Groundwater Resources Modelling:
A Case Study from the UK

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Groundwater Resources Modelling: A Case Study from the UK

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Foreword

When studying stratigraphy as an undergraduate geology major, I formed the impression that England was blessed with an orderly sequence of sedimentary rocks. This overly simplistic idea came from learning that William 'Strata' Smith (1769–1839) had used observations of fossils in southern England to correlate rock layers. Smith noticed that, in an undisturbed sequence of rocks, similar fossils occurred in layers in the same relative position. Unfortunately, an orderly sequence of rocks occurs only in southern England and even there the layers are deformed by bending. Considering the whole of the UK, the stratigraphic record is exceedingly complex, making for complex hydrogeology. Given such complexity, a programme to develop a network of regional groundwater flow models of the UK is ambitious.

Hydrogeologists dream of developing country-wide models for water resources management and planning. For example, regional models of the USA were developed by the US Geological Survey as part of the RASA (Regional Aquifer Systems Analysis) programme (Sun *et al.* 1997) and The Netherlands has a country-wide analytic element model (de Lange 2006). However, the UK modelling programme, which motivates this collection of papers, is unique in that it was initiated and is directed by a national regulatory agency and, importantly, is driven by mandates of the European Water Framework Directive (Hulme *et al.* 2002). Such legal requirements are imperative for an effective national network of models since they provide the incentive to maintain and improve the models long into the future. Too often models are 'shelved' and unused after the initial objective for developing the model is satisfied. Long-term upkeep of models, such as described herein by Hutchinson *et al.* (2012) and Jones *et al.* (2012), is rare.

As summarized in the excellent booklet by Downing (1998), there are four main aquifers in the UK, all found in the lowlands of England: the Chalk, the Permo Triassic Sandstones, the Jurassic limestones, and the Lower Greensand. Modellers have a good handle on simulating flow through continuous porous media like the Permo Triassic Sandstones, which comprise the UK's second most important aquifer. Models are essential tools in assessing management issues for these productive aquifers, for example as discussed herein by Daily *et al.* (2012) and Shepley & Soley (2012), who focus on the Permo-Triassic Sandstone aquifer in the West Midlands. Simulating flow in fractured rock is considerably more challenging. How unlucky that the most important and prolific aquifer in the UK is a fractured rock – the Chalk. Internationally, the Chalk is the UK's most famous aquifer. As discussed herein by Butler *et al.* (2012) and Watson *et al.* (2012), fundamental work in groundwater hydrology, including modelling flow in fractured rock, was conducted in the Chalk. Treating this aquifer as an equivalent porous medium (Jones *et al.* 2012; Soley *et al.* 2012*b*) can be appropriate for exploring questions of groundwater quantity, but it is likely that consideration of dual porosity/permeability will be needed to confront questions of groundwater quality (Butler *et al.* 2012; Cook *et al.* 2012; Taylor *et al.* 2012; Watson *et al.* 2012). Fractures are also important in the Carboniferous Limestone (Ingram *et al.* 2012), a karstified aquifer.

In documenting the first decade of a national modelling programme in the UK, the papers in this book reveal the possibilities of a regional network of groundwater models. For example, local models can be linked together to explore larger regional areas (Black *et al.* 2012) and also can be extracted from the regional network to explore site-scale problems (Gellatly *et al.* 2012). Not only are the papers in this book of historical interest in that they document the process of creating a national inventory of models, but they also form a casebook of modelling applications for some very challenging hydrogeological situations. In addition to the challenges of modelling fractured and karstified aquifers, the papers also describe approaches used in handling groundwater–surface water connections and the effects of abstraction on river flows (Daily *et al.* 2012; Hulme *et al.* 2012; Mansour *et al.* 2012; Shepley & Soley 2012; Soley *et al.* 2012*a*), sea water intrusion (Hutchinson *et al.* 2012), as well as ways of quantifying recharge for input to groundwater models (Quinn *et al.* 2012). The emerging push among modellers worldwide to engage stakeholders is also discussed (Hughes *et al.* 2012; Jones *et al.* 2012). Arguably, the most important challenge facing groundwater modellers in the twenty-first century is perfecting a practical approach for model calibration that effectively assesses uncertainties in parameter values. Calibration under uncertainty is best handled using an advanced inverse code such as PEST, as described by Black & Black (2012) and Taylor *et al.* (2012).

This is an important book. It forms a casebook of modelling applications to help guide both novice and experienced modellers. More importantly, it gives us a glimpse of a future when we will be able to access well-calibrated, standardized regional

models that can be combined or separated to solve hydrogeological problems on a variety of scales ranging from sites to countries and even continents.

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Preface

From the end of the 1990s to the present, the Environment Agency for England & Wales (the national environmental regulator with responsibility for water resources) has run a programme to develop regional groundwater flow models covering all the principal aquifers across England and Wales. We, the editors of this volume, have all been closely involved in this programme of work. The idea to produce the current volume germinated in 2009 when much of the work was nearing completion. It was a unique opportunity to record the state of groundwater resources modelling in the UK as a nationwide case study. Fortunately, many people thought likewise (i.e. the very large cast of authors) and it is thanks to them that we have enough material for a book.

The introduction to the volume provides a summary of the historical background to the programme and an overview of the papers presented. However, it does not fully highlight the role of three people in setting up the Environment Agency's programme and bringing it to fruition. Andrew Skinner, a former director of the Environment Agency, was the key person with the vision to appreciate the importance of groundwater modelling in future water resources regulation, and during 1994 created the mandate to make it happen. Steve Fletcher from the former National Groundwater & Contaminated Land Centre of the Environment Agency drove forward the implementation of the programme across the Environment Agency and invited Professor Ken Rushton, formerly of the University of Birmingham, to work with the Environment Agency team. Ken Rushton shaped the programme and set standards, work practices and guidelines, which were then followed by Environment Agency staff and the consultants working on the programme. Although an insight is provided of Ken's importance in the paper by Rushton & Skinner, it does not give the complete picture of how Ken has tirelessly and with good humour mentored, challenged and supported most of the people working on the programme for over a decade. We thank him for the help he has given us, and accept that any mistakes are likely to have arisen when we were not listening hard enough.

The setting up of the volume was facilitated by discussions and meetings of the UK Groundwater Modellers' Forum. This group was started at the instigation of Steve Fletcher in 2004 and has had much success bringing together hydrogeologists, groundwater modellers and other scientists and engineers from government, academia and industry to promote collaboration and particularly better use of groundwater models.

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