

Pengrowth Optimizes Well Design and Placement for Maximum Heavy Oil Recovery

ECLIPSE Thermal simulator aids sensitivity analysis and SAGD optimization at Lindbergh field, Alberta

CHALLENGE

Analyze initial well design and determine well placement for maximum recovery and optimized steam-oil ratio (SOR) in a steam-assisted gravity drainage (SAGD) pilot operation.

SOLUTION

Employ reservoir engineering software technology and techniques:

- ECLIPSE* Thermal Reservoir Simulation software
- ECLIPSE Multisegment Well option
- Sensitivity analysis
- High-performance computing cluster.

RESULTS

Produced thermal simulation model, enabled sensitivity analysis of SAGD process, and achieved confidence in pilot design; modified design to maximize oil recovery while reducing SOR; cut time to run simulations using parallel computing.

This industry-leading approach was more comprehensive than single-well-pair modeling, and the testing helped avoid steam chamber quenching while maximizing recovery.

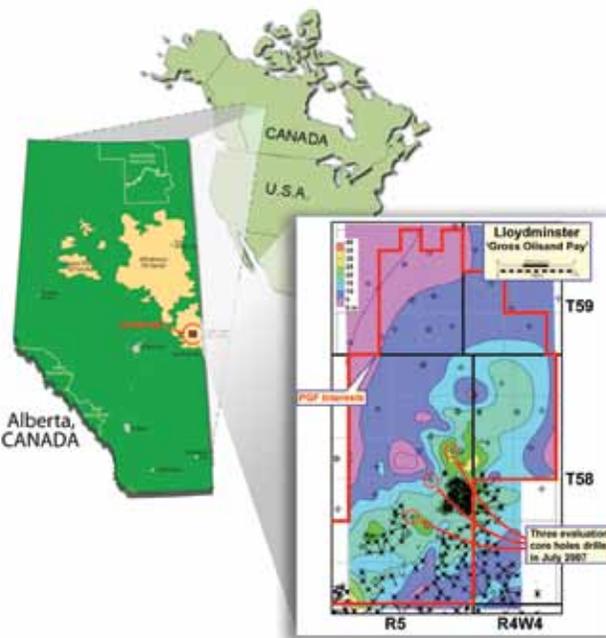


Analyze and optimize pilot design for SAGD operation

Canada has the world's largest deposits of ultra-heavy oil and bitumen resources, estimated at 2.5 trillion bbl. SAGD and cyclic steam simulation (CSS) are the only methods to extract these resources from deeper reserves such as those found in Lindbergh field. Lindbergh is the deepest formation (approximately 510 m TVD) using SAGD in the western Canadian sedimentary basin. Having proven the effectiveness of steam injection in horizontal wells, Pengrowth Corporation focused on analyzing and optimizing its initial pilot design for a complex and challenging SAGD operation to improve recovery.

Examine potential SAGD success in pilot area

Pengrowth used ECLIPSE Thermal Reservoir Simulation software and its Multisegmented Well (MSW) option to build a model representing field conditions and to evaluate the potential success of SAGD in the Lindbergh pilot area. Due to the reservoir's relative homogeneity, a layered model was created with the vertical variation in porosity and permeability derived from core data. The ECLIPSE Thermal simulator with MSW option enabled accurate representation of pressure drops and heat transfer effects along the wellbore. Reservoir simulation helped optimize completion design and well placement to ensure maximum economic oil recovery.



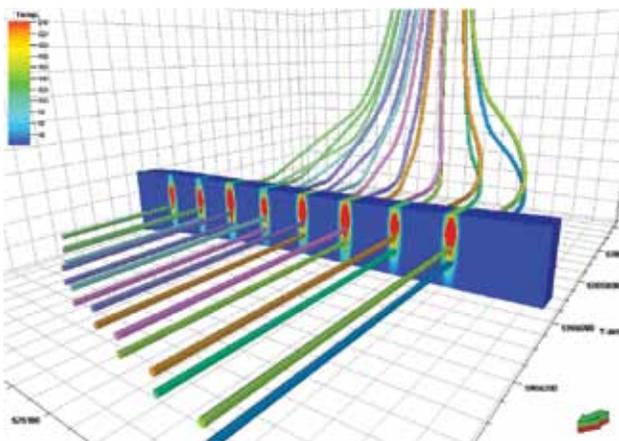
Lindbergh pilot area in the Cold Lake oil sands in Alberta, Canada.

Industry-leading approach to modeling.

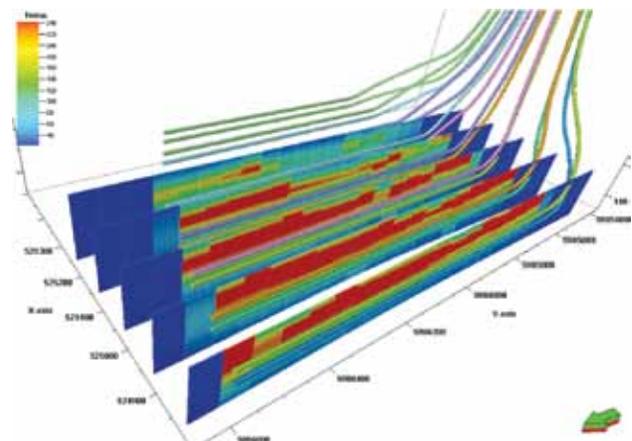
The pilot design was modeled using eight SAGD well pairs with multisegmented well models to test

- effects of viscosity variation
- spatial distance between the eight well pairs
- vertical separation between the injector and producer for each well pair
- vertical separation of the producer from the bottom water (i.e., how high or low the producer can be with respect to the bottom water to optimize SAGD)
- the multipoint injection scheme within each injector.

CASE STUDY: Reservoir simulation software enables innovative modeling approach



Steam fraction showing the vertical chamber growth in a plane perpendicular to the wells 1 year into the SAGD process (optimized case).



Steam fraction showing the vertical chamber growth in the plane of the wells 1 year into the SAGD process (optimized case).

Existing pipelines and facilities, horizontal well lengths and interwell spacing, and observation wells were also taken into account. A computing cluster with 32 cores was used for the modeling process. Each simulation was run 16-way parallel, effectively running two simulations at the same time. The run times for each eight-well-pair model with MSW were reduced from several days to an average of 18 hours. The simulation runs covered 11 years of SAGD production, with an additional 3 months for preheating via steam circulation.

This industry-leading approach was more comprehensive than single-well-pair modeling, and the testing helped avoid steam chamber quenching while maximizing recovery.

Pilot design modifications to maximize recovery. Five development scenarios were modeled to analyze the Lindbergh pilot design. Sensitivity analysis results were extremely useful in optimizing the design. Subsequent modification further maximized recovery while reducing SOR. The best case of each scenario was taken to run the remaining sensitivities.

The right horizontal spacing is essential for maximizing oil recovery and balancing SOR. Inter-pair horizontal spacing was evaluated at increments of 80 m, 100 m, and 120 m—resulting in an optimal interval of 100 m, with eight well pairs generating the most economically viable operation. Testing injector and producer vertical well spacing allowed Pengrowth to determine the best spacing for ultimate recovery. Spacing was tested using separation increments of 3 m, 4 m, 6 m, and 7 m. The greater the vertical separation between the injector and the producer wells, the higher the overall recovery, but the lower the initial production rates. The increase in reserves was incremental, and the original design of 5 m separation was within the acceptable range.

The number of injection points required to maximize recovery and minimize SOR was also investigated. The final simulation cases used several injection points, one point at the heel and five points spaced out in 25% increments along the horizontal length. Two injection points—at heel and toe—provided maximum recovery.

Maximized recovery and minimized SOR

This study shows that additional sensitivity analyses and uncertainty quantification are required to optimize the SAGD process under varying reservoir conditions. Geology plays a key role in dictating SAGD performance and must be adequately reflected in the simulation model. A detailed wellbore model is critical in understanding pressure and heat transfer effects on steam chamber formation. The ECLIPSE Thermal simulator and Multisegmented Well option provided the rigor to determine the best operational parameters, maximizing recovery and minimizing SOR. Pengrowth plans to introduce detailed heterogeneity into the model for further studies.

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