A simple deep monitoring well dilution technique

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Introduction

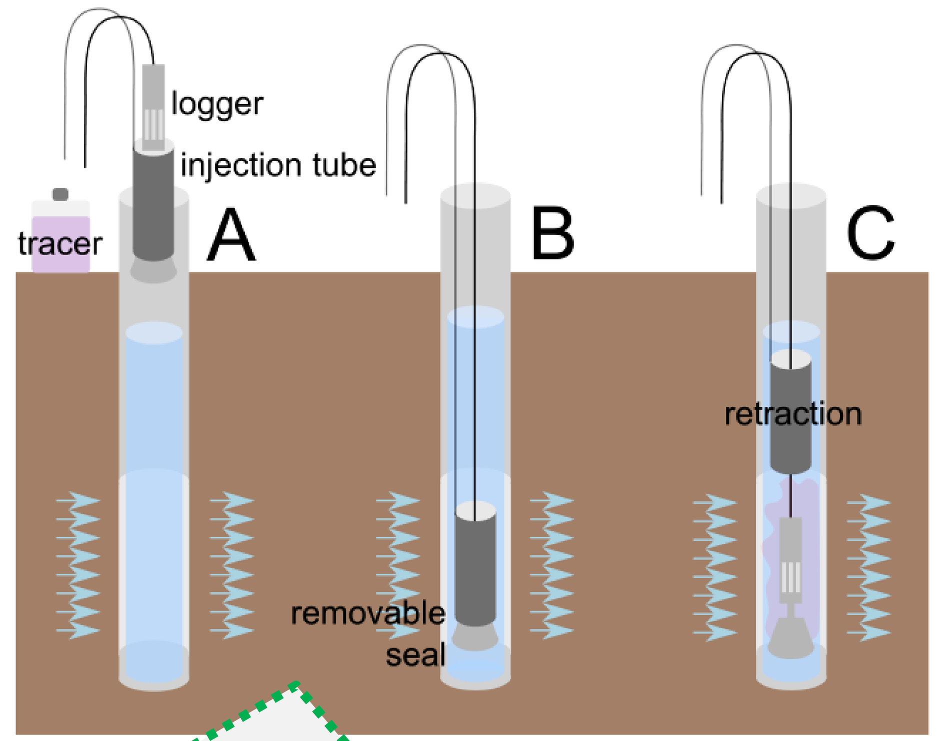
Well dilution techniques are one of the basic techniques to quantify groundwater fluxes. A typical well dilution test consists of

- the injection of a tracer,
- a mixing mechanism (e.g. water circulation with a pump) to achieve a homogeneous concentration distribution within the well, and
- monitoring of the evolution of tracer concentration with time.

An apparent specific discharge can be obtained from such a test, and when details on the well construction are known, it can be converted into a specific discharge representative of the undisturbed aquifer. For deep wells however, the injection of tracer becomes less practical and the use of pumps for circulating and mixing the water becomes problematic. This is due to

- the limited pressure that common pumps can endure at the outlet, as well as
- the large volume of water that makes it difficult to achieve a homogeneous concentration, and
- the impracticalities of getting a lot of equipment to large depths in very small monitoring wells.

Injection and monitoring of tracer at a specific depth omits several of the problems with deep wells. We present and test here a very simple device that can be used to perform a dilution test at a specific depth in deep wells.



Test overview

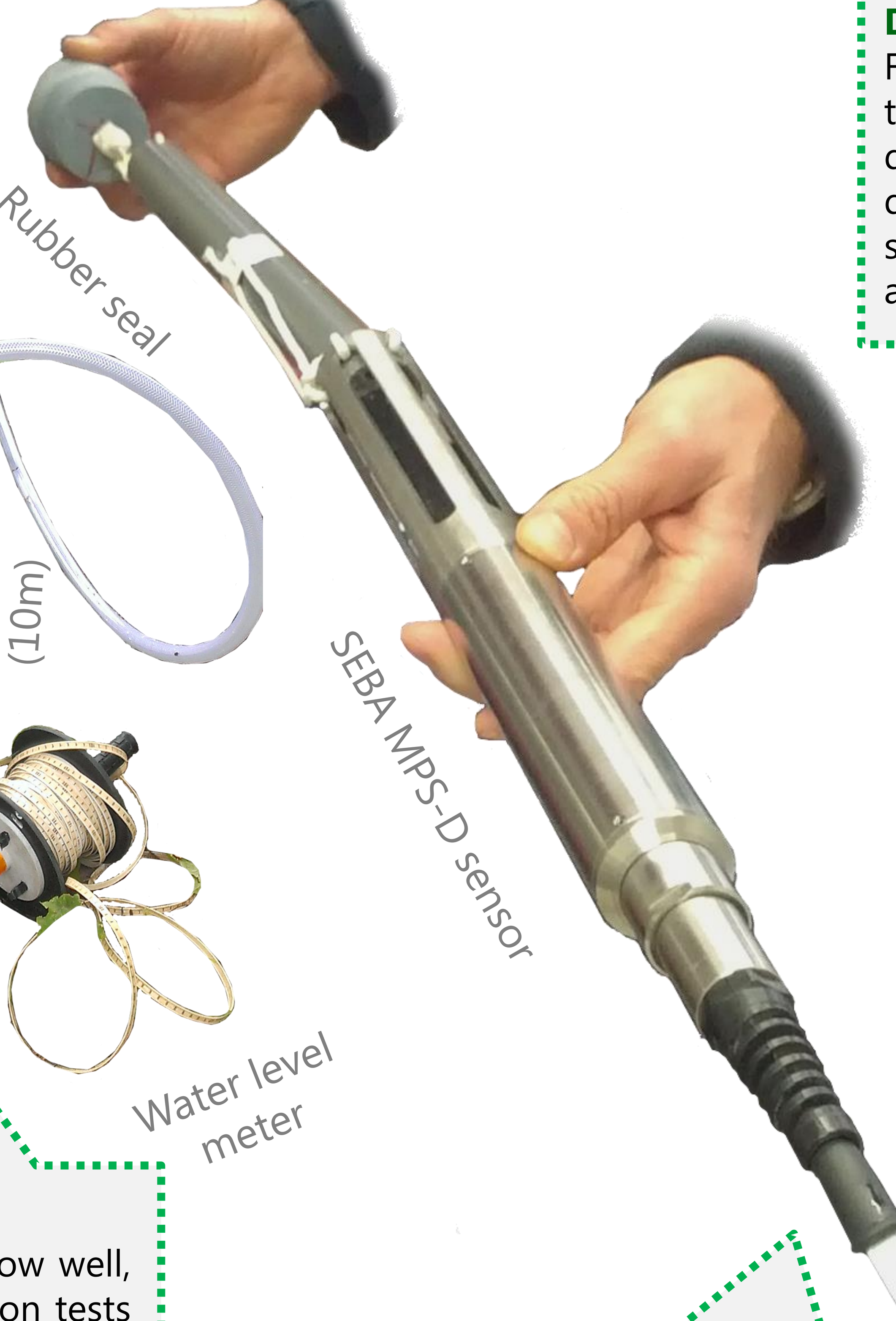
Once at the target depth, the PVC tube is retracted and detaches from the rubber seal. The EC sensor and tracer then become subject to groundwater flow.

Shallow well dilution tests

The device was tested on a shallow well, on which different types of dilution tests (classic test with pump circulation, dilution profiling, and discrete-depth tests; see *e.g.* Drost *et al.* 1968) were performed. The results of the other tests agree well with the injection device results.

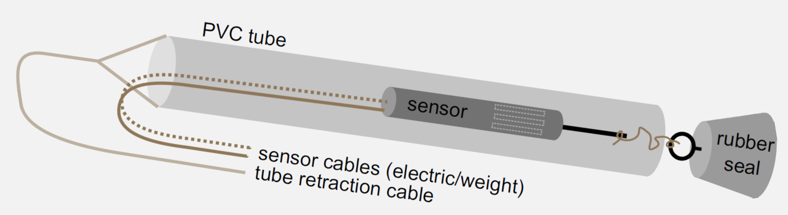
Demineralized water as a tracer

Filling the sealed tube with demineralized water, which we use as a tracer. The EC sensor integrated in the injection device was used to monitor the dilution of the demineralized water after retraction of the PVC tube.



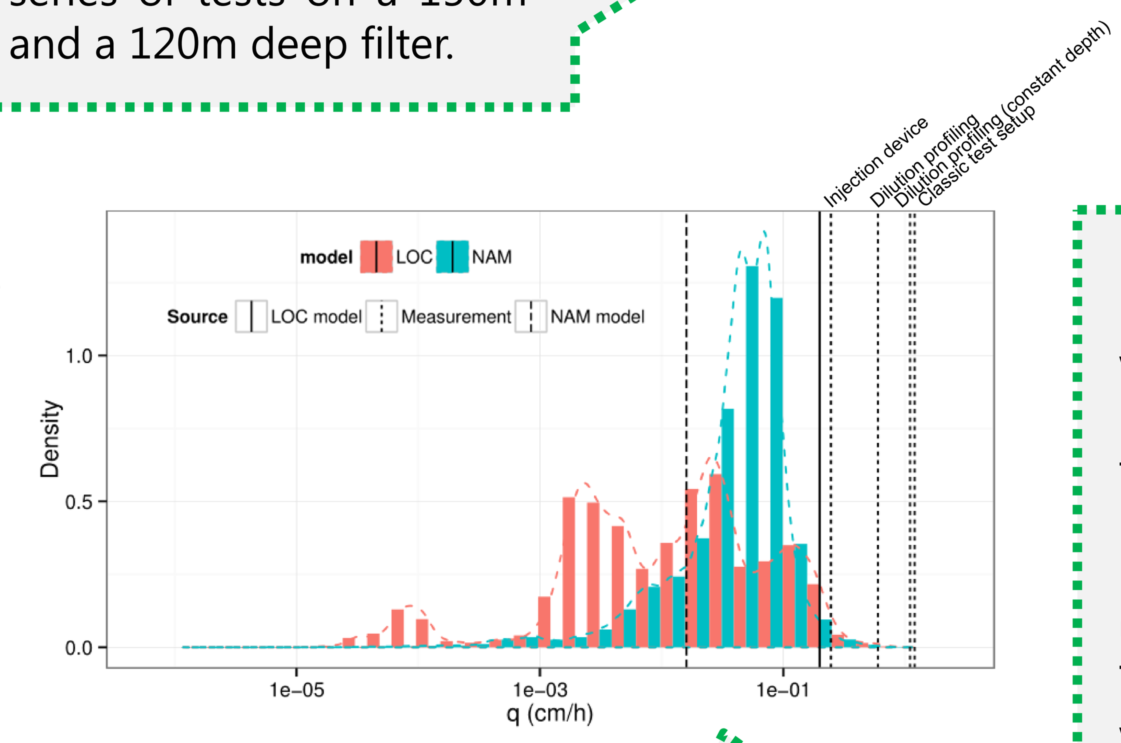
Injection device

consists of a PVC tube with a detachable rubber seal at its bottom. To minimize disturbance of the water column in the well, we integrated an EC sensor in this injection device. In theory, the designed setup can reach depths of 600 m.



Deep well dilution tests

Feasibility of performing the test with the injection device on deep wells was demonstrated with a series of tests on a 150m and a 120m deep filter.

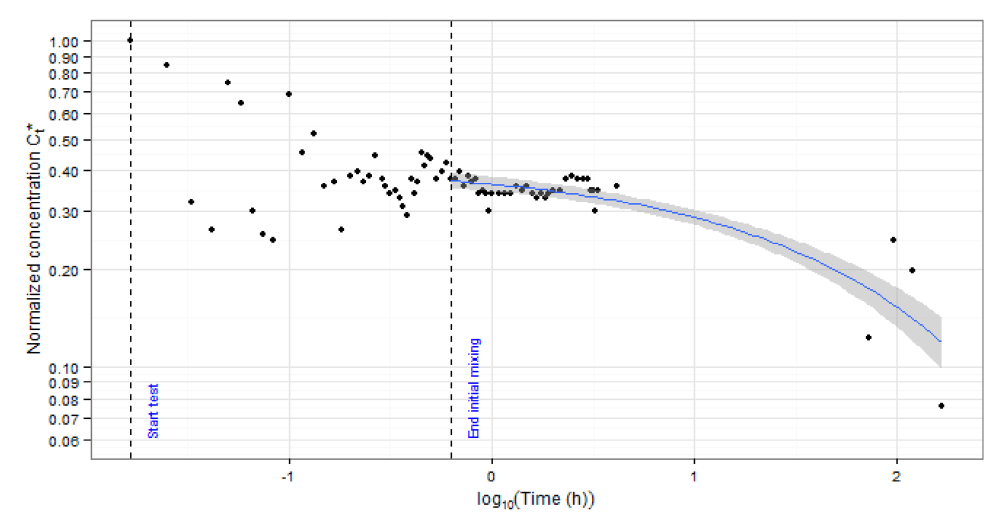


Shallow well results

Darcy flux distributions of two groundwater flow models (Gedeon 2008, Gedeon *et al.* 2011), and the predicted and measured values (with a flow distortion factor of 4.5) for the shallow test well. The apparent specific discharges are in the order of ~1-5 cm/h.

Deep well results

Example normalized concentration dilution curve, with the sensor at 123m below surface. Given the low groundwater flow in the deeper aquifer layers, the initial mixing of injected and well water takes longer than with the shallow well. Moreover, longer monitoring timescales are needed to come up with more reliable results.
The dilution obtained after approximately one week results in an apparent specific discharge of ~0.06 cm/h, whereas the LOC and NAM models predict 0.01 and 0.03 cm/h.



Conclusion

These exploratory tests indicate clearly that single well dilution tests can be used on shallow and deep wells to estimate groundwater fluxes. Given the current results however, we need further investigations at longer timescales on the deep wells, and more comparisons with a classic dilution test setup to quantify the uncertainty related to this method. For more details, see Rogiers *et al.* (2015).

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