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Simulation of regional CSG groundwater impacts – Errors Upscaling & Multi-Phase Flow

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Abstract: Coalbed methane (CBM) or Coal Seam Gas (CSG) is considered a valuable energy resource worldwide. To produce the gas that is adsorbed to the coalbeds, groundwater is withdrawn from the coal. The associated depressurisation of the coalbeds raises concerns about impacts on adjacent aquifer systems which are an important water resource for the agricultural sector and surface water systems. Typical tools for assessing regional CSG groundwater impacts include analytical and numerical groundwater models that assume single-phase flow and static, up-scaled hydraulic properties. The up-scaled hydraulic properties are a crucial element of these models as these embody the hydraulic properties of coalbeds and the hydraulic connection between coalbeds and adjacent aquifer systems. These properties are highly uncertain due to the relative small amount of publically available data, the complex geology of the coalbeds, confining units and faults. To take in account near well-field processes like coalbed desaturation, current efforts aim to combine traditional groundwater simulation tools with CSG reservoir models. To develop new models for regional cumulative groundwater impact assessment, it is still unclear how to combine CSG reservoir models with standard groundwater modelling tools. Due to the scale of regional impact assessment and the need to evaluate a wide range of possible hydraulic properties, it is unlikely to avoid up-scaling due to computational constraints and parameterisation issues. The presented research aims 1) to quantify and compensate for modelling errors incurred by up-scaling and neglecting dual-phase flow and 2) to describe the physical resemblance of parameters in up-scaled CSG groundwater impact models. To address the above questions results a number of semi-synthetic reservoir models and groundwater models are developed. These results help determine how fine-scale reservoir simulations can be integrated into regional groundwater model design to improve the assessment of risks to regional aquifer systems posed by CSG developments.

Keywords: *Coal Seam Gas, Up-scaling, Multi-phase Flow, Reservoir Model, Groundwater Model, ECLIPSE, MODFLOW-USG*

1. INTRODUCTION

Coal Seam Gas (CSG) is a valuable energy resource in countries as U.S.A., China and Australia. In the Surat Basin, the maximum predicted CSG production scale includes up to 40,000 wells, producing an estimated 95,000 Ml of water per year over the next half century. Previous modelling has demonstrated that these drawdowns may affect yields from existing wells used for irrigation, industrial applications and domestic/stock water supplies. For this purpose, a new regional groundwater model has to be developed to predict CSG groundwater impacts (QWC, 2012). Of major concern is the suitability of standard groundwater simulation tools to quantify the risk associated with CSG extraction.

This study aims to answer the following questions:

- Evaluate the performance of an up-scaled CSG reservoir model to simulate drawdowns and extraction rates induced by CSG extraction
- Determine the physical resemblance of rock and well properties in up-scaled groundwater and reservoir models
- Quantifying and compensating for errors incurred by traditional up-scaling techniques and neglecting dual-phase flow

2. METHODS

The research uses two sets of models. The first set of models are used to evaluate differences between single-phase and dual-phase flow in a single 1m thick coal-seam layer in which 9 CSG production wells are located. The setup of this model is described by Figure 1. The second set of models (Figure 2) is used to evaluate the performance of a rigorously up-scaled CSG reservoir model to investigate discrepancies between simulated drawdowns incurred by CSG extraction and to evaluate required changes in parameter and well specifications in order to match fine-scale reservoir simulations. Furthermore this model adopts lithological segregation that aggregates coal and non-coal layers. Simulations are performed with the reservoir simulator ECLIPSE (Schlumberger, 2012) and the groundwater simulator MODFLOW-USG (Panday et al., 2013).

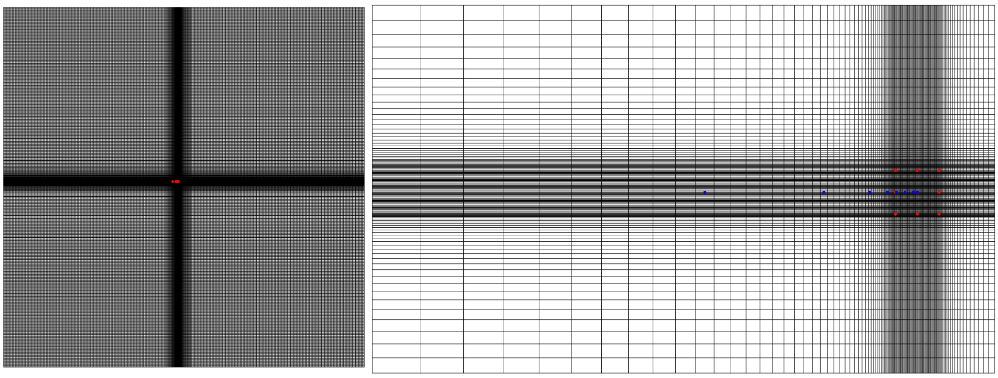

Figure 1 (Left) Grid. The red dots are a row of observation wells. (right) 9 pumping wells are located in the centre of the grid. Setup of CBM extraction wells (blue) and monitoring wells (red). Figure modified from Doherty and Herckenrath (2013).

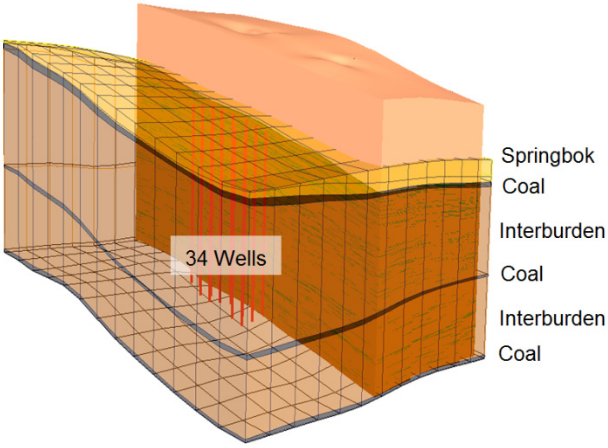

Figure 2. Relationship between the fine-scale model (614 layers) and up-scaled model (7-layers). Wells are indicated in red. Figure modified from Moore et al. (2013).

3. RESULTS

Results between the various models are investigated in terms of simulated drawdowns, water and gas production rates and parameter values used in the various models. Figure 1 shows the locations at which drawdown is evaluated in the first set of models. When comparing single phase with dual-phase flow simulations using similar production well constraints, drawdown is overestimated. A modified groundwater model is subsequently used by including a desaturation function that is based on the simulations with the dual-phase flow model, yielding an improved match in drawdowns and water extraction rates.

For the second set of simulations the up-scaled reservoir model generally matches the drawdowns and extraction rates of the fine-scale model, however, this required an inversion based up-scaling strategy to estimate effective parameter values in the up-scaled model. Permeability and well properties required values that could not be derived from general analytical up-scaling techniques (e.g. geometric, harmonic averaging).

4. CONCLUSIONS

The quantification of risks to aquifer systems as a result of CSG developments heavily depends on regional groundwater modelling. As standard groundwater modelling tools are not specifically designed for groundwater flow in a CSG context, this research quantifies the errors incurred by up-scaling and neglecting single-phase flow in CSG groundwater impact models using two sets of (semi-)synthetic CSG reservoir models. Furthermore, modified groundwater models are tested to compensate for such errors using an adapted desaturation function and lithological segregation. These simulations provide insight in how to approach the modelling of CSG groundwater impacts and how up-scaled properties of such models can be related to field observations and more detailed CSG reservoir simulations.

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