# Near-wellbore modeling in ECLIPSE with Computational Fluid Dynamics

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## Introduction

Reservoir simulation plays a crucial role in oil field development and is able to answer questions about what the availability of hydrocarbons in the reserves is, how much of it can be recovered, and how quickly. When choosing an optimal field development plan, several important considerations must be taken into account: number of wells and locations, types of completion, surface facilitates and application of EOR methods are among them.

In reservoir simulators, wells are most commonly modeled as simple sink terms (production wells) or source terms (injection wells) to represent fluid flow within a grid block as it leaves or enters the reservoir. These models ignore fluid flow inside the wellbore itself and cannot adequately solve the pressure distribution along the well, leading to inaccurate flow calculation near the well.

In order to get a qualified solution of the pressure field and the flow calculation in the vicinity of the well, we instead model wells using **computational fluid dynamics (CFD)**, coupled with full scale reservoir models. The method has been implemented and coupled with the Matlab Reservoir Simulation Toolbox (MRST), and in this work we present results on **coupling** with the **ECLIPSE** reservoir simulator. ECLIPSE is considered to be the industry standard among commercial reservoir simulators, and a large number of oil fields worldwide are modeled in the ECLIPSE format. The coupling itself is non-intrusive, and without significant modifications, we can couple fields already modeled in the ECLIPSE format with wells modeled using CFD.

## Coupling framework

In reservoir simulators, including ECLIPSE, source and sink terms $Q_\alpha$ are modelled as follows

$$Q_\alpha = PI_\alpha \cdot \Delta P = PI_\alpha \cdot (P_{cell} - P_{well}) \tag{1}$$

where $\alpha = \{oil, water\}$ and $\Delta P$ is the difference between pressure in the block containing a well and pressure in the well (see Figure 1 below). The productivity index $PI_\alpha$ is computed by

$$PI_\alpha = WI \cdot \lambda_\alpha = \frac{\theta\sqrt{k_x k_y}}{ln(r_e/r_w) + s}\lambda_\alpha \tag{2}$$

using the Peaceman equivalent radius $r_e$, which is derived on assumptions that rarely meet the conditions of real world reservoirs. Moreover, it is not possible to model and simulate complex well completions that contain downhole equipment using (2). As a consequence, accurate production forecasts are difficult to obtain without extensive parameter tuning based on historical production data.

To accurately predict fluid flow in the well vicinity and in the wellbore we replace $PI_\alpha$ in (1) with $PI^*_\alpha$ computed by an upscaled CFD model

$$PI^*_\alpha = \frac{\langle q_\alpha \rangle_i}{\langle p_{cell} \rangle_i - P_{well}} \tag{3}$$

where index $i$ indicates a CFD variable evaluated within the coarse grid block that contains the well. $\langle q_\alpha \rangle_i$ is the summarized CFD production rates, and $\langle p_{cell} \rangle_i$ denotes the average CFD pressure.

## Numerical results

The coupling algorithm has been tested on the waterflooding case below, where the producer experiences a nonuniform inflow due to the nearby nonpermeable reservoir boundaries, which is one of the limitations of the Peaceman well model (2) above. In Figure 1 we see an $11 \times 1 \times 1$ waterflooding case with one injector (blue) and one producer (red). The outlined grid blocks are modelled with CFD and coupled to ECLIPSE via the blue interface. Figure 2 depicts the CFD wellbore model, it counts approximately $10^3$ cells and the production well is modelled as an open-hole completion.

In Figure 3 we see a comparison between the Peaceman productivity index (2), that is used in ECLIPSE, and the productivity index (3) calculated by the CFD upscaling approach. By replacing the Peaceman productivity index $PI_\alpha$ in (1) with the CFD productivity index $PI^*_\alpha$, we couple the upscaled CFD grid block pressure with the coarse ECLIPSE model. This can be seen in Figure 4. Finally, in Figure 5 we show that the coupling method enables us to fit the production rates in a coarse ECLIPSE model with the production rates obtained from an upscaled CFD wellbore model.

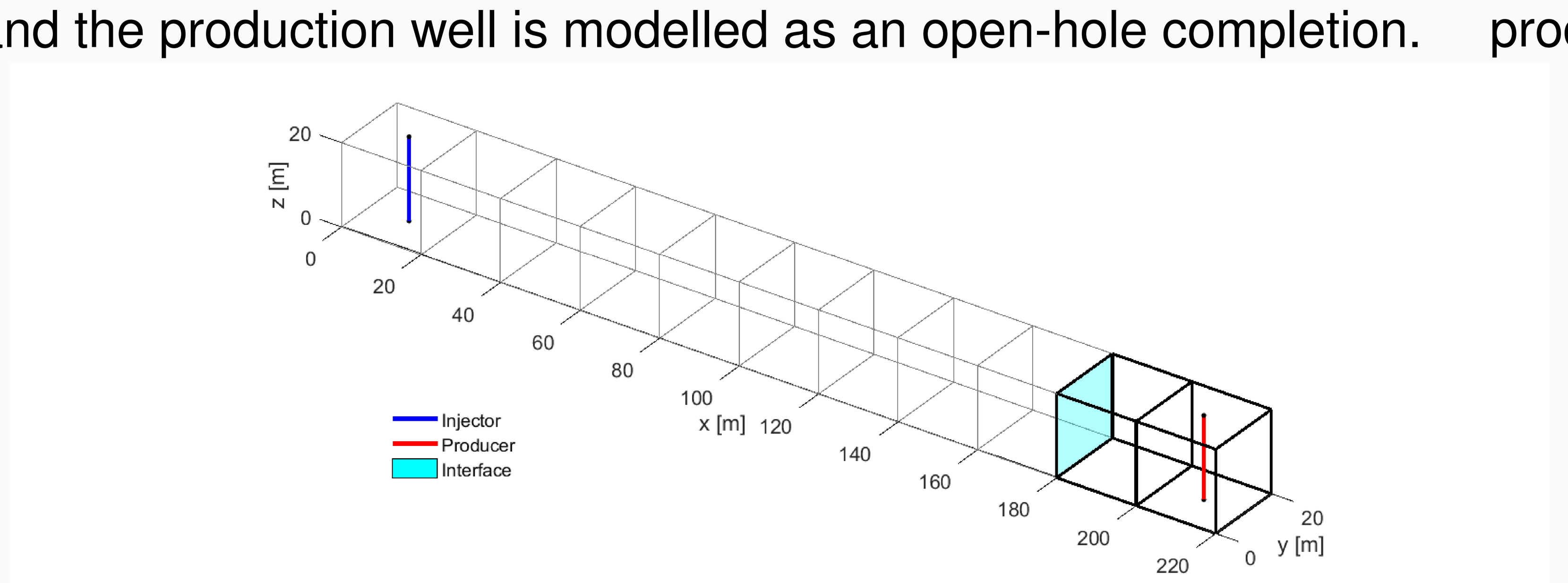


**Fig. 1:** ECLIPSE reservoir model with one injector (blue) and one producer (red).

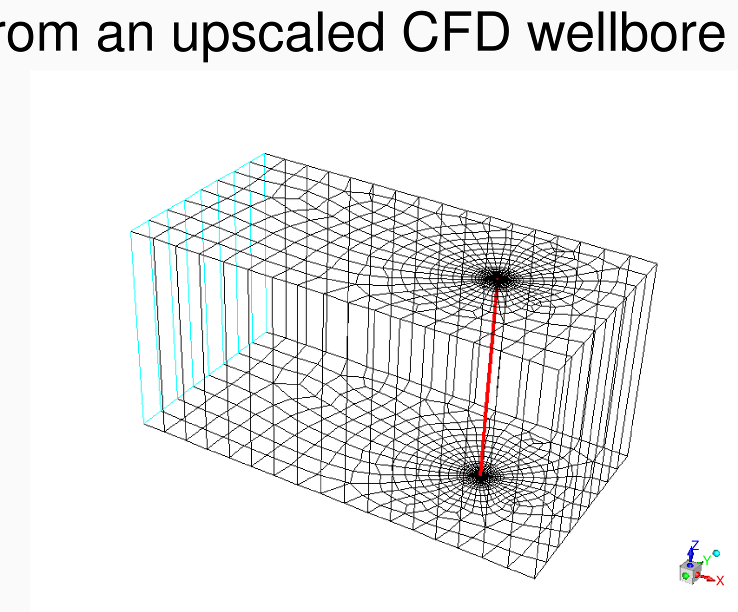

**Fig. 2:** CFD wellbore model of the outlined grid blocks in Figure 1.

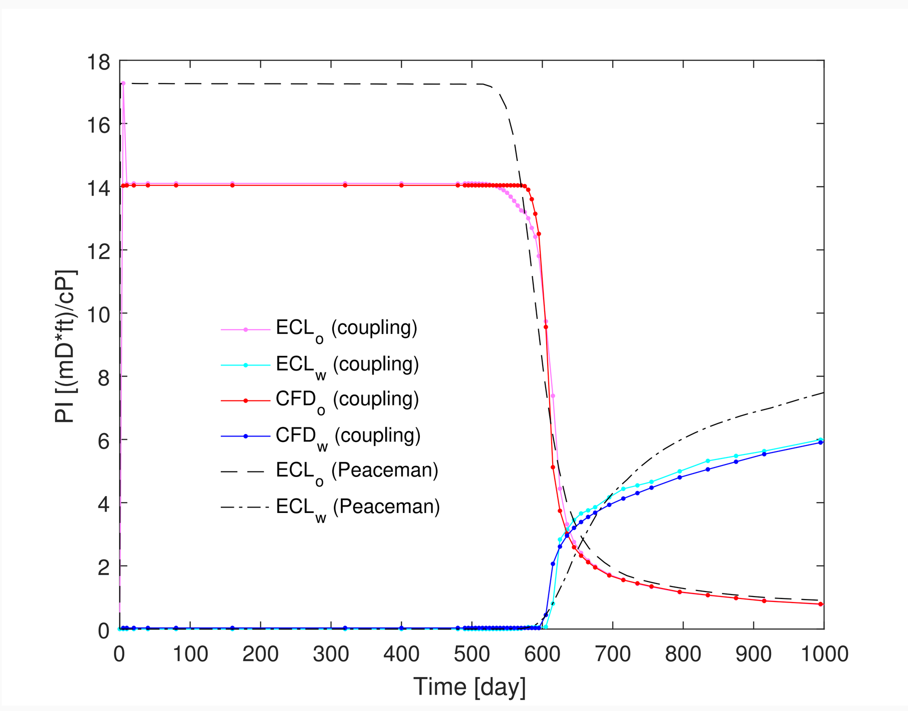


**Fig. 3:** Productivity index, Peaceman vs. CFD.

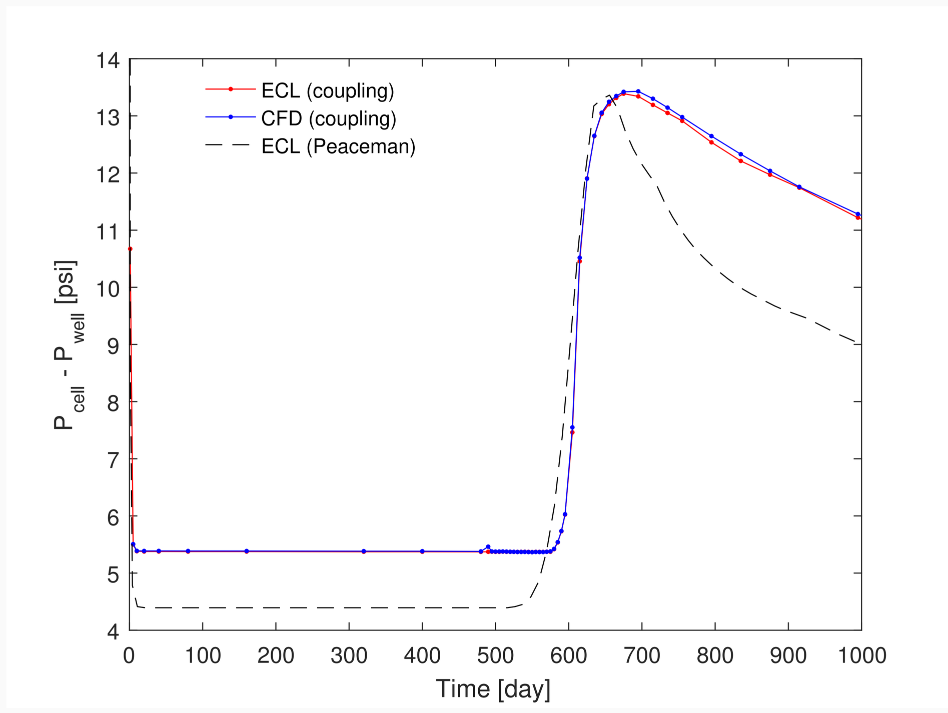


**Fig. 4:** Pressure difference between grid block and well.

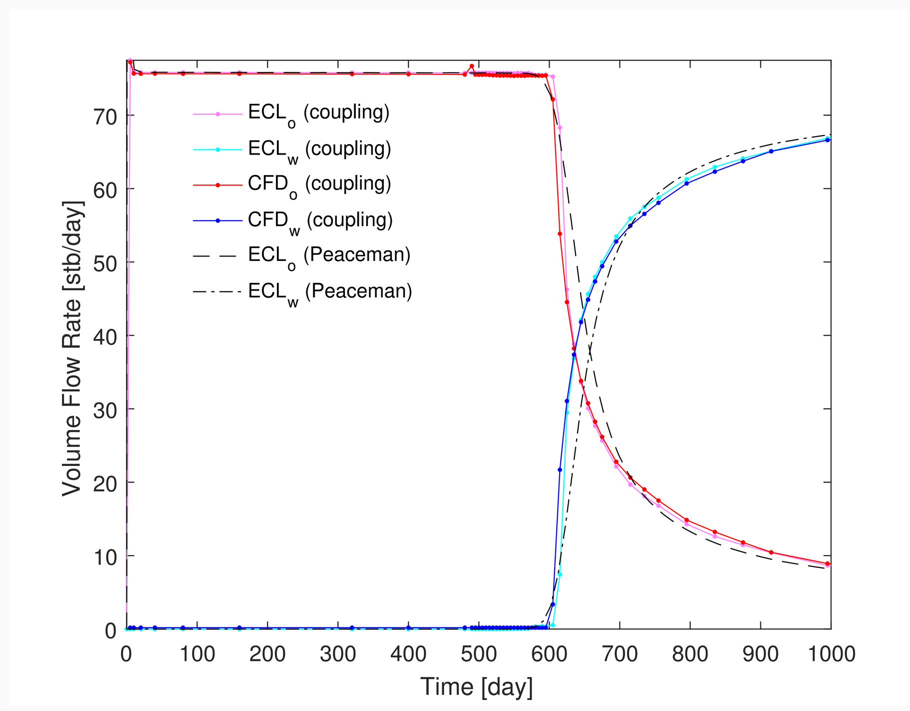


**Fig. 5:** Production rates of oil and water.