

## IPTC 12533-PP

# Integrated data analysis and dynamic fracture modelling key to understand complex waterflood: Case study of the Pierce field, North Sea

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This paper was prepared for presentation at the International Petroleum Technology Conference held in Kuala Lumpur, Malaysia, 3–5 December 2008.

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### Abstract

The performance of many waterfloods (and EOR schemes) is characterized by fluid injection under fracturing conditions. Especially when the geology is complex and the mobility of the reservoir is low induced fractures can be of the same order as the well spacing, which has a significant (in general undesired) impact on both areal sweep and vertical conformance. Therefore, fluid injection needs to be actively managed and surveyed in order to design an appropriate injection strategy over time.

We have analyzed historical injection/production, injection step-rate, and fall-off test data of an existing complex waterflood in the Pierce field, North Sea. The mental subsurface model that emerged from this data analysis was further developed through a series of dynamic fracture propagation simulations. While the data analysis was a relatively standard procedure, the fracture modeling part was far from trivial and included simulations using a stand-alone fracture-modeling tool and a more sophisticated coupled dynamic fracture propagation – reservoir simulator, both being in-house software tools.

The combined analysis was used to develop a better understanding of the waterflood performance. The main improvement compared to previous work was the integration of the data analysis and the dynamic modeling work rather than looking at each data source individually. In combination a consistent explanation of the observed reservoir behavior was achieved. This has resulted in changes in the day-to-day water injection management and is deemed to play a key role in longer-term development strategies.

### Introduction

The field geometry is characterized by two salt diapirs that are penetrating the reservoir formation, leading to two connected accumulations (North Pierce and South Pierce). Seismic control is relatively poor and only major geological features such as large faults are well localized. Geologically Pierce consists of many turbiditic sand-shale sequences, adding to the complexity. Since 1999 the field has been developed under depletion drive with gas re-injection. In 2004 water injection was introduced in South Pierce with the dual objective to give additional pressure support and better sweep down dip of the oil producers. The water injection project consists of a series of highly deviated (horizontal) injector-producer pairs surrounding the South Pierce salt diapir. Each well pair approximately covers one quarter of the total South Pierce reservoir area (see Figure 1). Initially, water injection uptime was poor (complicating the data analysis) which was resolved towards the end of 2006.

Overall the waterflood response is considered to be effective in terms of increasing the reservoir pressure while the impact of water injection on areal sweep is problematic. After the start of water injection initially indications of increasing field rates were recognized. But in the first half of 2006 the producer well A1 on the east flank of the salt diapir watered out very quickly and unexpectedly. One possible explanation is an induced fracture that created a shortcut from the injector to the producer. Note that the shortest lateral distance between the producer A1 and the injector A8z is in the order of 850 ft (with similar vertical offset). For the two well pairs in the south and west, water cut was increasing somewhat faster than expected (but still a lot slower than for A1) and, therefore, the water injection rate was decreased recently. So far, the apparent effect is positive though the time frame is too short to have a reliable explanation.

Optimal water injection rates are a subtle balance between voidage, induced fracture growth and reservoir heterogeneity and, therefore, each of the injector-producer well pairs requires a detailed data/modeling effort to design an appropriate injection management scheme.

Waterflood surveillance in Pierce is difficult, due to the way the wells have been completed. But it is absolutely essential to provide the basis for the type of analysis that is demonstrated here. Therefore increasing the understanding of the waterflood