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Improved Sharp Interface Models in Coastal Aquifers of Finite Dimensions

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Coastal aquifer management often involves aquifers of finite dimensions where optimal pumping rates must be calculated through a combined simulation-optimization procedure. Variable-density numerical models are considered more exact than sharp interface models as they better describe the governing flow and transport equations. However, such models are not always preferable in pumping optimization studies, due to their complexity and computational burden. On the other hand, sharp interface models are approximate and can lead to large errors if they are not applied properly, particularly when model boundaries are not treated correctly.

The present paper proposes improved sharp interface models considering aquifer boundaries in a proper way. Two sharp interface models are investigated based on the single potential formulation and the Ghyben-Herzberg relation. The first model (Strack, 1976) is based on the assumption of a semi-infinite aquifer with a sea-boundary only. The second model (Mantoglou, 2003) is based on an analytical solution developed for coastal aquifers of finite size and accounts for inland and lateral aquifer boundaries. Next, both models are modified using an empirical correction factor (similar to Pool and Carrera, 2011) which accounts for mixing.

A simple pumping optimization problem with a single well in a confined coastal aquifer of finite size with four boundaries (sea, inland and lateral impervious boundaries) is employed. The constraint prevents the toe of the interface to reach the well and the optimal pumping rates are calculated for different locations of the pumping well and different combinations of aquifer parameters. Then the results of the sharp interface models are compared to the 'true' results of the corresponding variable-density numerical model in order to evaluate the performance of the sharp interface models.

The results indicate that when the location of the well is close to the sea-boundary, the semi-infinite and the finite sized models produce similar, underestimated optimal solutions. However, when the well is placed inland, or near the lateral boundaries, the semi-infinite model yields much higher pumping rates than the finite sized model which are not always realistic and sustainable. This unrealistic performance is further exacerbated when the correction factor is applied to this model. Furthermore, it is observed that the correction factor is sensitive to different combinations of aquifer parameters in the case of the semi-infinite model.

On the other hand, the finite sized sharp interface model of Mantoglou (2003), improved using the correction factor, yields increased and sustainable pumping rates regardless of the well location. This is because this model considers inland and lateral boundaries and is better suited for finite sized aquifers whereas the unrealistic behavior of the semi-infinite model is expected since it neglects those boundaries. We conclude that the finite sized sharp interface model, improved with an appropriate correction factor is a better alternative when applied to aquifers of finite dimensions.