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Integrated Characterization of Lean Zones and Their Impact on SAGD Production: A Case Study from the Long Lake Field

Weixing Ding, Wade Zaluski, Randall Chodzicki
CNOOC Petroleum North America (CPNA)

Summary

The LLSW Pad has encountered unexpectedly large high-hardness water production volume attributed to the lean zones within the McMurray Formation. This study integrated depositional facies analysis, QI-derived geomodelling, and 3D/4D seismic data to delineate lean zone spatial distribution, map the water chemistry distribution, Quantify the water volume, optimize well trajectories and monitor the 'thief zone' and baffles character of the lean zone. These insights enable Reservoir and Production Engineering teams to optimize steam injection and water-handling capacity.

Keywords: SAGD, Long lake, McMurray Formation, Lean zone, Quaternary-Channel, Water chemistry, 3D/4D seismic, Modelling

Background and Production Anomalies

The LLSW Pad is a prolific asset within the Long Lake Field, situated south of a West-East trending Quaternary-Channel extension that incises the Clearwater and Grand Rapids Formations. During the ramp-up of bitumen production at pads, the operation encountered unexpected large high-hardness water production volumes. A significant discrepancy in water-cut was also observed compared to adjacent offset wells, despite identical completion strategies and close distance. This anomalous water production is attributed to internal lean zones—thick, water-enriched sand or sandy Inclined Heterolithic Stratification (IHS) intervals—situated within the Exploitable Bitumen in Place (EBIP) of the McMurray Formation.

Lean Zone Definition and Cutoff Criteria

To provide a consistent analytical framework across the pad, this study first summarized three lean zone cutoff definitions in industry:

- Bitumen mass fraction (< 6 wt%) as measured by Dean-Stark analysis, which was used prior to 2010.
- Water Saturation (Sw > Swirr): Water saturation exceeding irreducible levels. This focuses on the presence of mobile(free) water.
- Effective Saturation (Swe > 50%) coupled with a shale volume constraint (Vsh < 30%). This is the major characteristic of the thick sandy lean zones.

Lateral Accretion in Continuity Studies

Given that water volumes vary significantly between neighboring wells, a detailed study of spatial distribution is critical. This involves a depositional model study focused on lateral accretion processes and their control on lean zone continuity. By analyzing the architecture of point bar deposits and the lateral extent of IHS bedding, we try to determine if these water-enriched intervals are laterally extensive or compartmentalized.

Also, the "stand-off" definition was introduced—the vertical distance from the base of the lean zone to the producers' elevation. This metric is critical for well pair trajectory design to avoid drilling into the lean zone with the greatest effort and estimating the timing of steam-to-water zone contact and assessing the risk of water breakthrough during the production ramp-up.

Water Chemistry and Trend Study

To support the production team, the study integrates formation water analysis focusing on hardness distribution trends derived from MDT sampling. By mapping water properties across the pad, we provide a predictive trend for produced water hardness, which is essential for managing water treatment facilities and forecasting production chemistry.

Data Integration and Static Modeling

A streamlined static modeling workflow integrated petrophysics, QI-derived elastic attributes, and depositional facies interpretations to map lean-zone continuity across the pad. QI impedance and density trends were used to refine facies probabilities and improve prediction of water-rich sands and sandy IHS between wells. Facies-dependent petrophysical transforms—including piecewise PHIE-PERM relationships implemented through Petrel expressions—were applied to preserve realistic rock-property behavior within lean zones. A discrete VMW/HCPV-based baffle classification was incorporated to capture thief zones and vertical flow barriers. The resulting model provides a geologically consistent framework for assessing lean-zone connectivity, stand-off thickness, and their impact on early steam-chamber development.

4D Seismic and Conformance Monitoring

To evaluate the interaction between the steam chamber and these intervals, 4D seismic surveys (early 2024 and ongoing 2026 acquisitions) were used. We analyze Normalized Root Mean Square (NRMS) for repeatability and Time-Delay to track the steam front. Additionally, variations in multiple seismic inversion parameters are monitored to observe how lean zones act as thermal "thief zones" or vertical baffles.

Significance

This integrated approach provides a robust framework for delineating lean zones by combining depositional facies analysis, high-fidelity geomodelling, and 4D seismic monitoring. By enabling more accurate predictions of steam chamber development and produced water hardness trends, the study provides Reservoir and Production Engineering teams with the critical data needed to optimize steam injection strategies and water-handling capacity. Ultimately, these insights ensure the efficient recovery of bitumen and mitigate operational risks within the complex, heterogeneous reservoirs of the McMurray formation.

Acknowledgements

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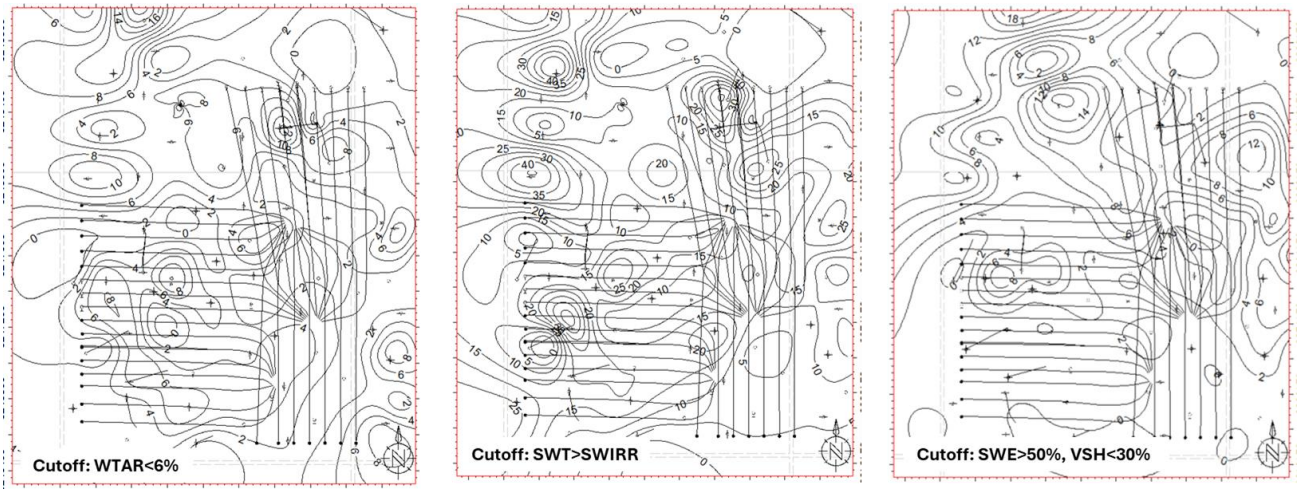


Figure 1: LLSW Lean zone net thickness
illustrating discrepancy due to cutoff difference (well data driven)

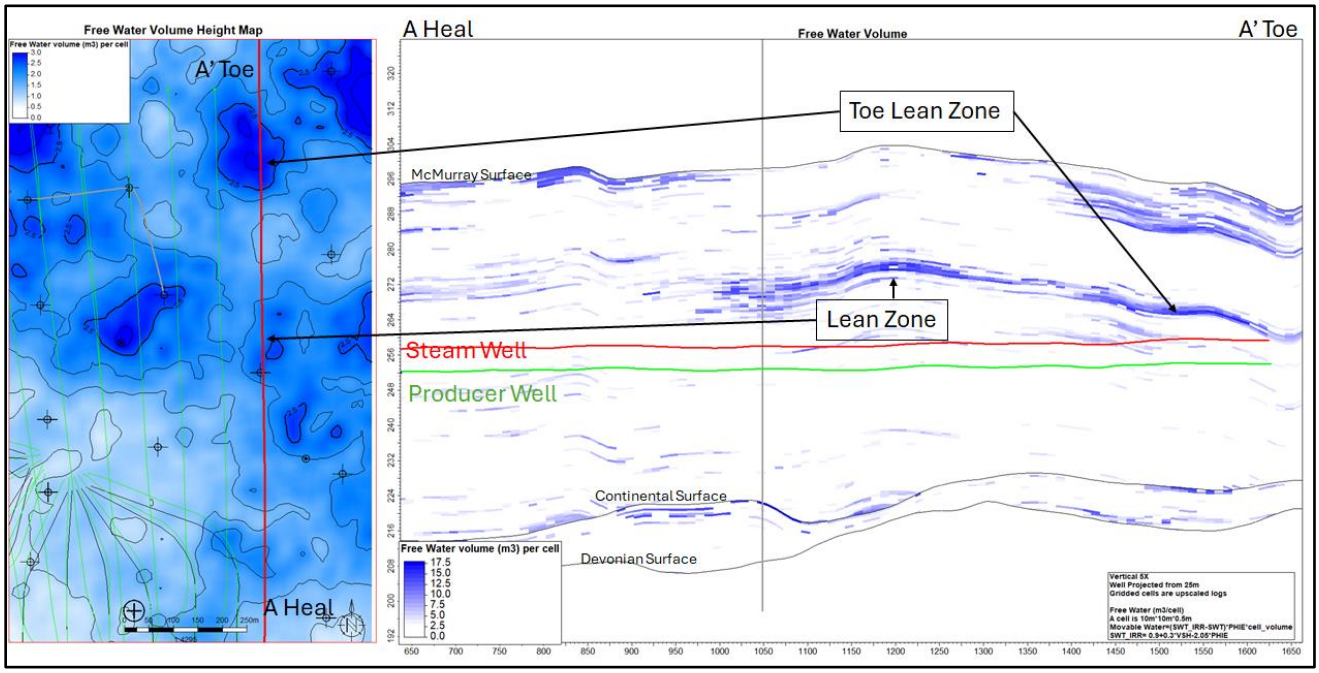


Figure 2: LLSW Free water volume height used to identify lean zones.

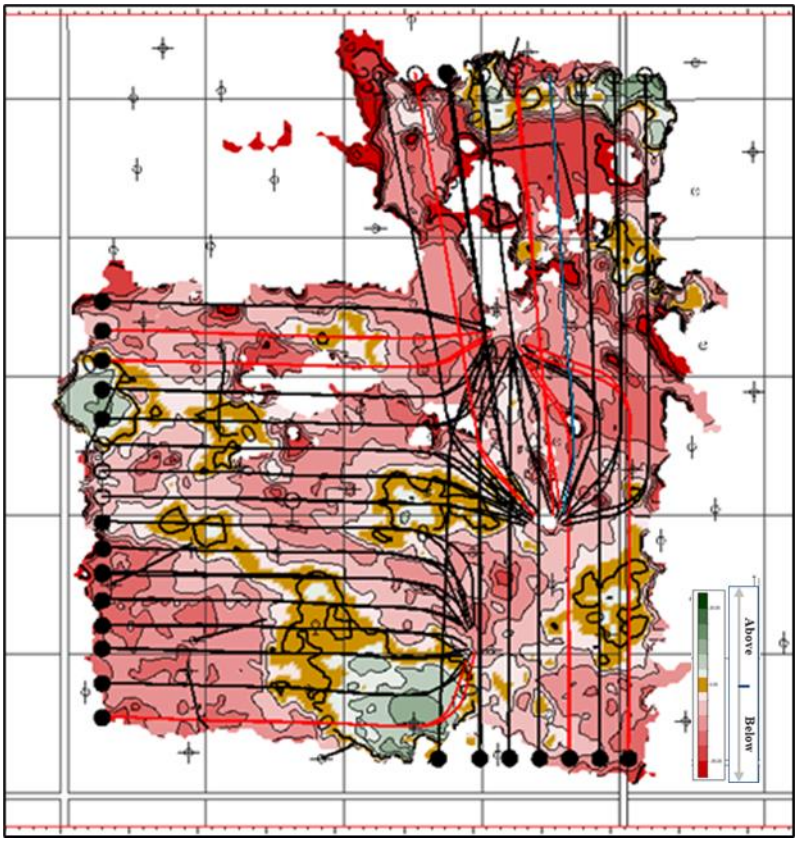


Figure 3: 2024 Steam Chamber growth illustrating Above (green) vs Below (red) EBIP top

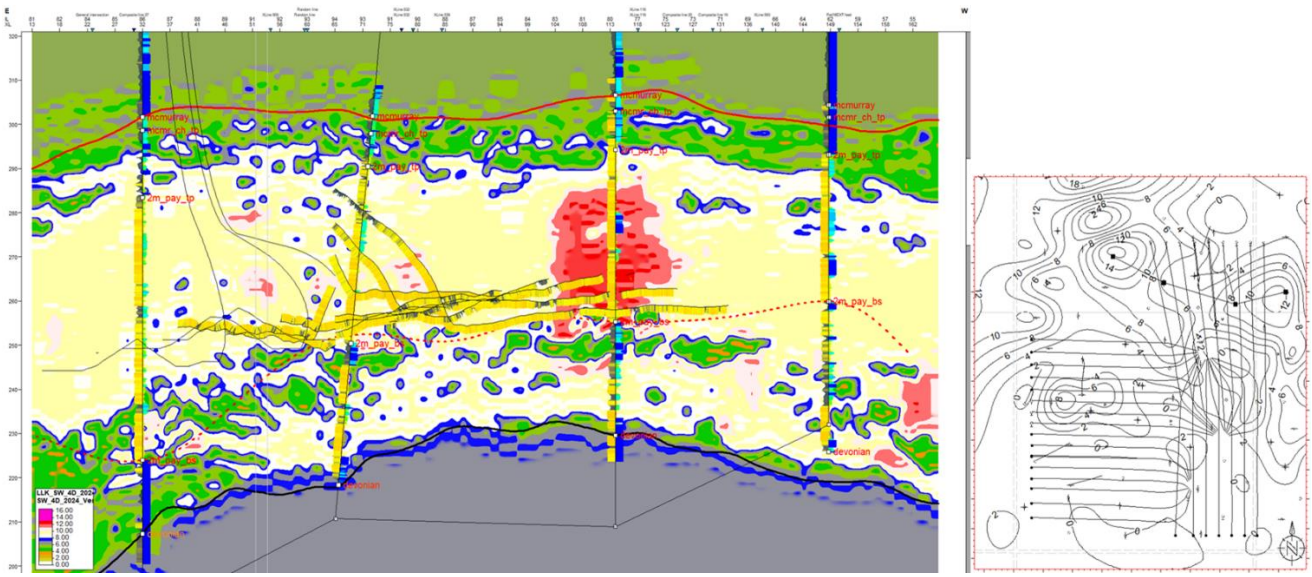


Figure 5: 4D Seismic Classification Profile
highlighting the lean zone acted as ‘thief zone’, the index map is lean zone thickness