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U.S. Geological Survey Combined Well-Bore Flow and Depth-Dependent Water Sampler

The U.S. Geological Survey has developed a combined well-bore flow and depth-dependent sample collection tool. It is suitable for use in existing production wells having limited access and clearances as small as 1 inch. The combination of well-bore flow and depth-dependent water-quality data is especially effective in assessing changes in aquifer properties and water quality with depth. These are direct measures of changes in well yield and ground-water quality with depth under actual operating conditions. Combinations of other geophysical tools capable of making these measurements, such as vertical-axis current meters used with wire-line samplers, are commercially available but these tools are large and can not easily enter existing production wells.

BASIC OPERATING PRINCIPLES

The U.S. Geological Survey device is a high-pressure hose equipped with valves for dye injection and sample collection. The hose is mounted on a reel for deployment, retrieval, and storage (fig. 1). The hose can be used to collect velocity-log data and, after cleaning and decontamination, the same hose can be used to collect depth-dependent water-quality data. Accessories, such as a Teflon® hose extension, are available for collection of organic compounds.

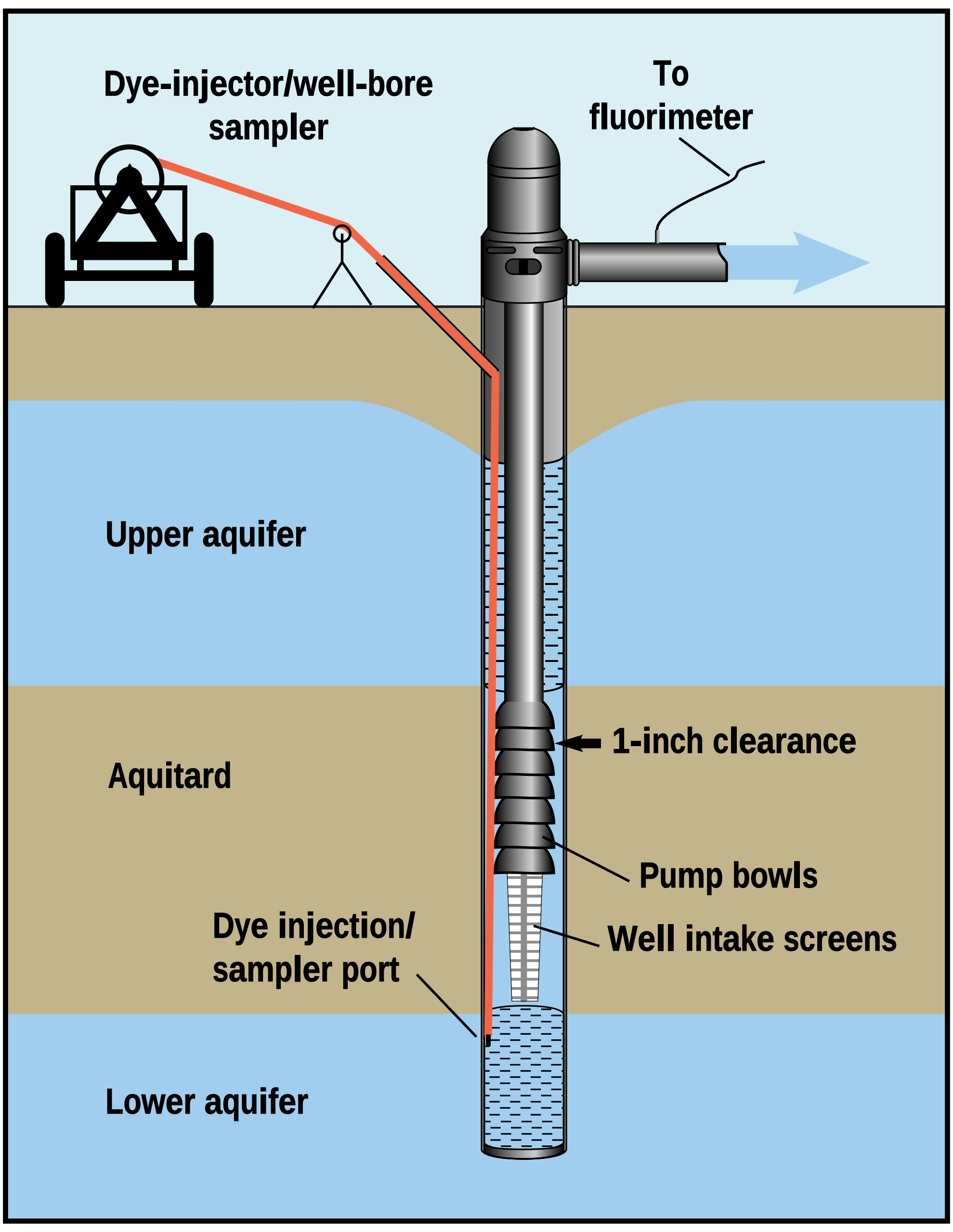

Figure 1. Example of typical deployment in a deep-turbine production well.

Velocity-Log Data

The equipment is used to obtain flow data within the well bore under pumping conditions using a technique we named the 'tracer-pulse method.' When operated in this mode, the hose is filled with fluid containing an easily measured tracer, such as water colored with Rhodamine dye. The hose is lowered to a known depth in the well (d_1) and a pulse of the tracer is injected into the water column. The travel-time of the tracer to a detector on the surface is measured (t_1). If Rhodamine dye is used, a commercially available fluorimeter is used to measure the arrival of the dye at the surface. The hose is then lowered to the next depth (d_2), another pulse of dye is released, and the travel-time is measured (t_2). The velocity is calculated as the difference in the travel-times. Assuming piston flow, the flow rate (Q), given a known well radius (r), is calculated using the following equation:

$$Q = (V\pi r^2) \quad \text{where: } V = (d_2-d_1)/(t_2-t_1)$$

A series of injections at different depths is done to construct a velocity profile for the well. The velocity profile can then be used to guide the collection and interpretation of depth-dependent water-quality data.

Depth-Dependent Water-Quality Data

To collect a water-quality sample from a given depth in the well, the hose is pressurized to greater than the hydrostatic pressure at that depth and lowered into the well. When the sample depth is reached, the hose is vented at the surface and water from the well at the sample depth enters the hose. The hose is retrieved and the sample expelled from the hose under pressure. The process is repeated at several depths to complete a water-quality profile within the well. If the concentrations of a constituent at the first sample depth (C_1) and the second sample depth (C_2) are known, the concentration in water entering the well from the intervening water-bearing zone (C_a) can be calculated from the water-quality profile and the velocity-log data:

$$[(C_1Q_1-C_2Q_2)/Q_a] = C_a$$
$$\text{where } Q_a = (Q_1 - Q_2)$$

This calculation assumes conservative mixing and conservation of mass.

APPLICATIONS

The data shown in figure 2 are from a deep production well in a complex multiple-aquifer system. These data illustrate changes with time in the chloride concentration of water entering the well at depth and changes with time in the distribution of flow into the well. Because changes in well yield and water quality measured at the surface were small, these changes would not have been detected using conventional sample collection methods which are a composite of all the water flowing into the well. A comparison of data from a velocity log using a conventional spinner tool and a velocity log using the tracer-pulse method also is shown in figure 2. The tracer-pulse method correctly identified the most important water-yielding zone and the depth below which almost no water enters the well. Neither of these important hydrologic features could have been identified on the basis of indirect data, such as a resistivity log (fig. 2).

The combination of velocity-log data and depth-dependent water-quality data is an especially effective data set for hydrologic interpretations. Specific applications for data collected using this approach include:

(1) Identification of changes in ground-water quality and well yield with time.
(2) Identification of different water-bearing units with depth.

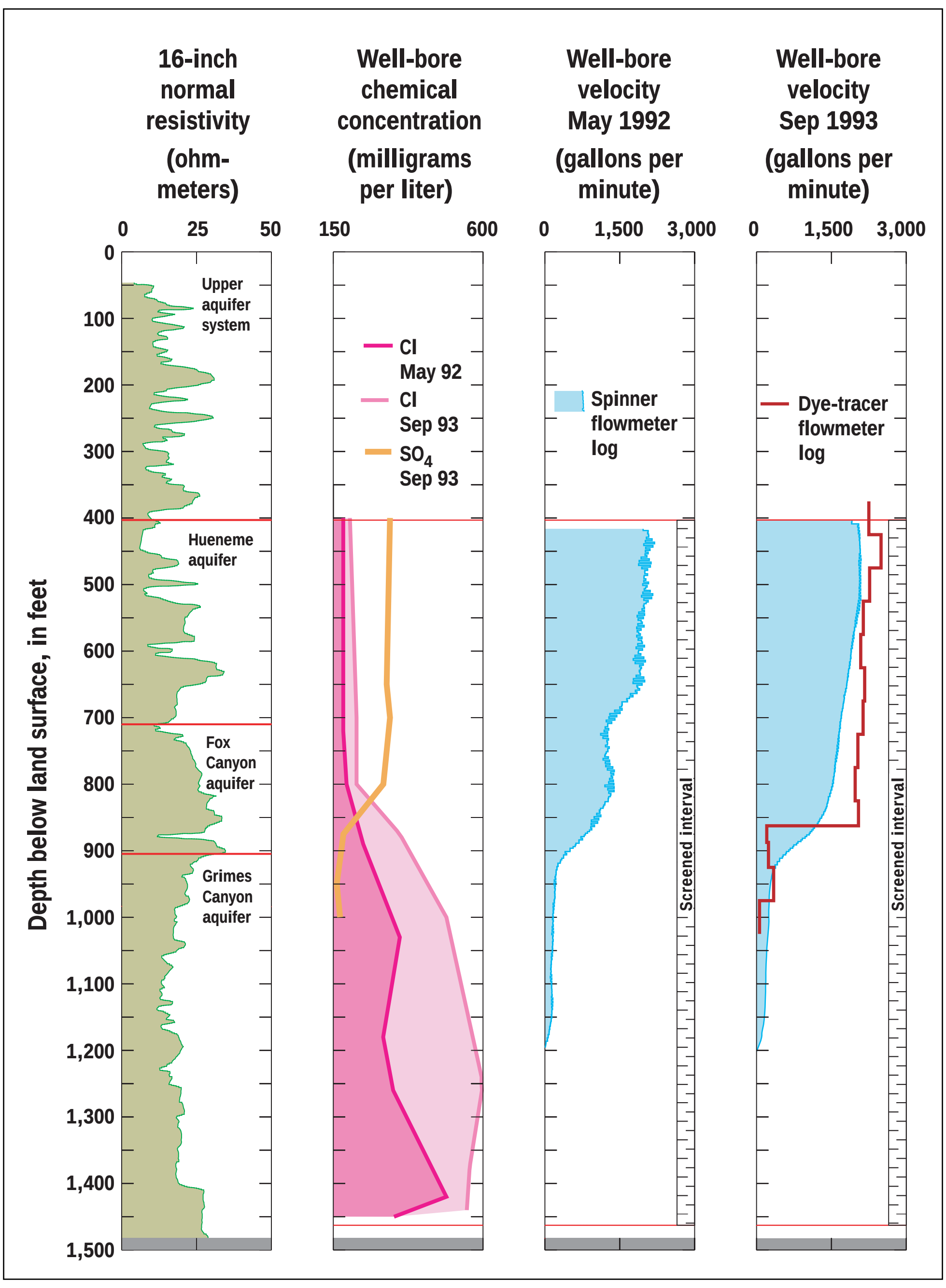

Figure 2. Example of depth-dependent flow and chemical data sampled from a deep production well.

(3) Identification of changes in natural ground-water chemistry with depth.
(4) Identification of man-made or natural contaminants with depth.

Although the applications described here are primarily for production wells, the approach also can be applied to observation wells. This approach may be especially useful to assess the performance of wells used for remediation if contaminants are stratified within the aquifer.

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