had undergone a multiyear characterization program resulting in an extensive data set from several monitoring wells. The aquifer is a reducing system with fine-grain clayey silts that exhibit relatively low permeability (Korte 1991). Three wells, 5-cm diameter with 1.5- or 3-m length screens, were selected

for the study. They are located in areas where the ground water is contaminated with chlorinated solvents. One well is screened across the water table, while the two remaining wells are completed at the base of the aquifer. Submersible sampling pumps were installed in the wells. These pumps remained dedicated to the wells for the duration of the sampling comparison.

Each well was initially sampled using the micropurge technique. The sample pump and line were purged and samples were collected at a flow rate of 100 mL/min. After micropurge sampling was completed, three bore volumes were purged at maximum flow rates (approximately 2 gpm), and samples were collected in the traditional method. A QA/QC program including charge balances was applied to the sample results from the initial round. After sampling, the pump rates were reset to 100 mL/min and the wells were left undisturbed until the next sampling event. This procedure was repeated at one-week intervals until four sampling events had been completed. Several months later the procedure was repeated, resulting in four additional data sets.

The second field site is located near Paducah, Kentucky. The aquifer underlying the site consists of permeable sands and gravels, providing a contrast to the less permeable aquifer at Kansas City. At the Paducah site, three monitoring wells, 4-inch diameter with 10-foot screen intervals, were sampled using the micropurge method. Flow rates for the sampling pumps were set at

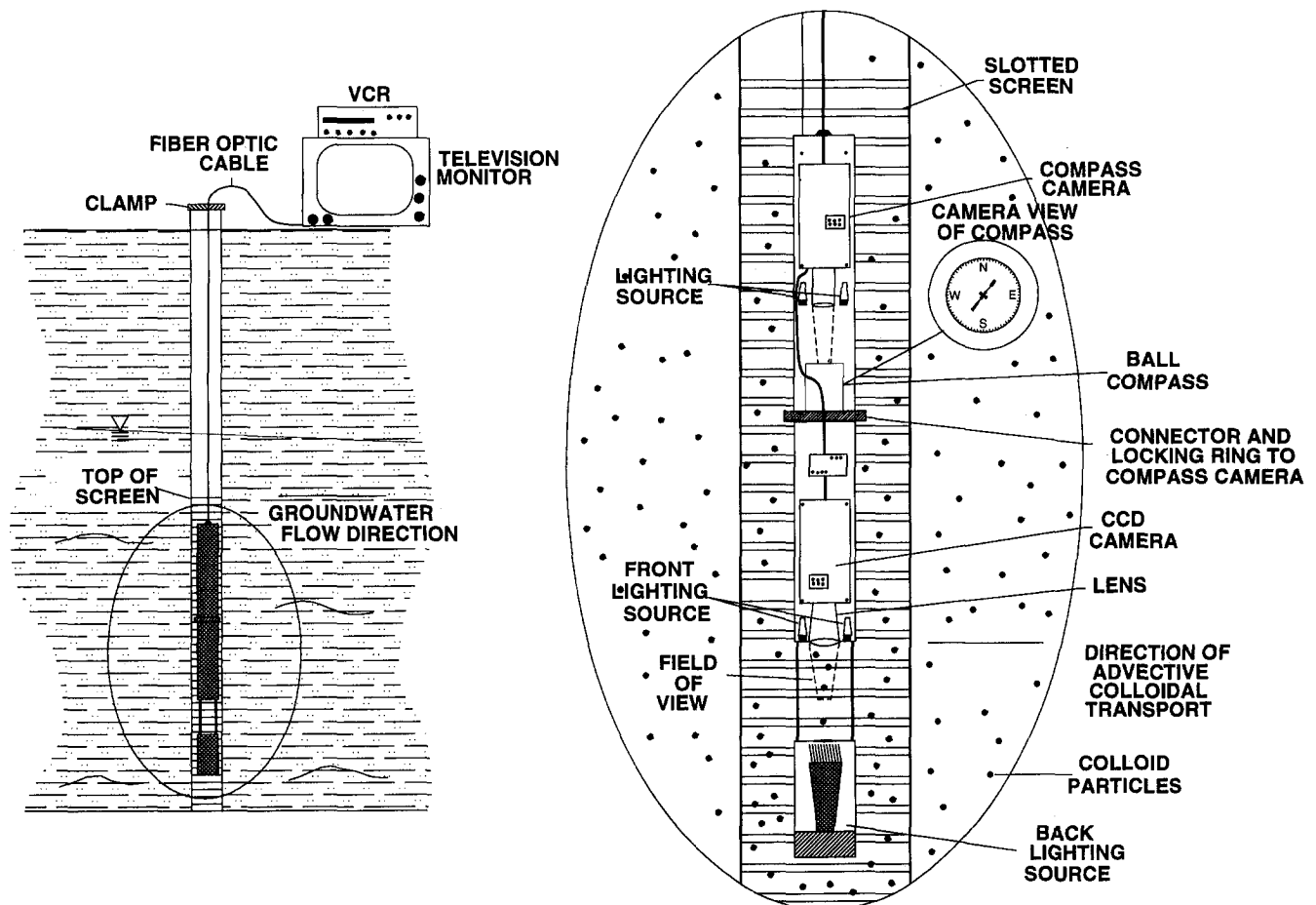


Figure 2. Diagram of the colloidal borescope.

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100 mL/min. Each well was sampled once a day for three consecutive days to assess the repeatability of the micropurge method. Sample splits were sent to two separate laboratories, resulting in 18 sets of water samples. Similar QA/QC and charge balance methods were applied to the results.

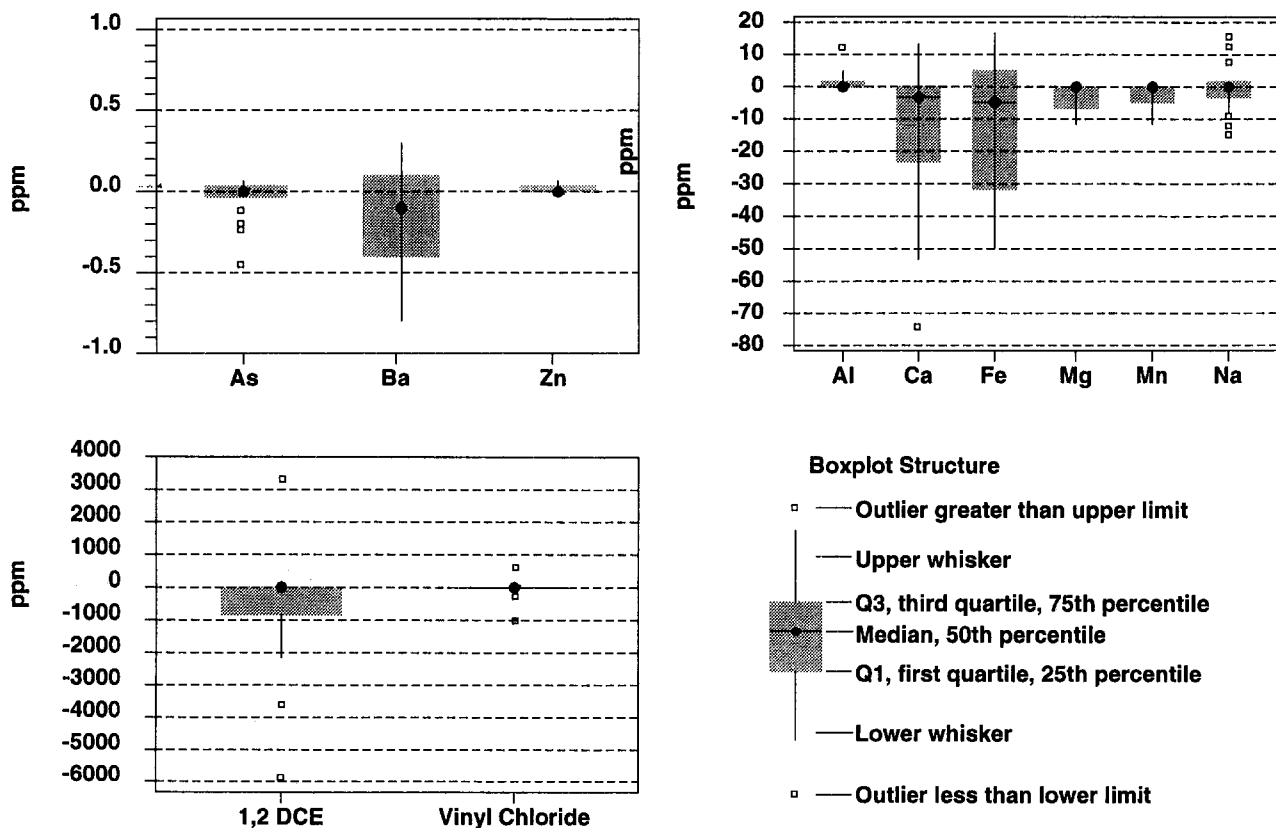
Additionally, the colloidal borescope was used at the Paducah site to observe the impacts of water sampling. The borescope consists of two charged-couple device (CCD) cameras, a ball compass for orientation, optical magnification lens, illumination source, and stainless steel housing (Figure 2). Particles are magnified 140 times and observed at the surface on a video monitor. A bladder pump was installed in a 6-inch-diameter well with the borescope focal plane located at the intake of the pump. Changes in particle characteristics from ambient flow conditions for various pumping rates were observed and recorded using a video image analysis system (VIAS). The VIAS consists of a video frame grabber that can digitize video images from the colloidal borescope every six seconds. A software program analyzes the digitized video images; calculates the particle number, size, flow direction, and flow rate; and records the data on computer files.

## Test Results

### Kansas City Site

Comparisons of the micropurge and traditional sampling results for the Kansas City site are presented in Figure 3 and Table 1. Figure 3 presents box plots of the differences between the median values of the individual analytes. Most of the analytes show a median difference near zero, which indicates that there is no difference in the values measured by the two methods.

Nonparametric sign tests (Gilbert 1987) were conducted on the sampling data to assess the statistical significance of the variation between the sampling methods (Table 1). The sign test is not as powerful as the paired t-test for rejecting the null hypothesis of no difference, but the sign test does not require a normal distribution of the data. Thirty-two tests were conducted on 11 analytes from 3 wells. Of the 32 tests, 26 showed no significant difference at the 95 percent confidence interval ( $p > 0.05$ ). Results for barium, calcium, iron, magnesium, manganese, and vinyl chloride indicated significant differences in one well. With the exception of vinyl chloride, the variation occurred in the same well. For this well, micropurging consistently yielded



The whiskers are lines that extend from the bottom and top of the box to the adjacent values. The adjacent values are the lowest and highest observations still inside the region defined by the lower limit,  $Q1 - (1.5 * IQR)$ , and the upper limit,  $Q3 + (1.5 * IQR)$ .

Outliers are observations outside the lower and upper limits and are plotted with a small square. IQR is the interquartile range,  $Q3 - Q1$ .

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Figure 3. Box plots of the differences between the median concentration values for micropurging and traditional methods for ground water samples collected at the Kansas City site.

**Table 1**  
**Statistical Comparison of Individual Analytes**  
**from Ground Water Samples**  
**Collected Using Micropurging Followed**  
**by Traditional Methods**

Analyte	Well number	P-value
Al	1	0.289
Al	2	0.070
Al	3	0.727
As	1	0.289
As	2	0.453
As	3	0.289
Ba	1	0.008
Ba	2	0.289
Ba	3	0.070
Ca	1	0.016
Ca	2	1.000
Ca	3	0.289
Fe	1	0.008
Fe	2	0.125
Fe	3	0.289
Mg	1	0.008
Mg	2	0.727
Mg	3	0.070
Mn	1	0.008
Mn	2	0.289
Mn	3	0.070
Na	1	0.727
Na	2	0.289
Na	3	0.727
Zn	1	0.070
Zn	2	0.070
Zn	3	0.453
1,2-DCE	1	0.219
1,2-DCE	2	0.344
1,2-DCE	3	ND
Vinyl chloride	1	0.375
Vinyl chloride	2	0.008
Vinyl chloride	3	0.727

ND = Not done because only one pair was above nondetect levels.  
P-values = Below 0.05 rejected the null hypothesis of no significant difference at the 95 percent confidence interval.

higher concentrations for these analytes.

With the exception of the one vinyl chloride analysis, all of the organic compounds showed no statistical difference between the two sampling methods. Because of their volatility, these organic compounds are sensitive to sampling variations that could result in their loss from the water prior to analysis. This evidence suggests that neither sample method resulted in a significant loss of volatile compounds due to sampling.

#### Paducah Site

Micropurge results for three consecutive days from the three test wells at Paducah are presented in Table 2. A review of the data shows that for most of the analytes,

there are only minor differences between sampling episodes. For example, trichloroethene shows less than a 10 percent change for all three wells, although it is common for concentrations of this compound to vary by as much as an order of magnitude between sampling episodes using traditional methods (Clark and Baxter 1989).

Because the limited data set does not allow a rigorous statistical analysis, coefficient of variation analysis was conducted on each analyte to quantify micropurge sampling repeatability. It is recognized that a much larger data set is necessary to provide unequivocal statistical significance. This statistical approach is based on the assumptions that (1) the mean values were constant over the three days of sampling; (2) a normal distribution existed for each analyte from each well; (3) virtually all of the data values were greater than or equal to zero; and (4) virtually all of the data were within three standard deviations of the mean (99.74 percent of the time). If these assumptions are valid, then the coefficient of variation should be less than or equal to 0.333. Under these assumptions, TCE, the principal site contaminant, and most of the major ions such as sodium, calcium, potassium, and magnesium showed coefficients of variation an order of magnitude less than the test case indicating that micropurge sampling produces repeatable results. Only iron and manganese failed this test.

Iron requires further discussion because its concentration is often important for accurately assessing geochemical and microbial conditions in ground water. The literature is replete with the difficulties of obtaining accurate values for trace levels of iron in ground water (Urasa and Mavura 1992). The difficulties are due to the complexity of the aqueous chemistry for iron, which is greatly affected by redox conditions (Drever 1988). There are additional potential problems due to the sampling and analysis of colloidal iron (Kennedy et al. 1974). Many of the same issues relate to manganese (Rai and Zachara 1984). Consequently, the inherent variability in the concentrations of iron and manganese in natural ground water may exceed the additional variability of the sampling method, whether micropurge or traditional methods are used.

#### Observations of Sampling Impacts

At the Paducah site, the colloidal borescope was used to visually observe the impact of water sampling on flow hydraulics and colloidal concentrations. As previously described, a bladder pump was attached to the colloidal borescope and inserted into the well. The intake of the bladder pump was located at the same horizontal level as the focal plane of the borescope.

After steady laminar flow conditions were established in the well, the bladder pump was set at three different flow rates — 100, 500, and 1450 mL/min. The VIAS system was used to analyze and record changes in flow speed, direction, number of particles, and particle size. Average particle sizes were found to be the most sensitive to variations in pumping, and are therefore presented in Figures 4 and 5. Visual observations indicate that only minor changes in the flow and col-

**Table 2**  
**Statistical Analysis of Repetitive Water Samples Obtained Using the Micropurge Method**

Analyte, mg/L <sup>a</sup>	Sampling Date			Mean	Standard Deviation	Coefficient of Variation
	05/19/93	05/20/93	05/21/93			
TCE	0.180	0.190	0.190	0.187	0.00577	0.031
1,2-DCE (total)	0.014	0.012	0.012	0.013	0.0012	0.091
Vinyl chloride	ND	ND	ND			
Technetium-99	63 ± 56	168 ± 59	70.3 ± 57			
As	<0.005	<0.005	<0.005			
Al	<0.025	<0.020	<0.020			
Cd	<0.0030	<0.0030	<0.0030			
Ca	46	45	46	45.67	0.577	0.013
Co	<0.0040	<0.0040	<0.0040			
Fe	0.27	0.14	0.16	0.190	0.070	0.368
Mg	18	19	18	18.333	0.577	0.031
Mn	0.025	0.014	0.015	0.0180	0.0061	0.338
Ni	0.14	0.087	0.12	0.116	0.027	0.231
K	5.7	5.8	5.6	5.700	0.100	0.018
Ag	<0.0060	<0.0060	<0.0060			
Na	54	55	53	54.00	1.000	0.019
Zn	0.0090	0.012	0.012	0.0110	0.00173	0.157
Chloride	114	121	111	115.33	5.132	0.044
Sulfate	56	54	80	63.33	14.468	0.228
Bicarbonate	116	118	117	117.00	1.000	0.0085

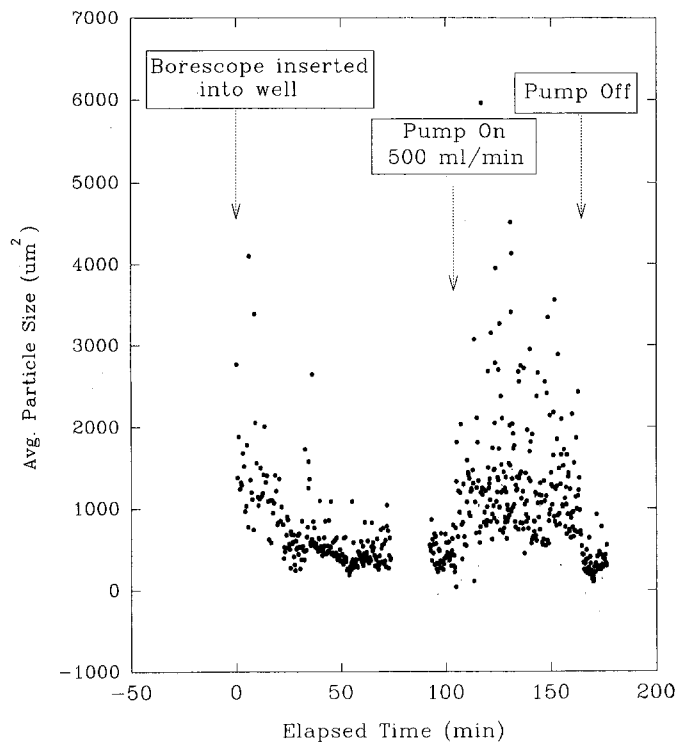
<sup>a</sup> All analytical results were obtained using the site's regulatory-approved ground water analysis program. The charge balance for the data sets agreed within 6 percent or better.

ND = Nondetect.

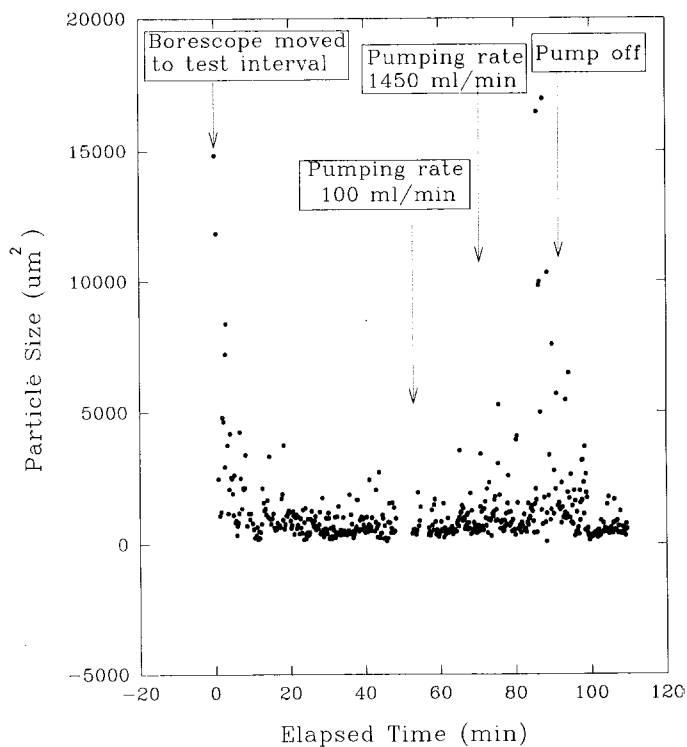
loidal concentrations occurred at the low pumping rates. Ground water flow maintained the same general direction as during ambient conditions. Minor displacement occurred during the pumping phase of the bladder pump cycle. Increases were observed in average particle size due to pumping.

Figure 4 shows the increase in particle size due to turbulence resulting from insertion of the borescope into the well. After approximately 30 minutes, laminar flow conditions dominated and the particle size decreased. At approximately 100 minutes, the sampling pump was turned on at 500 mL/min resulting in an immediate increase in particle size. The pump was turned off at approximately 160 minutes and observed particles returned to prepumping sizes.

Figure 5 shows the impact on particle size of sampling at 100 mL/min and 1450 mL/min. After the borescope was positioned at the test interval, flow conditions were allowed to stabilize before pumping. After 52 minutes, the pump was turned on at 100 mL/min resulting in a slight increase in larger particles. After 70 minutes, the pumping rate was increased to 1450 mL/min inducing high velocities in the well and a dramatic increase in particle sizes (Figure 5). The largest particles were probably dislodged from the casing or sand pack due to high flow velocities. After 92 minutes, the pump was turned off and within approximately 10 minutes,



**Figure 4. Particle size changes due to borescope insertion into the well and pumping at 500 mL/min.**



**Figure 5. Influence of insertion and pumping on average particle size.**

the pumping disturbance dissipated as evidenced by the slow decrease in particle size. Particle numbers also increased with pumping rates above 100 mL/min, but the effect was not as dramatic as were those for particle size. These results agree with a similar study that showed turbidity increasing sharply in response to pumping rate increases after a turbidity plateau had been established at a lower pumping rate (Backhus et al. 1993).

This demonstration suggests that if samples are collected at low flow rates with dedicated systems to minimize disturbance in the well, the samples need not be filtered. Filtering, however, is recommended when samples are collected using high flow rates, bailers, or any time there is a disturbance due to insertion of a sampling device.

## Conclusions

Observation of flow using the colloidal borescope and the sampling results presented in this paper support the use of micropurging as an effective method for obtaining representative samples of the total mobile pollutant concentration in ground water. For most major analytes, comparisons of results showed no significant statistical differences between samples collected by traditional methods or by micropurging. Moreover, micropurging may yield two distinct advantages over traditional methods: elimination of time and cost associated with well purging and rinsate samples, and the collection of samples that represent the total mobile pollutant load. Table 3 presents a recommended ground water sampling procedure utilizing the micropurge methodology. Results presented in this paper justify more extensive

study in order to provide a substantial data set for conclusive statistical analysis. Such an extensive study may provide insights into variation in redox-sensitive analytes such as iron and manganese.

**Table 3**  
**Recommended Ground Water Sampling Procedures to Assess the Total Mobile Pollutant Concentrations**

- Samples should be taken from dedicated sampling devices such as bladder or submersible pumps. No bailers should be used.
- Pump intakes should be located in the center of screens unless depth specific samples are required. Samples should be collected 24 hours after pump installation.
- Sampling rates should be approximately 100 mL/min. Higher rates are possible for permeable aquifers.
- The sample pump and tubing should be "micropurged" approximately two volumes to ensure the complete removal of stagnant water. It is not necessary to purge the well casing and screen.
- Water samples should be unfiltered.

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