Development of an Unsaturated Region Below a Perennial River

Grace W. Su, James Jasperse[1], Donald Seymour[1], and Jim Constantz[2]
[1]Sonoma County Water Agency, Santa Rosa, CA, 95406; [2]U.S. Geological Survey, Menlo Park, CA, 94025
Contact: Grace Su; 510/495-2338; gwsu@lbl.gov

RESEARCH OBJECTIVES

Field observations along the Russian River in Sonoma County, California, indicate that an unsaturated region exists below the streambed near two adjacent collector wells located along the riverbank. Understanding the conditions that give rise to unsaturated flow below the streambed is critical for improving and optimizing riverbank well-pumping operations. A three-dimensional model was developed using TOUGH2 to investigate the conditions under which an unsaturated region develops below a perennial river when the collector wells were pumping.

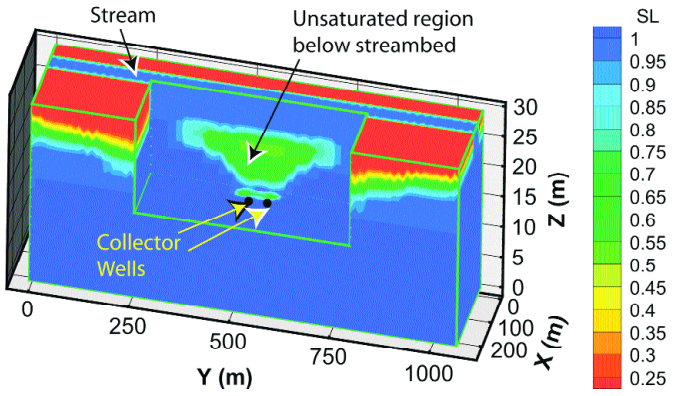

Figure 1. Simulated water saturation (SL) below the streambed after the two collector wells had pumped continuously for seven days at 1,600 m^3/hr. The aquifer permeability is 2.4×10^{-10} m^2 and the streambed permeability is 7.4×10^{-13} m^2.

APPROACH

The numerical model was based on the region near two collector wells in the Russian River Bank Filtration Facility. These wells consist of nine perforated pipes that are projected horizontally into the aquifer at a depth of approximately 20 m below the land surface. A grid was developed that was highly refined near the wells, so that the individual pipes could be represented. The two collector wells each pumped continuously at a rate of 1,600 m^3/hr.

ACCOMPLISHMENTS

The aquifer below the streambed remained saturated when the aquifer and streambed permeability were the same (both 2.4×10^{-10} m^2), and when the streambed permeability was one order of magnitude smaller than the aquifer permeability. When the streambed permeability was 2.4×10^{-12} m^2, which was two orders of magnitude smaller than the aquifer permeability, an unsaturated region developed below the streambed that was approximately 25 m wide, 130 m long, and 3 m deep. When the streambed permeability was 7.4×10^{-13} m^2, which was 2.5 orders of magnitude less than the aquifer permeability, a large unsaturated region formed below the river that extended across the entire river width (60 m), was over 350 m long, and up to 10 m deep. Under these conditions, the simulated unsaturated region that developed near the streambed after seven days of continuous pumping is shown in Figure 1.

SIGNIFICANCE OF FINDINGS

As the permeability of the streambed decreased relative to the aquifer permeability, the extent of the unsaturated region below the streambed increased. The results of the numerical simulations have important implications for well operation. During the summer and fall months, when the inflatable dam is raised at the Russian River Bank Filtration Facility and the streambed permeability decreases over time, well operation may have to be altered if the permeability decreases to a value such that a large unsaturated region forms below the streambed.

RELATED PUBLICATION

Su, G.W., J. Jasperse, D. Seymour, and J. Constantz, Estimation of hydraulic conductivity in an alluvial system using temperatures. Ground Water, 42(6), 890–901, 2004. Berkeley Lab Report LBNL-53167.

ACKNOWLEDGEMENTS

This work was supported by the Sonoma County Water Agency (SCWA), through U.S. Department of Energy Contract No. DE-AC03-76SF00098.