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A NEW METHOD FOR TRACING GROUND WATER FLOW WITH LOW HEAD GRADIENT

By

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Abstract

A method is presented for the determination of the velocity of ground water flow by tracer method without raising the ground weter head at the injection borehole. This method consists in inserting a capsule of gauze containing tracer material to the depth of active permeable layers, which are determined by measuring the advection loss of the concentration of tracer mixed homogeneously in the injection borehole. The merit of this method is distinctive in the case in which both the head gradient and the distance from the injection borehole to the detection borehole are small.

Introduction

An investigation of ground water flow was made by tracer method at Gotanda, Tokyo in August and September 1965. Five boreholes are installed on a half circle line with diameter of 5 m in every 45° angle (Fig. 1). Three

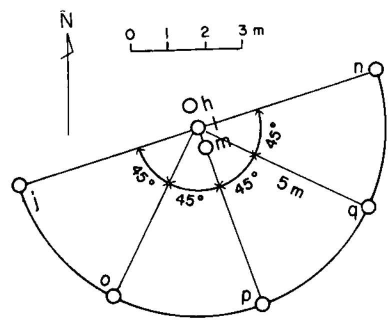

Fig. 1. Location of the boreholes,

boreholes are installed to different depths at the center of the half circle.

It is difficult to determine all of the depth, the direction, and the velocity of ground water flow by one tracing, and the problem was divided into three parts: determination of active permeable layers (the layers in which the flow of ground water exists), direction, and the velocity of the flow in the layer.

The method to find the active layers has been developed by Harada and Abe (1965), who raised the temperature of the water in the borehole by the reaction heat of calcium carbide and water, and measured the decrease of temperature due to the advection effect of the ground water flow. A rapid temperature decrease shows a ground water motion. However, this method was not successful in this case of weak flow, because the heat conduction through the wall was as large as advection. Then table salt was used instead of heat, because the concentration of the salt decreases only by advection.

Determination of the velocity of ground water flow by tracer method is not easy because the increase of ground water level due to the injection of water dissolving tracer material causes the rising of ground water head, consequently, the increase of the velocity of ground water flow near the injection borehole. This effect is significant in the case where the distance between the injection and detection boreholes is short. Then a method for the injection of tracer (table salt or uranine) without the increase of ground water head was devised.

Determination of active permeable layers

A little quantity of table salt dissolved by tap water was poured into the

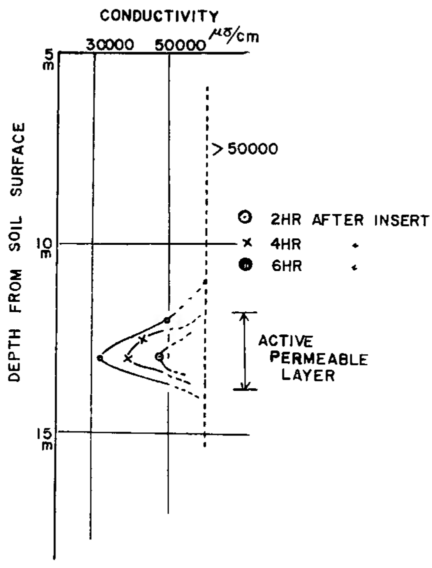

Fig. 2. Sounding of the active permeable layers at the borehole #M. The electrical conductivity at depth less than 12 m and more than 14 m did not drop below 50,000μ℧/cm.

injection borehole, and after stirring, the vertical distribution of electrical conductivity was measured. The result of the measurement is shown in Fig. 2, in which the thin zone from -12 m to -14 m seems to be an active permeable layer.

Determination of the direction of the ground water flow

Determination of the flow direction was done by ordinary tecnique of ground water tracing because the rising of the ground water head around the injection borehole has no influence on the direction of the ground water flow as long as the soil is isotropic. The tracer injected into the borehole #M was detected at the borehole #O and #P.

Determination of the velocity of the ground water flow in the active layers

In order to inject the tracer material without raising the ground water head around the injection borehole, a capsule (50 cm×5 cmϕ) made of gauze containing table salt (500 g) and uranine (20 g) was inserted to the depth of the active permeable layer as shown in Fig. 3. This method has a secondary

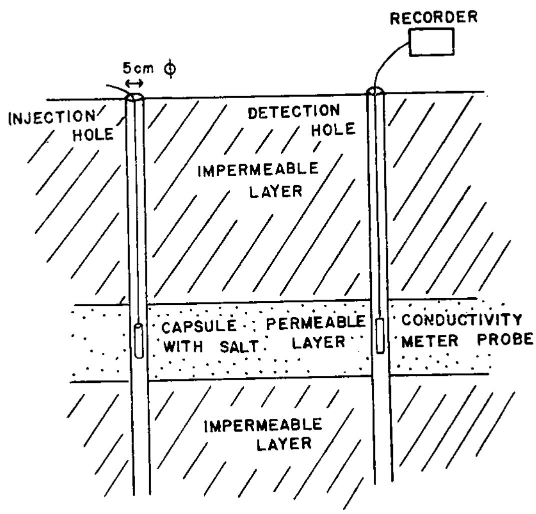

Fig. 3. A vertical profile of the injection and detection boreholes.

effect to keep the concentration of tracer emitted into the active layer at high lavel, because the tracer does not disperse to the whole depths of the injection borehole. When the tracer material in the capsule was entirely dissolved (about 30 min. after insertion), the capsule was renewed. The change of electrical conductivity of the ground water at the detecting points

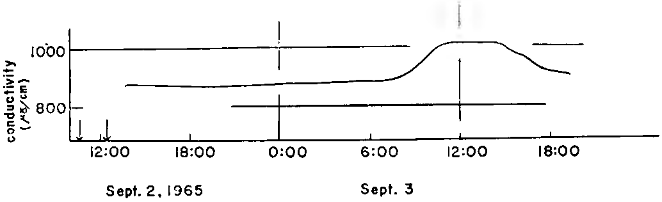

Fig. 4. The time change of electrical conductivity at the depth of 13 m at the borehole #O. Two vertical arrows show the insertion and the renewal of the tracer capsule at the depth of 12.5~13 m at the borehole #M.

in the experiment by this method is shown in Fig. 4, which gives the flow velocity of 0.006 cm/sec.

Discussion

In the preceding articles a method for the determination of the depth, the direction, and the velocity of the ground water flow was presented. Determination of the direction of the flow is easy because it is the same as the ordinary method of ground water tracing. In determining the depth of active layers it is difficult to make a uniform initial distribution of the concentration of tracer in a short time, because the mixing of water in the narrow and long borehole is very weak. Stirring by the up and down motion of the conductivity meter probe was not sufficiently effective, and additional salt water had to be poured to force the salt water to the whole depth. The method using the heating reaction of calcium carbide has a merit that the bubbles made by the reaction of calcium carbide have a strong mixing effect. However, this method has a disadvantage that the temperature decrease is caused not only by advection by the ground water flow, but also by heat conduction which is independent of the ground water flow, so that the existence of the active layers becomes indistinct especially in the weak flow.

The method for determining the velocity of the ground water flow presented in this paper is thought to be effective in the case in which the distance between the injection and detection points is short, and the gradient of the ground water head is small. In the other cases the rising of the ground water head at the injection borehole has no significant effect on the mean velocity of the ground water flow, and this method has no merits in this respect.

Acknowledgements

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References

Harada, Y., and T. Abe, Temperature sounding by ground water heating, Civil Engineering Technical Data, vol. 7, No. 2, 1965.