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Estimation of stream depletion using values of capacitance

Mikhail Baldenkov and Elena Filimonova
Lomonosov Moscow State Universary, Russian Federation (Dveac@yandex.ru)

Compensation pumping is used to alleviate deficiencies in streamflow discharge during dry seasons. Short-term groundwater pumping can use aquifer storage instead of catchment-zone water until the drawdown reaches the edge of the stream.

Stream-aquifer interactions are the key component of the hydrologic budgets and estimation of stream depletion has top-priority when evaluating the effectiveness of application of seasonal compensation pumping. Numerous analytical equations have been developed to assess the influence of groundwater pumping on nearby streams (C.V. Theis, R.E. Glover, C.G. Balmer, M.S. Hantush, C.T. Jenkins, B. Hunt, J. Bredehoeft, V.A. Zlotnik, E.L. Minkin, N.N. Lapshin, F.M. Bochever and other researchers). R.B. Wallace and Y. Darama obtained solution for cyclic conditions groundwater pumping. Numerical model approaches used in difficult hydrogeological conditions.

It is offered to estimate stream depletion by seasonal pumping using values of capacitance (complex, dimensionless parameter of an aquifer system that defines the delayed effect on steamflow when there is groundwater pumping). Capacitance (C) is determined by the following equation:

$$C = f\left(\frac{L^*}{\sqrt{\frac{T}{S}\Delta t}}\right),$$

where S and T are the aquifer specific yield (or storage coefficient for a confined aquifer) and transmissivity, respectively; Δt is the pumping time inside one cycle, L^* is the summarizing distance between the compensation well and stream edge; in some cases it can involve a function of the stream leakance and vertical leakance of the impermeable layer.

Three typical hydraulic cases of compensation pumping were classified depending on their capacitance structure (i.e. the relationship between surface water and groundwater): (a) perfect hydraulic connection between the stream and aquifer; (b) imperfect hydraulic connection between the stream and aquifer; and (c) essentially imperfect hydraulic connection between the stream and the underlying confined aquifer.

The form of capacitance was obtained for all three cases and is a function of aquifer hydraulic characteristics, pumping time and distance between the well and stream edge. The distance in the first and the second cases is the sum of the shortest distance between stream edge and the well and the stream leakance; in case; and in the third case, it is the sum of real distance, stream leakance and vertical leakance through the impermeable layer.

A regression test between unit stream depletion (i.e. the ratio of stream reduction to pumping rate

stream depletion and capacitance was performed, and power dependences were obtained in the form of $\overline{Y} = a + bC^{-0.5}$

The drained storage cannot be absolutely recovered by natural processes that cause 'residual' stream depletion (RSD) even in condition of perfect hydraulic connection between the stream and aquifer. The impact of various hydraulic characteristics and engineering factors on RSD was examined by numerical modeling.

It was realized lack of correlation between capacitance and RSD, but exponential dependences between capacitance and the annual amplitudes of stream depletion (A) were obtained in the form of:

$$A = 0.95\exp(-0.776C)$$

Although this approach cannot assess stream-aquifer interactions to the same degree of accuracy as analytical equations of detail as a numerical model, it can provide forecast estimation with the level of primary available data.