A Multi-Objective Optimization formulation for transient flow restriction in Wellhead Protection

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Groundwater is typically obtained via drinking water wells. To ensure safety and sustainable supply conditions, most groundwater protection programs restrict land use within the zone of groundwater abstraction that have the potential to contaminate the groundwater. The delineation of such wellhead protection areas (WHPAs) is commonly based on the use of groundwater models under the assumption of steady-state flow conditions. Despite this assumption transient groundwater flow can exert significant variation on the actually required WHPA outline. For example, during consecutive periods of warm and rainy seasons, pumping wells might increase and decrease their water abstraction, respectively. This, combined with changes in the mean ambient groundwater flow caused by same dynamic weather environment (e.g., changes in the regional flow direction or the regional hydraulic gradient) might trigger a variation over time of the water abstraction zone of the well. This can lead to a risk scenario, where locations with dangerous land use conditions (e.g., gas stations or agricultural lands) might be actually included within the abstraction zone, during particular time intervals.

The goal of this study is to present a novel pumping-injection management scheme that reduces the influence of transient flow conditions on the actual abstraction zone, so that abstraction remains within the delineated WHPA. Thus, steady-state WHPAs together with old schemes can represent a robust solution against dynamic environments. To formulate our management approach, we use multi-objective optimization (MOO) concepts, searching for compromise solutions that consider at least three objectives: 1) to minimize the risk of pumping water from outside of a given WHPA, 2) to maximize groundwater supply and 3) to minimize involved costs. Additionally, given the high computational cost attributed to dynamic MOO solutions, we explore and analyze a suboptimal alternative where the computed set of non-dominant solutions remain constant for longer time periods. This, provides a more stable well management operation, while skipping many time steps in the optimization.

With the presented framework, we aim to provide to decision makers well operation alternatives that reduce the impact of transiency while considering additional management issues in well catchment protection.

Keywords: Wellhead Protection Area, Transient groundwater analysis, Multiobjective Optimization

