*What are initial conditions? Describe various approaches to determining initial conditions for a groundwater model.*

Initial conditions are piezometric head values in all points of a system at the beginning of a simulation.

Initial conditions are derived from both static and dynamic average steady states according to the hydrologic question. Typically, initial conditions are selected from these steady-state head solutions for calibrated models. It is good practice to use these model-generated head values (and not field observations) to ensure that head data, hydrologic inputs, and parameters agree; otherwise, early time-steps would reflect both the model stress and the disconnect between these inputs, parameters, and head values (Franke, Reilly, & Bennett, 1987).

Drawdown simulations use static steady state to determine a system’s response to pumping. In these scenarios, only the relative head values are of importance as opposed to the absolute head values.

For transient simulations, the initial head distribution is generated by running a dynamic average steady state simulation that is run beforehand. This means that head values vary spatially but not temporally, and the water balance should be at equilibrium.

In some cases, dynamic cyclic initial conditions can be generated by running models with cyclic hydrologic inputs and this creates a cycle that is, as a whole, in steady state. There may be head variance temporally and spatially, but head distributions will return to these values in a cyclical and predictable manner (Anderson & Woessner, 1992).

*What does it mean for a groundwater model to be ‘spun up’?  How can we go about achieving this and how would we know if we are done?  What can happen if you run transient models on a groundwater model that is not spun up?*

Spin-up is a term that describes the length of time or the number of recursive runs that are needed to reach a point at which the state of the model at the end of a current run is the same as the state at the end of a previous run (equilibrium). It also means that the model is responding to the forcing in a consistent manner, regardless of the initial conditions. This state is reached if there is no change in model output over time due to the initial conditions.

Regardless of the initial conditions, the model itself adjusts in order to reach equilibrium. The original state, however, dictates spin-up and how long the model takes to reach equilibrium. Wet initial conditions are faster in spin-up than dry initial conditions.

If we run the transient models on a groundwater model that has not been spun up then it would be difficult to determine the initial conditions which can be used both for simulations and calibration of the model.

*Groundwater is generally the slowest moving component of the hydrologic cycle. Describe (1) the speeds at which groundwater flows compared to surface water (2) the time scales over which water tables and groundwater heads respond to changes in pumping vs recharge in both confined and unconfined systems?  What are the implications of these timescales for how we model groundwater systems?*

The highest rate of groundwater flow is in karst systems. However, in many cases the flow can be as low as 1 foot per year, decade, and/or even centuries. Also, it is faster in the areas where the hydraulic conductivity values are higher. Groundwater flow is much slower than surface water flow, where surface water has a possibility to speed up to high velocities in the steep river channels or due to currents.

Regions with changes in climate patterns and/or sustained groundwater pumping with unequally distributed recharge can face the groundwater depletion over time. In all cases, confined aquifers transmit changes in groundwater heads at higher rates than unconfined aquifers of the same storage capacity and hydraulic conductivity because the higher-pressure gradients found in the confined aquifer allow these changes to propagate faster.

In the saturated zone, which is completely filled with groundwater, the water pressure is high to enter the well and the water levels can be lowered by pumping. Pumping always cause the decline in groundwater levels at the well. Although, the pumping of a single well has a local effect on groundwater flow the pumping of many wells in large areas may have a regionally notable effects on groundwater.

On the other hand, depending on the recharge rate, the infiltration of water into the ground (aquifer) may, also, take hours, days, or even years which also depends on aquifer properties. Estimating the time scale of recharge is difficult because of the dependence on nonlinear soil characteristics, and modeling is intensive since it requires simulation of Richards’ equation (a nonlinear partial differential equation without analytical solution). Therefore, we use stress periods to analyze all the parameters that may change over the time we run the model.

In pumping, the effects of radial flow cause the pumping impacts to drastically reduce at distance because of the cross-sectional area that greatly increases for the cone of depression. The implications of these realities are that we as modelers need to build our models according to large timescales that incorporate decades if not quarter centuries.

# References

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