Waterflood Optimization

Learn The Best Practices of Waterflood Optimization to Maximize Your Production Rate!

Date: 23rd June 2014 – 27th June 2014
Location: Kuala Lumpur, Malaysia

Petrosync Distinguished Lecturer
Deepankar Biswas, Ph.D., P.E.
- President of Sitelark LLC
- Technical Editor of SPE Journal
- Vice Chairman Education of SPE Dallas Chapter (2006-07)

Course Objectives
- Learn what are the factors affecting successful institution of waterflood
- Understand how to design, predict and monitor waterflood
- Understand what are the different analytic and numerical techniques to predict waterflood recovery considering the important aspects of the drive mechanisms
- Learn various diagnostics and quantitative techniques to perform waterflood surveillance and rebalancing
- Learn special considerations of waterflood e.g. remediation of excessive water production by water shutoff and/or profile modification, improving sweep efficiency, polymer augmented waterflood, LoSal (low salinity) waterflood, reservoir souring

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Course Overview

This five-day course will cover various aspects of waterflood theory, diagnostics, planning, evaluation and analysis. Both analytic and numerical techniques to evaluate waterflood will be presented. The method of teaching will be a combination of slides, discussions and hands-on practice problems. Students will benefit from the presentation of actual results of instituted waterfloods around the world. The course assumes students to have basic knowledge of waterflood, some experience in oil-field operations and familiarity with functions of Excel™ and Windows™ based software.

Each attendee must bring a laptop computer with Microsoft operating system.

This course is intended for,

- Reservoir Engineer
- EOR Engineer
- Production Engineer
- Petroleum Engineer
- Geologist

PLUS anyone else responsible for the support of the waterflood.

Deepankar "Dee" Biswas is the President of SiteLark, an international petroleum engineering consulting firm. He specializes in reservoir simulation, reservoir engineering, engineering software development and economics. He has more than eighteen years of experience in industry, academia, research laboratories and field operations. These experiences span assignments in the Middle-East, Europe, Latin America, Asia and continental USA. He had previous tenures with such companies as Mobil Oil, ONGC, TXU, Blade Energy Partners and DeGolyer and MacNaughton. He has more than ten technical publications in archival literature and two book chapters on real options.

Deepankar has a Ph.D. and M.S. from the University of Texas at Austin and an undergraduate degree from the Indian School of Mines, all in Petroleum Engineering. He also received a Certificate in Corporate Finance from the Cox School of Business, Southern Methodist University. He has served as the Education Chairman of SPE Dallas Section and has been an active member of Society of Petroleum Engineers for the last thirty years. He has been a technical editor for SPEJ. He is a professional registered engineer in the state of Texas.
Course Agenda

DAY 1
The day begins with general history and development of Waterflooding, some case studies and highlighting the importance of at least five important factors governing the functioning of waterflood namely: mobility, heterogeneity, capillary pressure, crossflow and gravity. Issues of multiple oil water contacts will also be discussed. Various theoretical treatments and hands on exercise problems will elaborate on the concepts of:

- Wettability, imbitions, drainage concepts, capillary pressure, J-function, height above free water level
- Air permeability, absolute permeability, effective permeability, relative permeability
- Porosity-permeability cutoffs, net pay cutoff determination, rock continuity and floodable pay
- Vertical permeability variation, areal permeability variation, detection of stratification, selection of layers, Dykstra-Parsons coefficient, Lorentz coefficient, effect of cross flow, vertical sweep efficiency
- Need for waterflood patterns and selection criteria
- A lot of Case studies and exercises

DAY 2
The day is dedicated to examining the analytic techniques available to evaluate waterflood operations. Concepts of fractional flow, frontal advance theory and its application to Welge's method will be discussed. The concepts will be extended to multi-layered system to compute pseudo relative permeability curves. Several hands on problems will help understand the application of the above in Stiles and Dyksta-Parson's methods of computing vertical efficiency. Finally, a waterflood design problem will be solved using this analytic framework. Following topics will be included during the day:

- Frontal Advance theory, Water Tonguing, Viscous Fingering, Application of fractional flow, influence of rock wettability on oil production performance, influence of viscosities, influence of formation dip, influence of initial gas saturation
- Influence of Mobility ratio, gravity forces, capillary forces
- Waterflood displacement mechanism and sweep efficiency calculations
- A lot of Case studies and exercises

DAY 3
This day will be dedicated to waterflood evaluation using a numerical approach. First, the theoretical background of numerical simulation will be elaborated. Students will be exposed to a waterflood simulator and oriented to the various input components. Students will spend the rest of the day setting up a reservoir model, institute waterflood and run various sensitivities to mobility, viscosity, grid orientation, permeability heterogeneity, etc to optimize the waterflood. Finally, various case studies will be presented to highlight the importance of reservoir simulation in waterflood design and evaluation. The following topics will be covered:

- Mathematical representation of two/three phase systems of transport equations associated with the various constitutive laws for closure
- Review of numerical methods to solve the system of equations
- How to set up a reservoir model to initiate waterflood evaluation
- How to run sensitivities, history match (pressure and saturation), forecast and analyze results
- A lot of Case studies and exercises
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*23rd – 27th June 2014, Kuala Lumpur, Malaysia*

**DAY 4**

This day is dedicated to monitoring both waterflood production and injection as needed to decide on remedial solutions, surveillance and monitoring. Participants will learn about methods to plot and map diagnostics information to gauge the overall health of the ongoing waterflood. Production diagnostics metrics will reveal areas of the field needing more attention and redistribution of water. Similarly, various injection well monitoring techniques (Hall and Modified Hall plots) and injectivity loss calculations will be discussed. Moreover, mechanical and chemical techniques to alleviate excessive water production will be elaborated. Various successful water shutoff /profile modification treatments will be elucidated. Participants will learn about:

- Production plots, WOR-cumulative production, Wcut-cumulative production, Rate of Change of Watercut-cumulative production
- Injection plots, Hall/Modified Hall plots, injectivity loss calculation, step rate test
- Swept volume calculation to determine water shut off or profile modification treatment volumes
- Capacitance Resistance Modeling
- A lot of Case studies and exercises

**DAY 5**

The final day discussions will include variations of waterflood for special reservoir/fluid systems. In particular, low salinity (LoSal) waterflood will be presented. Some reasons of its success based on the current state-of-the-art understanding will be presented. Furthermore, for viscous oil, polymer augmented waterflood will be taught. The instructions will include extension of fractional flow theory for this type of systems (exercise problem). Finally, various case studies of actual successful waterflood (in different geological setting and reservoir attributes) will be cited. The participants will learn about the following:

- LoSal waterflood – reasons of increased recovery and mechanisms to capture production upside.
- Polymer augmented waterflood – fraction flow theory, recovery calculation
- Reservoir Souring (causes and remedial actions)
- Case studies of various successful waterfloods

### Reservoir Engineering Training Courses (JANUARY - DECEMBER 2014)

<table>
<thead>
<tr>
<th>DATE</th>
<th>COURSE TITLE</th>
<th>INSTRUCTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>10th – 14th Mar</td>
<td>Mastering Gas Condensate &amp; Volatile Well Test Analysis</td>
<td>Alain Gringarten</td>
</tr>
<tr>
<td>23rd – 27th June</td>
<td>Waterflood Optimization</td>
<td>Deepankar Biswas</td>
</tr>
<tr>
<td>04th – 08th Aug</td>
<td>Applied Reservoir Engineering</td>
<td>Tarek Ahmed</td>
</tr>
<tr>
<td>18th – 22nd Aug</td>
<td>Practical Aspects of CO2-EOR Project Development</td>
<td>Ashok Singhal</td>
</tr>
<tr>
<td>08th – 12th Sep</td>
<td>Integrated Reservoir Characterization and Modelling</td>
<td>Hai Zui Meng</td>
</tr>
<tr>
<td>29th Sep – 03rd Oct</td>
<td>Advanced PVT &amp; EOS Fluid Characterization</td>
<td>Bahman Tohidi</td>
</tr>
<tr>
<td>17th – 21st Nov</td>
<td>Naturally Fractured Reservoir Characterization</td>
<td>Deepankar Biswas</td>
</tr>
</tbody>
</table>

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Please circle the package that you are attending!

<table>
<thead>
<tr>
<th>Investment Package</th>
<th>Deadline</th>
<th>5 DAYS MASTERCLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Price</td>
<td>20th Jun 2014</td>
<td>SGD $ 5,995</td>
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<tr>
<td>Early Bird Offer</td>
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