Low-Flow Purging and Sampling Ground Water

Evolution of Technology and Standards

BY JOE RITCHEY

The human suffering caused by groundwater contamination has been dramatized in films such as "Erin Brockovich" and "A Civil Action." Joe Ritchey describes the ASTM standards behind the scenes that help ensure safe drinking water and provide proof of contamination when necessary.

Throughout history a safe drinking water supply has been among the top criteria for the sustained development of a community. As such, it is not surprising that successful ancient civilizations engineered their water supplies to get a safe source to their citizenry. Evidence of ancient wells as a source of water is present today at least in the Middle East and Central America and probably many other locations. Although something was known then about what made water good or bad to drink, much of what we know today has been learned in the past 50 years.

We now understand the mechanics of ground-water flow and contaminant transport even if we are unable to describe subsurface conditions sufficiently to determine the contamination's exact whereabouts. Often contamination occurs from unidentified sources so that even an understanding of the mechanisms of transport leaves us unsure of the extent of migration. Monitoring wells are one of the tools to examine subsurface conditions. Collecting groundwater samples from several wells at nearly the same time and then repeating the sampling procedure several months later may enable the investigator to interpolate between past and current conditions and even extrapolate to some future time.

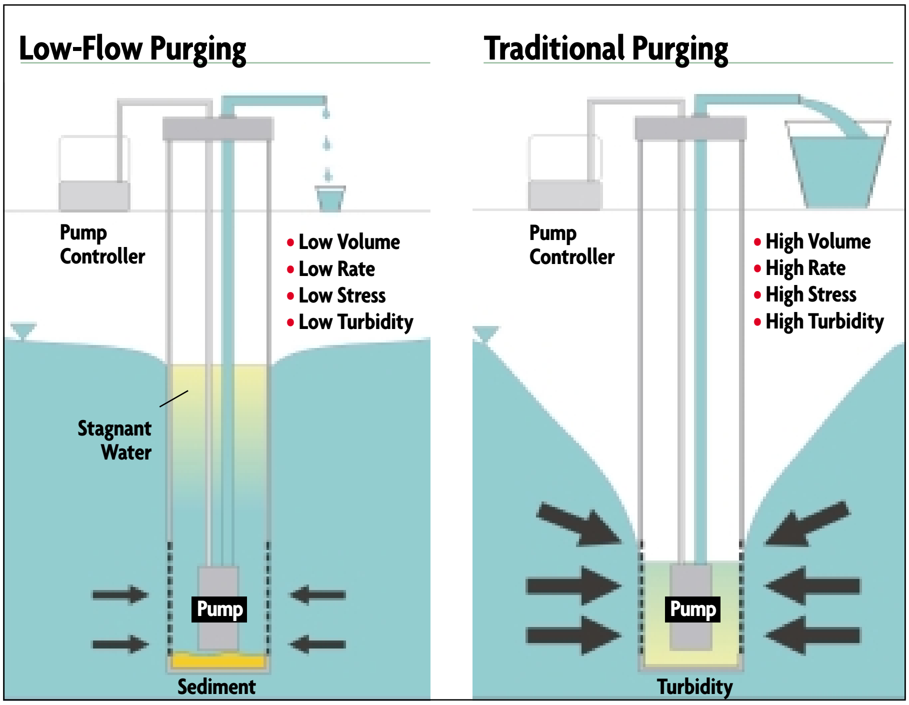
To make a valid comparison between past and present, the samples need to be representative of the water in the soil and rock. In addition the samples need to be evaluated in a consistent manner so as to eliminate effects due to sampling procedures or chemical analysis techniques. Changing the sampling procedure is done at risk of changing some characteristic of the samples. Knowing the cause and effect relationship of each procedure helps the investigator focus on eliminating the significant impacts first.

A REVIEW OF GROUND-WATER PURGING METHODS

The usual purpose of collecting ground water samples is to determine the concentration of a particular dissolved chemical in the geologic formation. Getting the ground water from the formation in to the sample bottle without changing it is crucial and you don't need to be trained in hydrology to immediately identify obstacles. The water to be sampled may be several metres to tens of metres below the ground-water surface so that it may be pressurized above atmospheric pressure. The distance from the water surface to the ground surface may also be significant, requiring a pumping device. The ground water temperature (usually the annual average air temperature at the ground surface) may be warmer or colder than the temperature at the ground surface at the time of sampling. Warmer temperatures at the ground surface are usually more problematic. Ultimately ground water must pass through a sand pack surrounding the well screen, the well screen itself, well casing, and sampling device before it is placed in a container for shipment to a laboratory.

Changes in the pressure and temperature will affect the sample and so will the presence of air or gases and contact with foreign materials such as the sand pack and well casing. To minimize this possible effect specific recommendations for material-chemical compatibility were established. Beyond the materials, ground water itself will often reside in the well casing exposed to the atmosphere for months if not years between subsequent sampling events. This passage of time further affects the sample such that the water in the well is clearly not representative of the formation water. Hence the procedure was instituted of purging "stag-

FIGURE 1



Low-flow purging extracts much less water than traditional purging.

Apparatus for collecting a groundwater sample – from left to right: purging and sampling pump controller, air tank for pump, bucket to contain purge water, and flow-through cell to measure indicator parameters.

nant" water from the well so that representative ground water is sampled.

In the late 1970s, purging three to five times the volume of water initially in the well was arbitrarily considered adequate to produce samples representative of formation water. However, calculation of the percent formation water with volume purged was recommended to provide a more rational basis to determine the amount of purging required. The rate and volume of ground water pumped was to be determined on the basis of soil or rock properties and the well diameter. Wells were purged in the minimum time required to produce "representative" ground water samples.

The 1980s brought an enormous number of site investigations for soil and ground water contamination in response to regulations by national agencies such as the U.S. Environmental Protection Agency. Monitoring well technology, sampling procedures, and analytical techniques were developed and many were defined in ASTM standards.

Through the decade of the 1990s industries frequently complained about the expense of continued monitoring of a large number of wells, while regulators saw little progress in cleanup. The goal of corrective actions was changed to include an evaluation of risk at the point of exposure rather than cleanup to an arbitrary cleanup value for a particular chemical, and efforts were focused on reducing costs in monitoring programs and the waste generated by environmental investigations. One of the activities that was scrutinized was the volume of water purged from a well prior to sampling that had to be disposed of as a waste. In many municipalities wastewaters from well purging and corrective actions were specifically excluded from publicly owned treatment works because of the fear of violating of their own discharge permit. Along with the expenses of investigating an ever-increasing number of sites came extensive research that, in part, showed what was happening in a well during purging and sampling by different methods. Purging a fixed volume of water was usually done as quickly as possible, which usually re-suspended sediments that had settled to the bottom of the well. In particular, acid added as a preservative, would leach metals from any suspended sediment, exaggerating the metals results. To address problems such as these, a method called "low-flow" purging proved effective at enabling collection of representative samples while reducing the volume of water extracted.

WHAT IS LOW-FLOW PURGING?

"Low flow" refers to the movement of ground water from the formation through the well screen. Flow must be minimized to preclude the entrainment of sediment in the water to be collected as a sample. Some researchers refer to the method as "low-stress" purging, where "low stress" refers to the impact of pumping the well on the formation. Water-level drawdown and turbidity provide measurable indicators of the stress on a given formation imparted by a pumping device operated at a given flow rate.

Low-flow purging directly followed by sampling is a method of collecting samples from a well that does not require the removal of large volumes of water from the well (Figure 1, previous page). Low-flow purging differs from previously developed methods of purging because "stagnant" water is left in the well and the turbidity is minimized. The method depends on moving ground water through the well screen at approximately the same rate as it flows through the formation. This enables significant reduction in the volume of water extracted before sampling. For the natural movement of ground water to flow through the well, the well must have been properly designed, constructed, and developed such as described in ASTM standards D 5092, Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers, and D 5521, Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aqufiers.

Typically, flow rates on the order of 0.1 to 0.5 L/min are used; however, this is dependent on site-specific and well-specific factors. Some very coarse textured formations have been successfully purged and sampled in this manner at flow rates up to 1 L/min. Pumping water levels in the well and water-quality indicator parameters should be monitored during pumping, with stabilization indicating that purging is completed and sampling can begin. Because the flow rate used for purging is, in most cases, the same or only slightly higher than the flow rate used for sampling, and because purging and sampling are conducted as one continuous operation in the field, the process is referred to as low-flow purging and sampling.

Low-flow purging and sampling can be used to collect samples for aqueous-phase contaminants and naturally occurring analytes, including volatile and semi-volatile organic compounds, metals and other inorganics, pesticides, PCBs, other organic compounds, radionuclides and microbiological constituents. Low-flow purging and sampling is effective with aqueous-phase constituents that may sorb or partition to particulate matter. Low-flow purging and sampling is not applicable to sampling either light or dense non-aqueous-phase liquids.

BENEFITS OF LOW-FLOW PURGING AND SAMPLING

Purging and sampling at a low-flow rate offers a number of benefits over traditional methods including:

- Improved sample quality and reduced (or eliminated) need for sample filtration, through elimination of mixing of the water column in the well and minimized disturbance of the well and the formation, which result in greatly reduced sample turbidity and minimization of false positives for analytes associated with particulate matter.
- Improved sample accuracy and precision and greatly reduced sample variability as a result of reduced stress on the formation, reduced mixing and dilution of analytes, and reduced potential for sample agitation, aeration and degassing or volatilization.
- Samples represent a smaller section or volume of the formation, representing a significant improvement in the ability to detect and resolve contaminant distributions, which may vary greatly over small distances in three-dimensional space.
- Overall, improved sample consistency, especially when using dedicated pump.
- Ability to directly quantify the total mobile contaminant load (including mobile colloid-sized particulate matter) without the need for sample filtration.

Ground-Water Sciences on the Big Screen

IN YEARS PAST THE FLAVOR OF BEER WAS ADVERTISED AS IMPROVED WITH GROUND WATER DERIVED FROM springs. You often can find advertising that exemplifies the virtues of "artesian" water in bottled drinking water. Within the last several years contaminated ground water has been the subject of two popular movies: "**A Civil Action**" (1998, Touchstone Pictures and Paramount Pictures) and "**Erin Brockovich**" (2000, Universal Pictures and Columbia Pictures). Both movies portray the tragedy of families suffering due to contact with contaminated ground water and difficulty in identifying its source, path, and effect.

"A Civil Action" is about the Woburn, Mass., case in which chlorinated solvents from two industries contaminated wells G and H in the city's well field. As is sometimes the situation, an investigation was carried out in the course of a legal battle between citizens against the industries rather than by compliance between the industry and state or federal environmental protection agencies. Whether the investigation is carried out at the direction of legal counsel or a regulatory authority, the engineers and geologists doing the work are anxious to perform the work in a logical manner, trying to balance the cost of additional samples verses the increased uncertainty of fewer samples. Either way the representativeness of the samples is crucial.

In "Erin Brockovich," groundwater contamination in Hinkley, Calif., is caused by release of hexavalent chromium, an additive to inhibit corrosion in a compressor station cooling tower water. Spent cooling water was placed in lagoons that leaked impacting residential wells. As with many contamination cases, the releases to groundwater began before there was a real awareness of environmental management. Unfortunately even after the releases were identified and the risk was assessed, the ramifications were ignored.

Neither movie is on the list of 100 top grossing films of all time, however, "A Civil Action" grossed over $55 million and "Erin Brockovich" over $125 million. These numbers indicate that the movies were well received by the public. The impact of sampling techniques in the cases portrayed in these movies were not shown on screen, however, they most likely were an important part of the legal proceedings; they always are.

Installing the purging/ sampling pump.

Chronology of a Sampling Event

A SAMPLING EVENT IS THE STEPS FOLLOWED FROM PLANNING THE activity to submitting the samples to the laboratory performing the analyses. The steps are outlined below:

- **Perform calibration checks** on field monitoring instruments.
- **Inspect the well** and surrounding site for security, damage, and evidence of tampering.
- **If volatile organic compound (VOC)** contamination is present or suspected, determine ambient VOC background levels in the immediate vicinity of the well with an appropriate instrument. Then remove the well cap and immediately measure VOCs at the rim of the well and record the readings in the field logbook or on the well data sheet.
- **Locate** the well survey reference point.
- **Measure** the static water level in the well.
- **Containerize wastewater** until analytical data are available to determine the proper disposal process.
- **Purging (with an installed dedicated purging and sampling device) -** Start the pump at a low flow rate until surface discharge occurs. Check water level. If no drawdown occurs, gradually increase the pump rate until flow is optimized with minimal drawdown.
- **Connect the pump discharge tubing directly to the flow-through-cell.** Monitor and record water level and pumping rate every three to five minutes (or as appropriate) during purging.
- **Monitor Indicator Field Parameters -** During well purging, monitor selected indicator field parameters (e.g., turbidity, temperature, specific conductance, pH, oxidation-reduction potential, dissolved oxygen) every three to five minutes.
- **Collect Water Samples -** Disconnect the flow cell from the water path before collecting samples. Water samples for laboratory analyses must be collected before the water has passed through the cell to prevent cross contamination or chemistry changes.
- **Add the preservative** as required by analytical methods.
- **Label each sample** as it is collected. Samples requiring cooling (e.g., VOCs and cyanide) are to be placed into a cooler with ice or refrigerant for delivery to the laboratory.
- **Post Sampling Activities -** Measure the final flow rate and record on the field data sheet and measure the final depth to water and total well depth, if required and not previously measured during this sampling event, and record.
- **Secure the well.**

Apparatus for collecting a ground-water sample – flow-through cell to measure indicator parameters (left) and purging and sampling pump controller (right).

- Increased well life through reduced pumping stress on the well and formation, resulting in greatly reduced movement of fine sediment into the filter pack and well screen.
- Greatly reduced purge-water volume (often 90 to 95 percent), resulting in significant savings of cost related to purge water handling and disposal or treatment, and reduced exposure of field personnel to potentially contaminated purge water.
- Reduced purging and sampling time (much reduced at sites using dedicated pumps), resulting in savings of labor cost.

STANDARDS DEVELOPMENT

The expansion of environmental activities in the 1980s and early 1990s led to new products, methods, and standards. One of the early standards developed was D 4448, Standard Guide for Sampling Ground Water Monitoring Wells, developed by Committee D34 on Waste Management. In 1987 Subcommittee D18.21 on Ground Water and Vadose Zone Investigations was formed under Committee D18 on Soil and Rock. A D18 task group on ground water sample collection and handling then assisted D34 in revising D 4448 in 1995, and most recently in 2001.

Standard D 4448 describes the general options available for sampling ground water. Additional standards have been developed to provide more detail on many of the options presented in D 4448. Related standards include:

- D 5903, Guide for Planning and Preparing for a Ground-Water Sampling Event;
- D 6634, Guide for Selection of Purging and Sampling Devices for Ground-Water Monitoring Wells;
- D 6564, Guide for Field Filtration of Ground-Water Samples;
- D 6517, Guide for Field Preservation of Ground-Water Samples;
- D 6089, Guide for Documenting a Ground-Water Sampling Event.

Recently D34 and D18 worked cooperatively to develop a new standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations. Although initially developed independently, a joint committee week meeting in January 2002 resulted in a committee approval of the standard. D18 and D34 are committed to working together on the development of future standards for ground-water investigations. //

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