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A review of conceptual model uncertainty in groundwater research

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For more than a century, the strong advice in geology has been to rely on multiple working hypotheses. However, in groundwater research, as supported by modelling, often a stepwise approach with respect to complexity is promoted and preferred by many. Defining a hypothesis, let alone multiple hypotheses, and testing these via groundwater models is rarely applied. The so-called 'conceptual model' is generally considered the starting point of our beloved modelling method. A conceptual model summarises our current knowledge about a groundwater system, describing the hydrogeology and the dominating processes. Conceptual model development should involve formulating hypotheses and leading to choices in the modelling that steer the model predictions. As many conceptual models can explain the available data, multiple hypotheses allow assessing the conceptual or structural uncertainty.

This presentation aims to review some of the key ideas of 125 years of research on (not) handling conceptual hydrogeological uncertainty, identify current approaches, unify scattered insights, and develop a systematic methodology of hydrogeological conceptual model development and testing. We advocate for a systematic model development approach based on mutually exclusive, collectively exhaustive range of hypotheses, although this is not fully achievable. We provide examples of this approach and the consequential model testing. It is argued that following this scientific recipe of refuting alternative models; we will increase the learnings of our research, reduce the risk of conceptual surprises and improve the robustness of the groundwater assessments. We conclude that acknowledging and explicitly accounting for conceptual uncertainty goes a long way in producing more reproducible groundwater research. Hypothesis testing is essential to increase system understanding by analyzing and refuting alternative conceptual models. It also provides more confidence in groundwater model predictions leading to improved groundwater management, which is more important than ever.