Fresh keeper without reverse osmosis: can we prevent upconing by pumping brackish water to a deeper aquifer?

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ABSTRACT

At the former well field of Noardburgum in the Northern part of the Netherlands, a new pilot is started with a Fresh keeper well. Three well screens are placed in a single borehole: a fresh water extraction, a brackish water extraction, and injection of the brackish water. The fresh extraction will be pumping at a constant rate, while the combined brackish extraction and injection will adjusted to keep the fresh/brackish interface stable in between the two extraction well screens.

INTRODUCTION

Noardburgum is a village in the Northern Part of the Netherlands (see Figure 1). The well field of Noardburgum had been abandoned in 1993 due to salinization by upconing of deep brackish paleo groundwater. The water supply company Vitens wants to re-open the well field using Fresh keeper wells to obtain a stable extraction of fresh water.

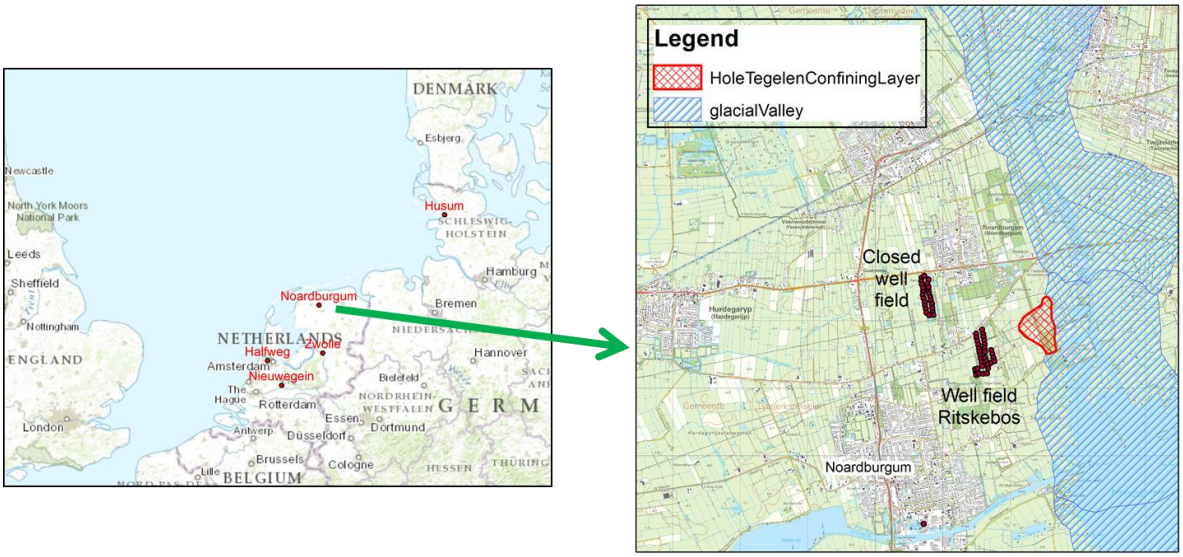

Figure 1. Location of Noardburgum and important geological features.

The philosophy of Fresh keeper wells is to prevent salinization of extraction wells by pumping also in the saline water. This reduces the head in saline water and prevents it from flowing toward the fresh extraction. A question to answer is what to do with the extracted saline water. Usually, discharge into surface water is not feasible. An option is to use reverse osmosis and use part of the water, but then the question becomes what to do with the

concentrate. In several pilots this has been injected deeper into the subsurface (Raat & Kooiman, 2012).
A first pilot with a Fresh keeper well has been operated at the former Noardburgum well field between 2009 and 2011 (Oosterhof & Raat, 2010, Raat et al., 2012, Oosterhof et al., 2013). The water from the saline extraction was treated with reverse osmosis (BWRO – Brackish Water Reverse Osmosis) so that part could be used as drinking water and the concentrate was injected below a regional aquitard. For full scale operation, reverse osmosis would require a large investment in the installation and relatively high energy costs for operation. Therefore, Vitens has started a new pilot in which all abstracted saline water is injected in a deeper aquifer to investigate whether this would be a better option for revitalizing the well field. Moreover, several aspects of the technical implementation of monitoring and operation of the Fresh keeper are developed and tested.

HYDROGEOLOGICAL SITUATION AND WELL SETUP

Noardburgum is located in an area with a lot of controlled surface water (see figure 1). The surface waters are separated from the aquifer system by a Holocene confining layer. To the East, a deep glacial valley is present in the subsurface, which is filled with tight clays.
The aquifer system at Noardburgum consists of two main aquifers separated by a clay layer belonging to the Tegelen Formation (see Figure 2). The upper aquifer consists of two parts (1A and 1B) which are not separated by a resistance layer like the two parts of the lower aquifer (2). The properties of this resistance layer are not well known because only a few bore holes have been drilled to this depth. The inversions in the Chloride concentration indicate that this layer has a significant resistance and presence. The regional presence of the Tegelen clay is better documented, including a hole near the glacial valley (see Figure 1).

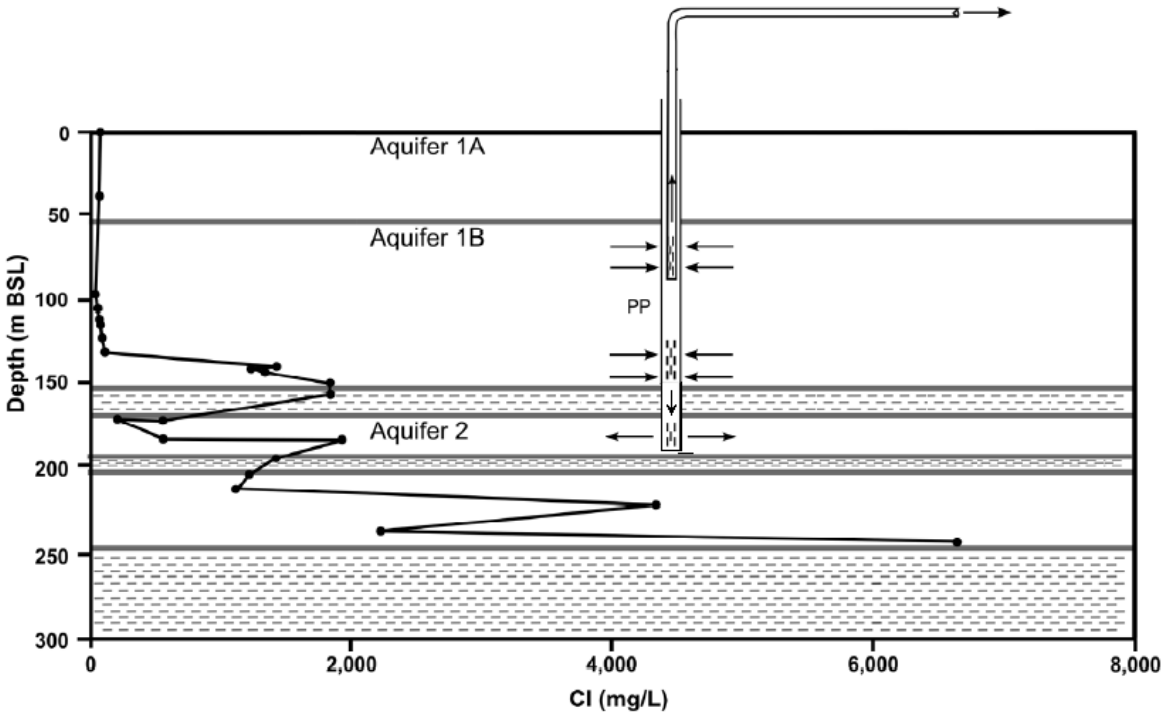

Figure 2. Hydrogeology at Noardburgum.

The fresh keeper well has three well screens in a single borehole (see Figure 2). Moreover, several monitoring wells will be installed of which one is wide enough for an EM-39 probe. The upper well screen is located above the fresh-brackish interface. The middle well screen is located near the base of Aquifer 1B below this interface. All water abstracted from the middle well screen will be injected into aquifer 2 through the lower well screen underneath the Tegelen confining layer.

MODELLING

An existing groundwater flow and transport model (Royal Haskoning, 2007) has been updated and refined to determine the effects of the new Freshkeeper at Noardburgum. The model can also be used to interpret the monitoring results. The upward flow through the hole in the Tegelen confining layer is the most sensitive aspect toward the existing well field of Ritskebos (see Figure 3).

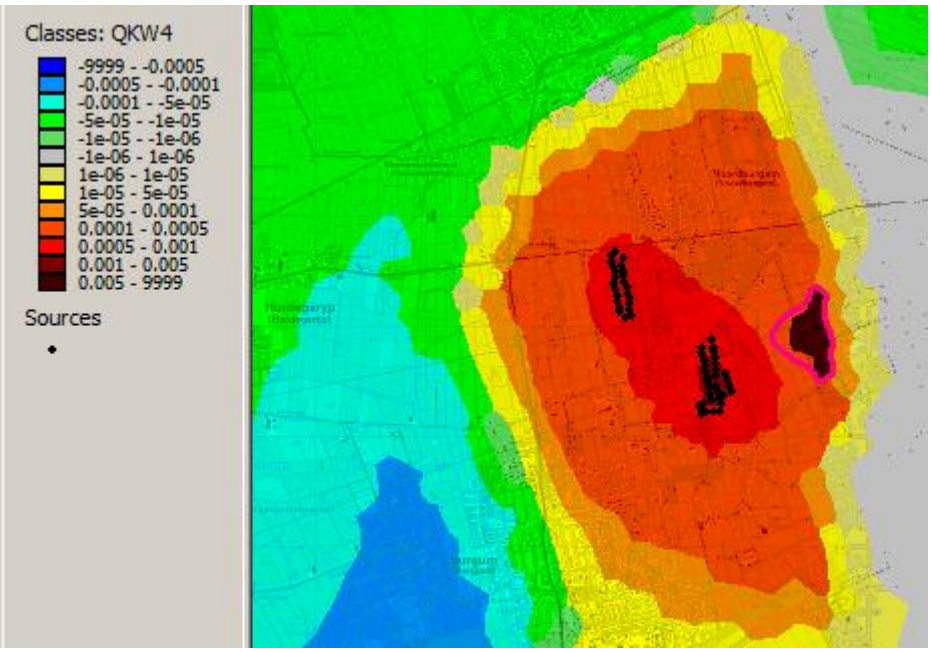

Figure 3. Flux from injection aquifer (2) to pumped (1B) through Tegelen clay.

DISCUSSION

The fresh abstraction will have a constant rate for the production of drinking water. The brackish abstraction will vary. The aim is to pumped at the minimum rate required to prevent upconing of brackish water toward the upper well screen. The brackish discharge will be adjusted automatically based on the signal from an electric conductivity sensor. The sensor will be placed in a monitoring well outside the well screen near its top. The brackish pumping rate will be decreased, when the electric conductivity (Ec) declines and increased when the Ec goes up. The control values will be established based on the values encountered during the installation of the well and will be adjusted when necessary based on the monitoring information.

CONCLUDING REMARKS

The new aspects of the Freshkeeper well to test in this pilot at Noardburgum are 1) three well screens with separate standpipes in a single borehole 2) monitoring the fresh/brackish interface between two extraction well screens 3) automatic control of the brackish extraction/injection to stabilize the interface, and 4) injection of the full amount of the brackish extraction instead of reducing its volume (and increasing the concentrations) by applying reverse osmosis.

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