地下水流和傳輸建模中處理地質不確定性的策略回顧

Refsgaard, J.C., Christensen, S., Sonnenborg, T.O., Seifert, D., Højberg, A.L., Troldborg, L., 2012. Review of strategies for handling geological uncertainty in groundwater flow and transport modeling. *Advances in Water Resources*, **36**, 36-50.

報告者：簡佑安
指導教授：王士榮 老師
報告日期：2022/04/21

摘要

在建立地下水模式時，與地質相關之不確定性主要來自於地質架構和水力參數；評估與地質相關之不確定性的方法可以分成三個主要類別，其分別考慮了地質架構、有效模式參數與局部尺度的異質性（heterogeneity）所造成的不確定性。本次報告將著重在介紹文章中有關於地質架構的不確定性。地質鑽探雖提供垂向特定深度的地質材料組成，然而成本資源有限，要透過有限鑽探資料得知整體地質架構就必須建立適當的地質模型，並透過評估地質模型的不確定性，將其延伸到地下水模式中。

文章中簡要介紹了常見的不確定性評估方法，例如多重建模（multiple modeling）與蒙地卡羅分析（Monte Carlo analysis）等方法，並且強調它們的關鍵特徵。除此之外，回顧前人的研究，評估了不確定性類別對於不同條件下地下水模式的相對重要性，同時討論不確定性評估方法的優勢、局限性以及相互作用，並探討需要進一步研究的關鍵主題。

文章揭示，儘管對於地質架構的未知性造成了地質模型中不可避免的誤差，但此誤差通過率定時水力參數值進行補償後，地下水模式模擬結果與觀測結果仍然相近；然而，在僅能對觀測資料做率定的情況下，預測如抽水等會受到含水層特性影響的結果時，地質結構的不確定性則成為模式不確定性的主要來源，因此地質模型變得至關重要。

Advances in Water Resources 36 (2012) 36–50

Contents lists available at ScienceDirect

Advances in Water Resources

journal homepage: www.elsevier.com/locate/advwatres

Review of strategies for handling geological uncertainty in groundwater flow and transport modeling

Jens Christian Refsgaard [a,*], Steen Christensen [b], Torben O. Sonnenborg [a], Dorte Seifert [c], Anker Lajer Højberg [a], Lars Troldborg [a]

[a] Geological Survey of Denmark and Greenland (GEUS), Øster Voldgade 10, DK-1350 Copenhagen K, Denmark
[b] Department of Earth Sciences, Aarhus University, Denmark
[c] ALECTIA, Denmark

ARTICLE INFO

Article history:
Available online 20 April 2011

Keywords:
Conceptual model
Geological structural uncertainty
Local scale heterogeneity
Monte Carlo analysis
Regression analysis
Bayesian Model Averaging

ABSTRACT

The geologically related uncertainty in groundwater modeling originates from two main sources: geological structures and hydraulic parameter values within these structures. Within a geological structural element the parameter values will always exhibit local scale heterogeneity, which can be accounted for, but is often neglected, in assessments of prediction uncertainties. Strategies for assessing prediction uncertainty due to geologically related uncertainty may be divided into three main categories, accounting for uncertainty due to: (a) the geological structure; (b) effective model parameters; and (c) model parameters including local scale heterogeneity. The most common methodologies for uncertainty assessments within each of these categories, such as multiple modeling, Monte Carlo analysis, regression analysis and moment equation approach, are briefly described with emphasis on their key characteristics. Based on reviews of previous studies, assessments are made on the relative importance of the three uncertainty categories for different types of model predictions. Furthermore, the strengths, limitations and interactions of these methodologies are discussed and conclusions are made with respect to identifying key subjects for which further research is needed. When all sources of uncertainty are analyzed by exploring model parameter and local scale heterogeneity uncertainty for several plausible geological model structures the joint uncertainties can be assessed by use of model averaging techniques, such as Bayesian Model Averaging (BMA). General challenge in model averaging with respect to choosing mutually exclusive and collectively exhaustive choice models, as well as to assign weights when models are used beyond their calibration base, are discussed.