A HYDRO STRUCTURAL MODELLING (HSM) CONCEPT. CREATE SEMI-AUTOMATED HYDROLOGICAL MODELS DERIVED FROM RESISTIVITY MODELS AND LITHOLOGY LOGS

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Predictions made from ground water models are very dependent on the uncertainty of the inputs into the ground water model. Hence, to achieve predictions with relevant uncertainty spans, the uncertainties on the input variables need to be carefully described. One of the major causes of uncertainties in the predictions comes from uncertain knowledge about the subsurface structures, the hydro-stratigraphy. The Hydro Structural Modelling (HSM) concept is a transparent, objective, and data-driven workflow to create an ensemble of equally probable hydro-stratigraphic models for groundwater modelling.

The Hydro Structural Modelling (HSM) concept contains a 3-step semi-automated workflow to create hydro-stratigraphic models by combining resistivity information from geophysical data and borehole lithologies. The three steps are Accumulated Clay Thickness (ACT) modelling to create a clay fraction model, a clustering routine to create a zonated model (which will be the hydro-stratigraphic model when assigning hydrological parameters to the zones) and Multi Point Statistics (MPS) to create an ensemble of equally probably models and thereby quantify uncertainties of the hydro-stratigraphic models.

ACT model

In sedimentary environments a first general assumption is that low resistivities derived from geophysical data mainly corresponds to clay or clay rich sediments (aquitards) and high resistivities mainly correspond to potential aquifer lithologies such as sand, gravel, chalk, etc. This general link is utilized by the Accumulated Clay Thickness (ACT) concept linking the geophysical data and the borehole information to build a combined clay thickness (or clay fraction) model. First, the available lithological borehole logs are divided into aquifers and aquitards (say, sand and clay). Then a 3D model grid covering the area of interest is defined. On each of the nodes in this model grid a translator function is defined which links resistivities and clay fraction. The translator function is described by two parameters – an upper and a lower resistivity value. Resistivity layers below the upper value will get a weight of 1 which means that the full length of the resistivity layer is presumed to be clay, while resistivity layers above the lower value will get a weight of 0, corresponding to no-clay content (sand) for this resistivity layer. Mixed layers exist for values between the upper and lower value. By inversion we find the set of parameters in the translator model (upper and lower) which produces the best fit between the borehole-derived clay fractions and the geophysical predicted clay fractions. A key aspect in this concept is that the translator function can change horizontally and vertically, adapting to the local conditions and borehole lithologies. Therefore, not one "global" translator function is used for an entire survey, but a translator function which is spatially varying on the 3D model grid. The result is a 3D clay fraction model.

Cluster model

Step 2 is combining the clay fraction values from the ACT model and the geophysical resistivities in a k-mean clustering routine. As the clay fraction and resistivity models are correlated, the k-mean analysis is done on their principal components (PCA) to obtain uncorrelated variables. This produces a model reduced to a number of zonated clusters (typically 4-6), which can be used as hydrostratigraphic units in a groundwater modelling when assigned relevant hydrological parameters.

Multi Point Statistics for generating an ensemble of equally probable hydrostratigraphic models

By using a MPS algorithm (direct sampling) and the cluster model as training image, we finally generate 100's or more equally probable realizations of the cluster model. The direct sampling method uses both hard data and soft data to guide the simulations into a relevant output. The hard data points in the simulation grid are the points that are set to a specific value and are constant in between the simulations. They are the anchor points of the simulation and are based either on measurements or on other data points that have a high probability. The soft data in the simulations are the cluster model. From these realizations the uncertainty of the cluster model can be estimated and used in the groundwater modelling, or the full ensemble of models can be used individually.

In the talk we will present the concept by showcasing results from an area close to Aarhus, Denmark. The area is of special interest due to the rich groundwater resources.