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Calibration of Hydraulic Conductivities by the Kalman Filtered Double Constraint Method

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To assess the consequences of a changing environment for future management decisions we need quantitative techniques validated by case studies. In this context dealing with the limited data availability and inherent uncertainty is a major challenge. In this contribution we present a combination of two techniques (the Double Constraint Method and the Kalman Filter) exemplified by case studies. The techniques assist in the calibration of hydraulic grid block conductivities as well as in finding the reliability of the result. To focus on the basic principles we exemplify our approach for flow in which storage by water compressibility and pore space deformation is negligible. Only storage by water table movements plays a role. Such conditions hold for most flow problems in the relatively shallow aquifer-aquitard systems of deltaic regions. In a forward problem the conductivity is specified in all grid blocks. In addition, on each point of the boundary and in each well only one type of boundary condition has to be specified: either head, or flux. Our approach is based on the principle that calibration of the initial conductivities is meaningful only if we can specify both head and flux at a number of boundary points or wells, including no-flux monitoring wells. In general a hydrogeological model is a “flux model,” i.e. the model is as much as possible based on specified (“measured”) fluxes through the boundaries and in the wells. An exception is Tóth’s flow systems analysis where, instead of the usual recharge fluxes, heads are specified on the water table. This suggests building a second forward model, a “head model,” that is as much as possible based on specified (measured) heads on the boundaries and in the wells. The initial conductivities are then updated by applying Darcy’s law K = -q/(¶h/¶x) to the fluxes q obtained by the “flux model” and the head gradients ¶h/¶x obtained by the “head model.” This so-called “double constraint method” (DCM) leads to a distinction between “measurement ranges,” where conductivities are updated, and “terra incognita,” where conductivities remain unchanged. The time-dependency found in repeatedly calibrated conductivities under different hydrological conditions can be used to determine the measurement error in the specified heads and fluxes. Application of a Kalman Filter results in an uncertainty of the conductivity estimation that is appreciably smaller than the observation error. Practical use of the DCM-KF method has been exemplified by applications to the Kleine Nete catchment and the Schietveld catchment, Belgium.