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USE OF ELECTROMAGNETIC BOREHOLE FLOWMETER TO DELINEATE GROUNDWATER PRODUCING FRACTURES

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INTRODUCTION

Ground water flow on the Oak Ridge Reservation (ORR) is dominated by permeable fractures within the relatively impermeable rocks. It is possible to detect the fractures which intersect a borehole using conventional logging tools (electrical, sonic, acoustic televiewer, caliper, temperature), but not with any certainty which of these fractures are permeable and are part of a connected network. This poses a problem for the groundwater modeler. Should all known fractures be included in the model? Only major fractures?

ELECTROMAGNETIC BOREHOLE FLOWMETER

Recently, we have been experimenting with a new electromagnetic borehole flowmeter, designed by researchers at the Tennessee Valley Authority (TVA), which measures the vertical flow of water within a screened or open-hole interval while water is pumped in or out of the well. Changes in flow between depths indicate an interval where water is entering or exiting the well.

The system has three primary components: the flow probe, the packer assembly, and the electronics package. The flow probe includes an electromagnet, two electrodes on opposite sides of the cylinder, and an amplifier, all cemented in a water-tighht epoxy and covered with a stainless steel jacket. Water moving through the hollow core of the flowmeter in the presence of the magnetic field created by the electromagnet induces a voltage directly proportional to the flow rate, which is measured across the two electrodes.

The probe will fit into a 2 inch diameter well. For wells 2-3.5 inches in diameter a plexiglass collar is fitted to the probe to force flow through the hollow core. For uncased wells or 3.5-10 inch wells a packer is used. The entire probe and packer assembly has no moving parts, so the probe is durable and rarely needs recalibration.

The probe transmits the flow-induced voltages through a waterproof cable to the electronics package at the surface. A portable

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computer converts the voltage into units of flow and records the raw and processed data. The entire system is compact and easily mounted in a van or truck. For more detail on the system see Young and others (1991).

DATA COLLECTION

The flowmeter is progressively positioned at intervals down the well and vertical flow is recorded while water is being pumped into or out of the well. Changes in vertical flow with depth indicate water entering or leaving the well. Assuming horizontal, unbounded flow to the well, the equations developed by Cooper and Jacob (1946) can be used to calculate an hydraulic conductivity profile (Figure 1).

RESULTS

In most wells tested on the ORR, more than 70 percent of the total discharge is from less than 20 percent of the total screened interval. In the open holes tested to date, most of the flow enters and exits the well at one or two fractures over a several hundred foot interval (Figure 2). Over the same interval conventional logging tools show many more fractures (Figure 3).

Although these data are preliminary and more wells need to be logged, our results to date suggest that the number of fractures in ORR rocks detected by geophysical means and by geologic mapping far exceeds the number of highly permeable conduits; equivalent porous media and stochastic network fracture flow models are likely to work poorly, and every effort must be made to develop the capability to locate and map the few fracture that are hydrogeologically significant in areas of groundwater contamination.

REFERENCES

Cooper, H.H., and C.E. Jacob, 1946, '' A generalized graphical method for evaluating formation constants and summarizing well-field history,'' Trans. Am. Geophys. Union, 217, pp 626-634.

Young, S.C., H.S. Pearson, G.K. Moore, and R.B. Clapp, 1991, ''Demonstration of the electromagnetic borehole flowmeter technique at the Oak Ridge National Laboratory, TVA report WR28-1-900-247.

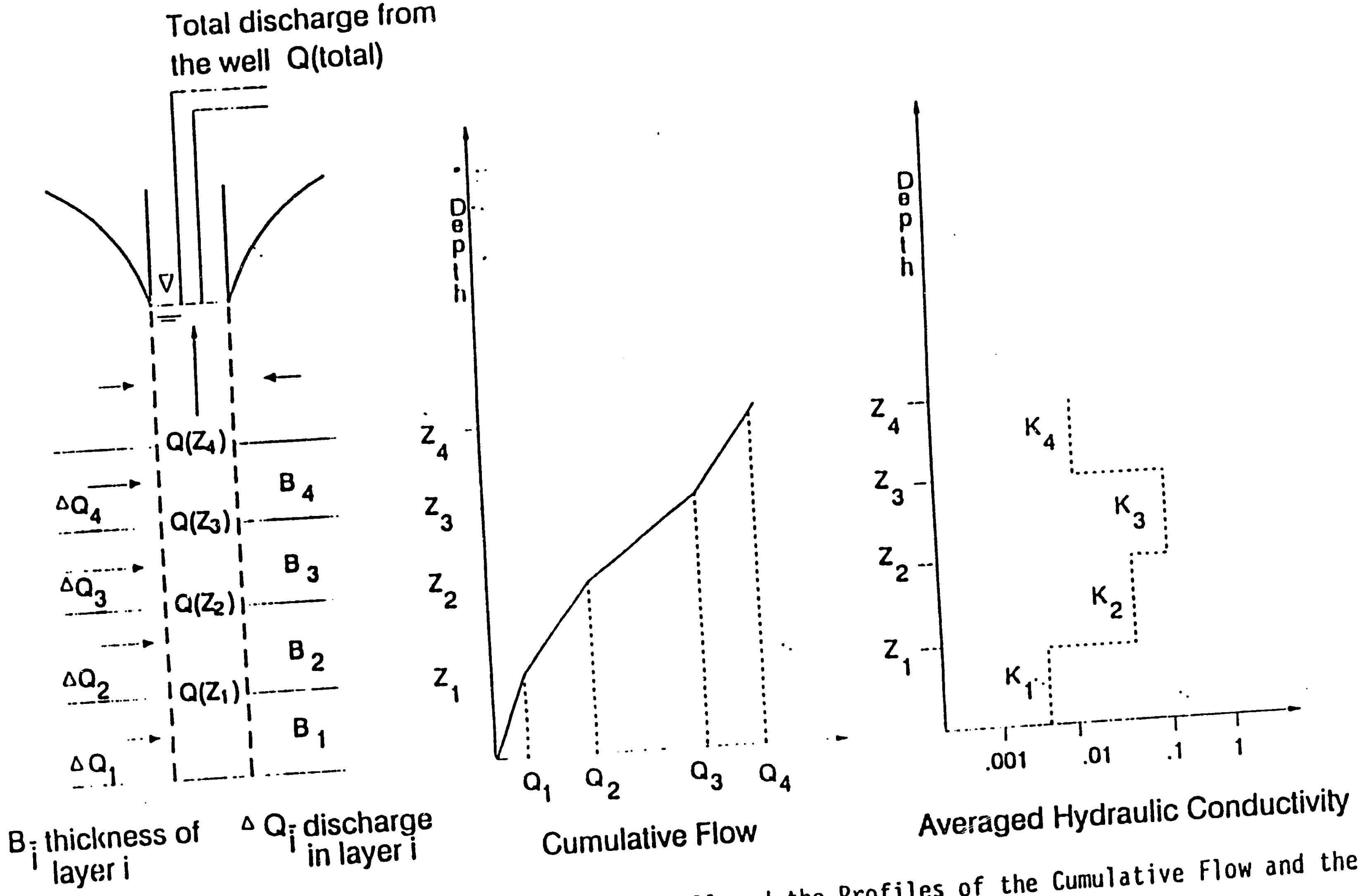
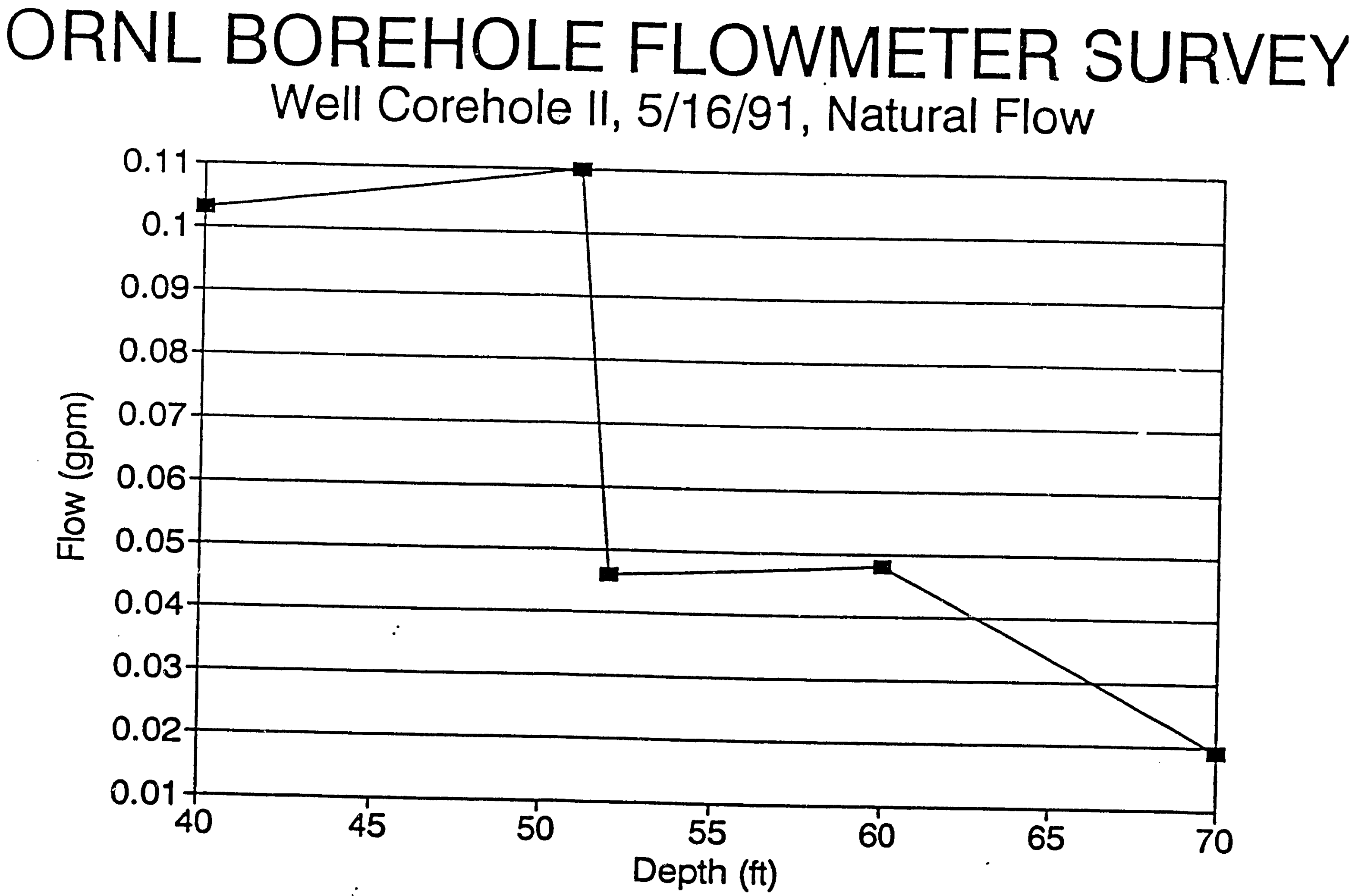


Figure 1. Schematic of Horizontal Flow to a Well and the Profiles of the Cumulative Flow and the Calculated Hydraulic Conductivities.

Figure 2: Borehole flowmeter survey of corehole 2. A single flowing fracture was detected in this survey.



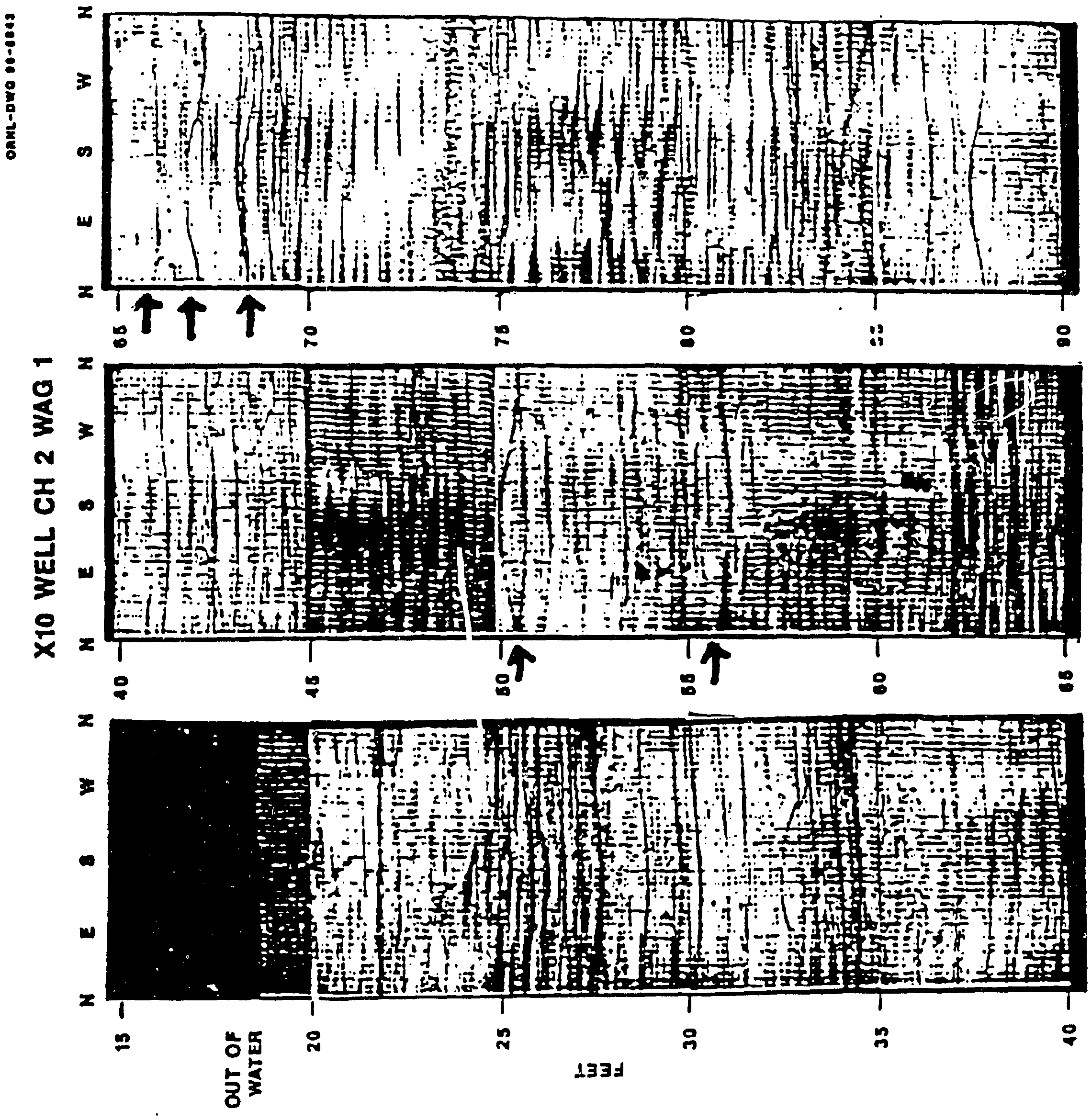


Figure 3: Borehole televiewer log of corehole 2. Sinusoidal patterns are indicative of fractures (arrows).

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