A semi-automatic level-accurate groundwater sampler

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Large resources are spent in the chemical analysis of groundwater quality. Therefore, great care should be taken to make accurate sampling. Many types of sampling equipment based on pumpage between packers are available. However, fissured rock or gravel pack outside the screen may result in inflow of water from a different level than the packed level. However, this paper describes a groundwater sampler of the packer type which will sample groundwater from a usually screened interval of a well, guaranteeing level representativity.

The sampling procedure involves pumping from separated intervals above and bolow the sampled interval. The pumpage produces a simultaneous flow of water to an inflatable sampling vessel, installed within and totally separated from the flow through the pumping system. As distinct from earlier groundwater samplers of the packer type the described sampler is able to sample level-accurate groundwater from a usually screened well or open borehole penetrating an aquifer.

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During several projects within the field of hydrogeology, accurate sampling of groundwater from a given level is important, i.e. location of pollution, dating of groundwater, hydrochemical studies, saltwater intrusion etc. Most of the existing samplers do not insure sufficiently accurate sampling of the formation water in boreholes or screened wells, not even by the use of packers. Leakage between the packers and the borehole wall or screen often leads to a mixing of the sample with borehole water or water from other levels than the packed level.

Therefore, in 1976 the Hydrogeological Division at the Geological Survey of Denmark started to develop groundwater sampling equipment in order to

* After delivering of the manuscript the author was by personal communication from *Lucien Bertrand* informed about the existence of a Triple-Zone-Packer Prope developed by *BRGM Orléans* and patented by *C. Louis* in 1969. The prope was designed for determination of permeability normal to a borehole in fissured rocks. Elimination of permeability parallel to the borehole axis was established by injection of water at the same pressure through the three packed intervals.

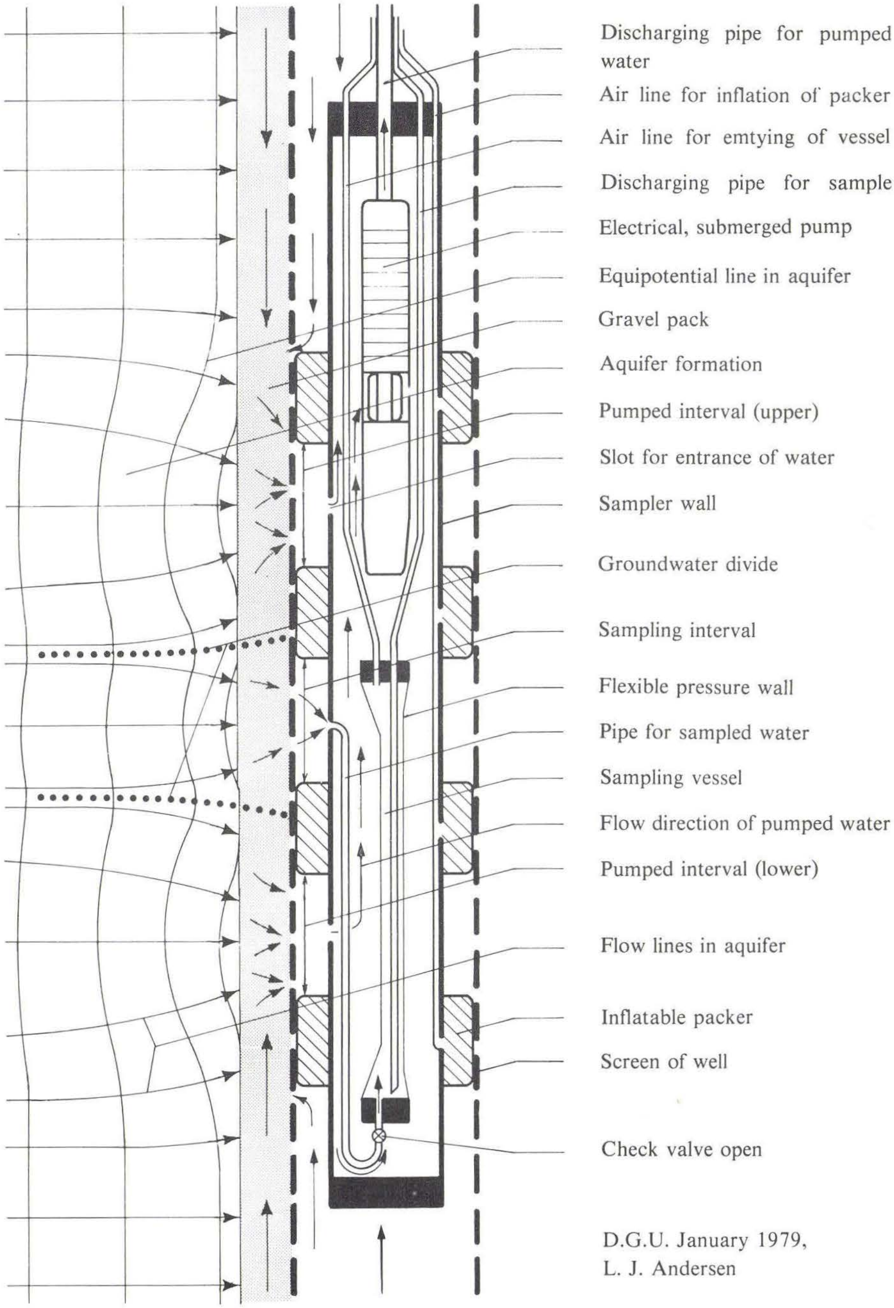

Fig. 1. Sampling equipment and schematic flow distribution during sampling.

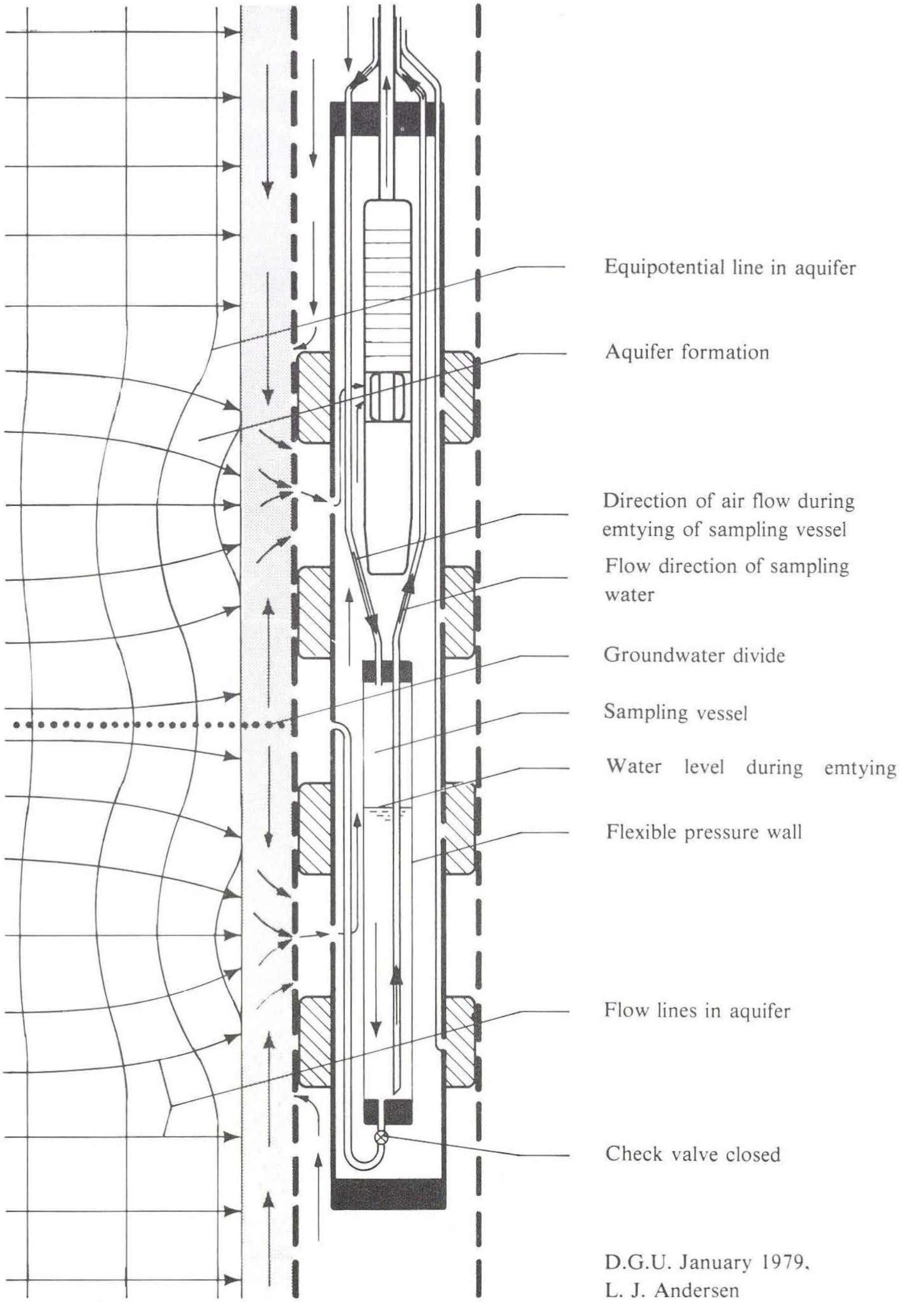

Fig. 2. Sampling equipment and schematic flow distribution during discharging of sample

improve the groundwater sampling technique. This publication mentions some fundamental conditions of accurate sampling of groundwater from a screened or open section of a well penetrating af waterbearing formation, and furthermore it describes sampling equipment for the establishment of these conditions as well as the mode of operation of the sampler.

Flow conditions in the aquifer outside the sampler

Conventional samplers take the water sample through pumping or suction from an interval separated from the rest of the well by packers. This way of sampling produces a converging groundwater flow within the sampling interval of the aquifer. Leakage around packers means inflow of water from the space outside the sampling interval, i.e. erroneous sample.

The sampler described below is based on the principle that a water sample taken from the central part of a diverging groundwater flow should possess good representativity of the water as the diverging conditions prevent lateral influx of water by continuous sampling. Therefore, the problem was to design and construct sampling equipment which will produce a diverging groundwater flow in the level of the sampling interval. Furthermore, the sampling rate was to be low enough to prevent a fundamental change in the flow conditions.

Description of the sampler

The sampler, shown in fig. 1, consists of a cylinder outside which 4 inflatable packers have been placed. Two of the intervals between the packers are pumping intervals, and the third one in the middle is the sampling interval. Inside the sampler a submerged pump and an inflatable pressure vessel for collection of the sampled water have been placed.

The sampler should have slots over the two pumped intervals for inflow and an aperture in the top for the discharging of pumped water. A tube containing a check valve connects the sampling interval with the sampling vessel.

A tube from the bottom of the vessel allows the sampled water to be discharged to the ground surface when commpressed air is added through an airline connected to the top of the sampling vessel.

Operation of the sampler

The sampler is lowered into the well and placed at the depth at which a groundwater sample is required. The packers are inflated and the pump started. The pumping creates a hydraulic gradient from the formation outside the sampling interval upwards and downwards to the inside of the sampler. As the water in the sampling vessel, because of its inflatability, has the same hydraulic head as that of the water passing the sampler, water from the sampling interval will flow into the vessel and fill it. Compressed air (or nitrogen) is added through the airline, and the vessel is emptied through the pipe leading to the ground surface. After that the pressure in the sampling vessel is released, and water will again flow into the vessel. The procedure is repeated until sufficient water has been taken from the sampled interval to flush out the borehole water confined between the packers due to their being inflated.

In fig. 1. the flow systems around and inside the sampler are illustrated schematically during the filling of the collecting vessel. In this case groundwater divides are surrounding the sampling interval upwards and downwards against the two pumped intervals. These conditions prevent water from other levels from flowing to the sampling vessel.

From fig. 2. the flow systems during the emptying of the vessel appear. In this case there is no flow of water to the sampling vessel, and a groundwater divide is established in the middle of the sampling interval, i.e. no flow of groundwater into the sampling interval.

Field tests of prototype

The sampler has been designed as a prototype. All parts in contact with the sampled water are made of PVC or rubber. As the pumped water is totally separated from the sampled water, the pump system and the pipe system are selected independently. The pump is an electrically driven submerged water well pump.

The prototype of the sampler has been designed for 6 in. screens. The sampler has been tested and used for sampling of groundwater from water wells at depths down to 50 m and a water level more than 10 m below surface. The sampler operates without any problems, and it has been checked that the water sample is accurately sampled due to the fact that it has been possible to localize a boundary between groundwater with and without nitrate based on water sampled with the sampler. The sampling time depends on the hydraulic conductivity of the waterbearing formation. In a normal waterbearing formation it takes only a few minutes to sample 4 litres of water. Until the first emptying stage has been finished, it is not possible to know whether the sampling vessel is full or not. By measuring the volume of the discharged sample, it is possible to determine whether the vessel has been full or not. If not, the sampling time has to be prolonged before emptying. However, the degree to which the vessel is full does not affect the quality of the sample.

When sampling is finished, the pressure in the collecting vessel increases to that of the groundwater of the sampling interval. By measuring the head inside the vessel the sampling time may be determined. By placing the upper orifice of the discharging pipe below the water table in an open vessel at the surface, it should be possible to observe when the pressure inside the pipe increases as a few bubbles of air will appear at the surface at increasing pressure. The orifice of the pipe should be lowered only one centimeter or so below the water table. If it is lowered too deep, no air will appear.

Bacteriological sampling

Finally, it should be mentioned that for desinfection of the sampling interval the sampler has been supplied with an electric heating element in the sampling interval for sampling of groundwater for bacteriological analysis.

Discussion of the sampler

The sampler will sample level-accurate groundwater samples from aribitrary levels of a screened interval in a normal water well.

If the sampling interval consists of impermeable rock, no water will be sampled, except in cases where gravel pack outside the screen connects the sampling interval with a waterbearing formation above or below the sampling interval. However, in such cases the collection of a sample will take more time as the driving force, the head difference between the groundwater of the sampling interval and the pumped water inside the sampler, will be low, and furthermore the pumping capacity will decrease. In such cases, the representativity of the sample may be bad as it may derive from levels above or below the sampling interval. In cases where the pumping produced divides around the sampling interval may deviate from a symmetrical arrangement normal to the well axis and slope in direction of the layer with the highest hydraulic conductivity.

A leakage around one or more of the packers will result in an increase of flow in the direction of the pump and a decrease of flow to the sampling vessel but never in an influx of water from outside the sampling interval. The head distribution prevents this.

As illustrated in figures 1 and 2, the pumpage results in a slight discharge of water from the whole screened part of the well, and only just above the upper and lower packers the directions of the flow will be from the well into the gravel pack or formation. However, this part of the flow will pass through the pumping system owing to the presence of the hydraulic boundaries, the groundwater divides, around the sampling interval.

Sampling equipment, by means of which it should be possible to take samples in wells of different diameters, is being developed at the Hydrogeological Division at the Geological Survey.

Acknowledgements. For valuable assistance during design, construction, and testing of the sampler I would like to thank the staff of the Hydrogeological Division, especially *Bjarne Madsen, Erik Clausen* and *Torben Jensen*, who has also made the drawings.

Dansk sammendrag

I nærværende artikel er beskrevet en grundvandsprøvetager af pakningstypen til udtagning af grundvandsprøver i filtersatte eller åbne vandboringer. Den består af et rør, på hvilket der er monteret 4 oppustelige pakninger, som adskiller 2 pumpeintervaller fra et prøvetagningsinterval beliggende mellem disse.

Inden i prøvetageren er der anbragt en dykpumpe, som pumper vand fra de to ydre afspærrede filterintervaller. Desuden indeholder prøvetageren en sammenklappelig prøvebeholder, som er placeret i pumpevandets strømsystem. Da prøvebeholderen er sammenklappelig, vil der herske samme tryk indvendig i den, som i pumpevandet. En slange indeholdende en contraventil, som kun tillader indstrømning af vand, forbinder prøvebeholderen med prøvetagningsintervallet. Så snart prøvetageren er anbragt, pakningerne er oppumpede og pumpningen på det øvre og nedre, afspærrede filterinterval påbegyndes, strømmer vand fra prøveintervallet ind i prøvebeholderen.

Pumpningen medfører, at der dannes grundvandsskel over og under prøvetagningsintervallet. Den udtagne vandprøve fra dette interval kan derfor ikke være forurenet med vand uden for dette. Prøvebeholderen tømmes ved tilførsel af trykluft eller kvælstof. Efter trykudligning i prøvebeholderen strømmer der atter vand fra prøvetagningsintervallet. Proceduren gentages, indtil vandet, der befandt sig i borehullet før prøvetageren anbragtes, er udvasket, hvorefter en repræsentativ grundvandsprøve kan udtages.

Prøvetagerens opbygning og strømningsforholdene i og uden for prøvetageren under fyldning og tømning fremgår af fig. 1 og 2.

References

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