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FIELD ESTIMATION OF HYDRAULIC CONDUCTIVITY FOR ASSESSMENTS OF NATURAL ATTENUATION

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ABSTRACT: A Geoprobe is a sampling tool that drives hollow steel rods into the earth to serve as a temporary ground water monitoring well. The rods are threaded to allow them to be joined together, and the leading rod is slotted to admit the ground water being sampled. A simple technique was developed by EPA staff that uses a Geoprobe to estimate the hydraulic conductivity of the depth interval that provides the water sample. The approach can be used where ground water can be sampled by suction lift using a pump on the surface.

INTRODUCTION

Risk assessments of natural attenuation (intrinsic remediation) of organic contaminants in ground water often require an accurate estimate of the residence time of the contaminants along a flow path to a receptor. This is particularly true if first-order rate constants for depletion of the contaminant are used to estimate contaminant concentrations at the receptor or some point of compliance. Traditionally, the time of travel from one monitoring location to another is inferred from Darcy's law based on measured hydraulic gradients, the hydraulic conductivity of the interval in the aquifer sampled by the monitoring wells, and an estimate of effective porosity.

The Geoprobe and similar push technology is finding wide application as an alternative to conventional wells. The hydraulic conductivity of the interval yielding water to permanent monitoring wells can be estimated by pumping tests or slug tests conducted in the well. However, no equivalent test exists for the Geoprobe or other similar push technology.

MATERIALS AND METHODS

The test was developed using off-the-shelf Geoprobe tools and equipment.

Specific capacity refers to the flow of water yielded by a well at a particular drawdown. The test is usually done by pumping from a well at a fixed rate and monitoring the drop in the level of water in the well over time. We refer to the test devised for the Geoprobe tools as an ***inverse specific capacity*** because the drawdown is set at a predetermined level, and the yield at that predetermined level is measured.

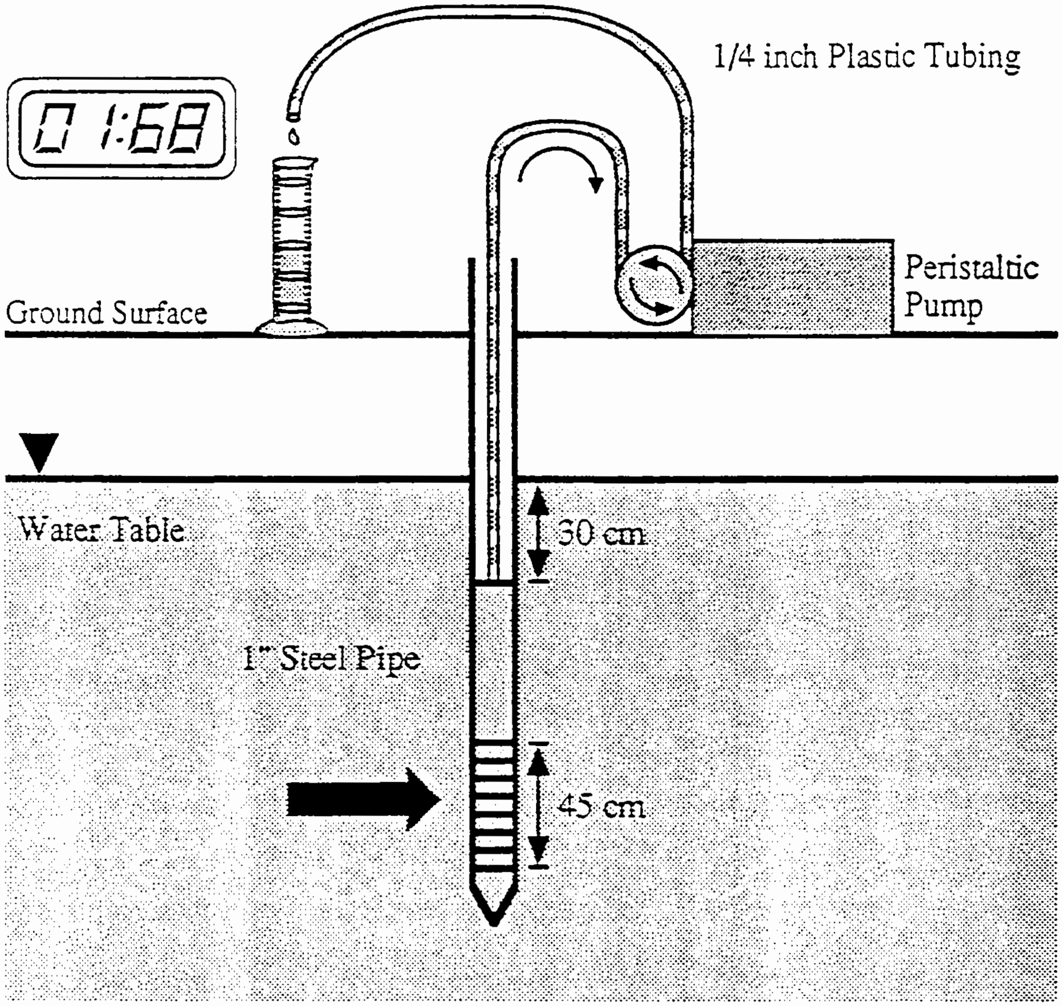

FIGURE 1. A test to measure the specific capacity of a Geoprobe well.

The tests were conducted as follows. A Geoprobe screened rod was driven to the depth to be sample. The rods were screened over an interval of 1.5 feet (45 cm) with 0.020 inch (0.51 mm) slots. A polyethylene tube was inserted to the bottom of the rods and pumped to remove all the sediment from the interior of the rods. Occasionally sediment entered the screen when the drawdown in the well exceeded 1.0 feet (30 cm). To remedy this, distilled water was poured into the rods during pumping of the sediment to prevent excessive drawdown. The water level inside the Geoprobe was allowed to come to equilibrium. A polyethylene tube was inserted in the well with the tip at an elevation of 1.0 foot (30 cm) or 0.5 foot (15 cm) below the static water level. Water was pumped from the tube at a rate that produced both water and air. This poised the level of water in the Geoprobe rods at the predetermined level. The well was pumped until the flow rate came to equilibrium, the time required to collect 100 ml was measured. If the yield was very slow, the yield in five minutes was measured. Inverse specific capacity was calculated in milliliter per second per centimeter of drawdown. The specific capacity was multiplied by an empirical calibration factor of 0.03 to estimate hydraulic conductivity in centimeters per second. After the test for inverse specific capacity, the tube was lowered and ground water was sampled for routine parameters (FIGURE 1).

RESULTS AND DISCUSSION

Reproducibility. The reproducibility of the Geoprobe specific capacity test was evaluated at a site on the North Beach area of the U.S. Coast Guard Support Center at Elizabeth City, NC.

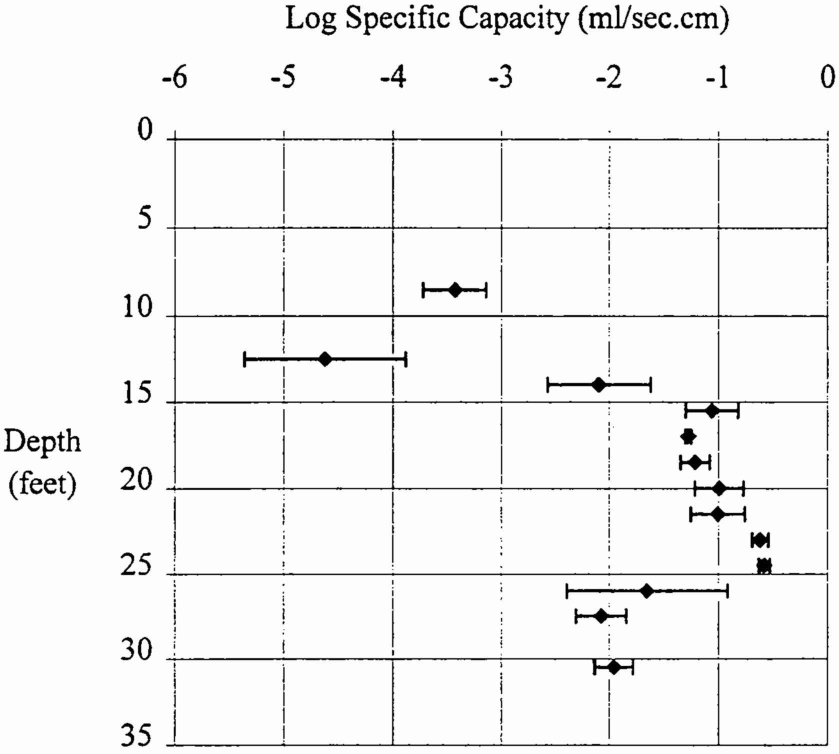

FIGURE 2. Reproducibility of the test for specific capacity using a Geoprobe. The diamonds are the logarithmic means of three independent tests. The bars are the standard deviation of the logarithms of the independent tests.

At the test site, the shallow sediments are clay and silt, transitioning to silty fine sand and fine sand at 15 feet (4.6 m) and back to silt at 25 feet (7.6 m). The water table was 4.0 feet (122 cm) below the surface in clay and silt. FIGURE 2 plots the mean of three tests conducted at thirteen separate depth intervals extending from the water table to the bottom of the first semi-confined aquifer. As expected, the specific capacity is low in the clay and silt extending to 15 feet (4.6 m) in depth, it is about two orders of magnitude higher in the silty fine sand and fine sand, and between one and two orders of magnitude lower in the deeper silty layer.

FIGURE 2. plots the standard deviation of the common logarithm of the means. In the interval of silty fine sand to fine sand, the widest standard deviation corresponds to a factor of 1.8, and the average of nine standard deviations corresponds to a factor of 1.4. The standard deviations are much wider in samples across the transition zones at 15 feet (4.6 m) and 26 feet (7.9 m). This may reflect natural heterogeneity in the aquifer, or more likely, error in the vertical position of the Geoprobe screen. In uniform material with specific capacities ranging from 0.000366 ml/sec.cm up to 0.232 ml/sec.cm, the standard deviation of tests in general corresponded to a factor of 2.0 or less. However, the standard deviation of the tests conducted at 12.5 feet (3.8 m) increased to a factor of 5.4. The specific capacity of this material was 0.0000237 ml/sec.cm. Apparently 0.000366 ml/sec.cm is the effective lower limit for reproducibility in the test. As discussed below, this corresponds to a hydraulic conductivity of 0.00001 cm/sec.

Calibration. The specific capacity of the Geoprobe wells was calibrated by comparing the specific capacity to the hydraulic conductivity of a conventional monitoring well 2.0 inches (5.1 cm) in diameter, or to the hydraulic conductivity of a core sample subjected to a permeameter test (TABLE 1).

TABLE 1. Empirical calibration factors that estimate hydraulic conductivity from the specific capacity of the Geoprobe well.

Location	Method	Hydraulic Conductivity (cm/sec)	Specific Capacity (ml/cm.sec)	Calibration Factor
Elizabeth City, NC	Pumping test in 2 inch well	0.0246	0.70	0.035
Elizabeth City, NC	Pumping test in 2 inch well	0.00244	0.081	0.030
Eglin AFB Florida	Slug test in 2 inch well	0.036	0.32	0.11
Eglin AFB Florida	Permeameter test on core	0.015	0.35	0.043
Plattsburgh AFB, NY	Permeameter test on core	0.0089	0.34	0.026
Pontotoc Co, OK	Permeameter test on core	0.0078	0.40	0.020
Pontotoc Co, OK	Permeameter test on core	0.000018	0.0044	0.004

The calibrations at two sites at Elizabeth City, NC were conducted by determining the average specific capacity of Geoprobe samples extending across the interval sampled by an adjacent permanent monitoring well. Data for a well at the U.S. Coast Guard Support Center in Elizabeth City, NC are illustrated in FIGURE 3. When a particular interval was not sampled by the Geoprobe, the specific capacity was estimated by linear interpolation from the adjacent samples. The permanent wells were 2.0 inches (5.1 cm) in diameter. They were pumped at a rate of 1.0 to 2.0 gallons (3.8 to 7.5 liters) per minute for twenty to thirty minutes. Drawdown in the permanent well was used to estimate transmissivity using the equation of Jacob as described in Appendix 16.D, page 1021 of Driscoll (1986). The calibration on material from Eglin AFB, FL was conducted by comparing the specific capacity of the Geoprobe wells to a permanent monitoring well that was 2.0 inches in diameter (5.1 cm) with a 5.0 foot (152 cm) screen. The 1.5 feet (45 cm) of screen in the Geoprobe rod was located at a depth adjacent to the center of the screen of the permanent monitoring well.

Core samples were selected from sites that were known to be uniform over the vertical interval sampled by the core. The calibrations on material from Plattsburgh AFB, NY and Eglin AFB, FL were conducted by packing core material from the same depth interval into a laboratory permeameter. The calibrations on material from Pontotoc Co. OK were conducted by collecting a core in plastic sleeve that was 1.5 inches (3.8 cm) in diameter, then conducting a permeameter test in the field. The elevation of the cored interval corresponded within 1.0 inch (2.5 cm) with the interval sampled by the Geoprobe.

In general the agreement between the empirical calibrations as listed in TABLE 1 is good. Five of the calibrations involving two permanent monitoring wells and three core samples produced empirical calibration factors that varied over a small range, from 0.043 to 0.020. The hydraulic conductivity of these materials varied from 0.0246 to 0.00244 cm/sec. At Eglin AFB, the Geoprobe yielded less water than was expected from a slug test on the neighboring permanent monitoring well. This may have resulted from the differences in the screened intervals. In the less permeable material from Pontotoc Co, OK, the Geoprobe well yielded ten times more water than would be expected from the permeameter test on the core sample. The result is outside the expected standard deviations as determined in FIGURE 2.

The lower range for effective calibration is probably 0.0001 cm/sec. Below that range the estimates should be considered accurate only within an order of magnitude. The upper limit for effective calibration is controlled by the rate at which the pump can pump water and air. The Masterflex pumps used at Kerr Research Center have a maximum rate of about 300 ml/minute. The lowest imposed drawdown that can be accurately measured is about 1.0 inch (2.5 cm), making the upper limit that can be measured about 0.1 cm/sec.

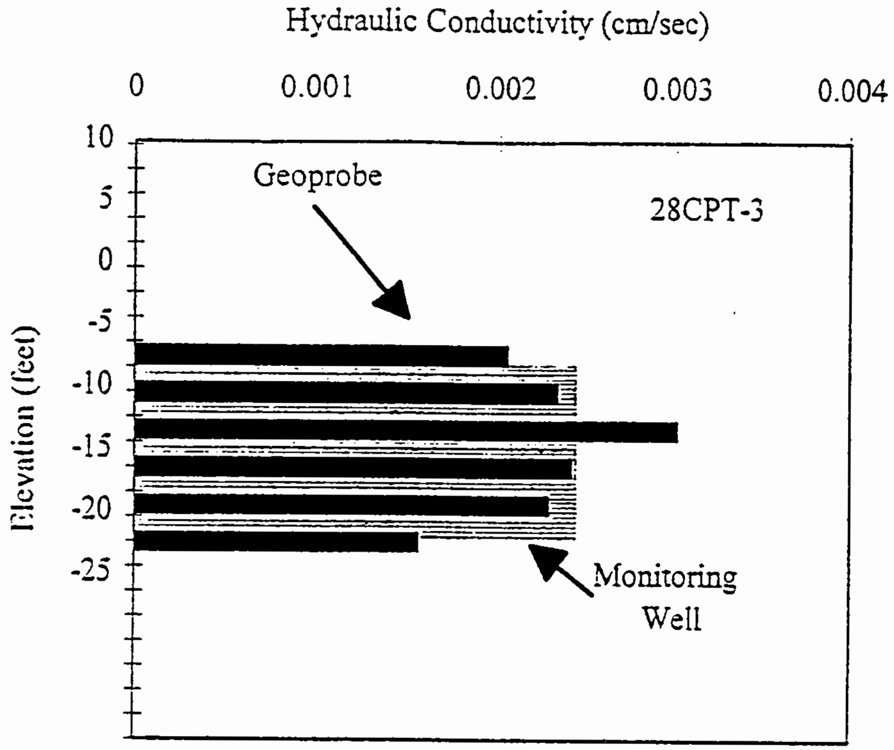

FIGURE 3. Correlation between hydraulic conductivity as determined by a pumping test in a permanent monitoring well and the specific capacity test in temporary Geoprobe well.

DISCLAIMER

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16. ABSTRACT

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