Managing Highly Fractured Waterflooded Reservoirs Using Streamline Simulation

September 13th, 2018
OREGON BASIN - OVERVIEW

**Discovered in 1912**
- 540 Wells
- 7,300 Gross Conventional BOEPD
- 660 MBWPD Produced
- 627 MBWPD Reinjected
- 33 MBWPD Surface Discharged

**Challenges:**
- High well count
- Large field
- Long history
- Fractured reservoir
- Active water drive
- Water Handling
Field Characteristics and Challenges

- Irregular patterns
- High well count
- High well status change frequency
- Fractured reservoir
- Multiple zones with varying permeabilities
- Active water drive
- No established no-flow boundaries

Workflow

- Determine patterns
- Define allocation factors
- Assign volume
- Calculate recovery
- Sense check
- Iterate for each pattern change
• Map of instantaneous velocity
• Solves the Transport equations numerically in 3D assuming constant pressure
• Matches producer and injector rates in the form of streamlines (representing a volume of flow)
• Computes at each chosen timestep – monthly, yearly, etc
• Simpler than full simulation and little history match is required – just enough to spot check the data

• Defines Patterns, allocation factors and efficiency
• Calculate volumetrics and pore volumes swept
• Optimize Waterflood

Diagrams courtesy to StreamSim
• 4 layer model: Embar, Upper Tensleep, Lower Tensleep, Madison
• 3D PhiH Grid built from tops we supplied from our PETRA project
• Production history taken from OFM
• Perforations and well locations and trajectory taken from PETRA and well files
• Check input data with historical field production
3 Month Streamline Snapshot

3 Month Simplified Streamline Snapshot

All-Time Simplified Streamline Snapshot

Color = Pattern
Thickness = Allocation
• RF per layer can be calculated from streamlines
• Identify swept areas and areas of opportunity
• Cross reference with production data to confirm
RECOVERY FACTOR VS. HCPV INJECTED

10 Most efficient injectors
Increase injection!

10 Least efficient injectors
Decrease injection!

How an injector reaches its end point is important!
Snap-shot in time of liquid rate vs ROIP each producer ‘sees’.

Inefficient Producers
Decrease rate!

Efficient Producers
Increase rate!
Flood Optimization

- Calculates injector and producer rate changes to optimize the WF
- Utilizes current perforations and well configurations
- User can set processing rate constraints
- Increases rate in more efficient areas and decreases rate in less efficient areas

Net 120 BOPD and potential LOE savings

Recommended injector and producer changes

Injectors and Producers

Net 120 BOPD Gain!

Shift water North!
Most wells have multiple zones perforated.
Profiles show majority of fluid flowing into Upper Phosphoria and Lower Tensleep.
2/3 of wells aren’t injecting into Lower Phosphoria or Upper Tensleep.
Increase field recovery by increasing injection to partially swept or unswept zones.
• Attempt to move water from SE to NW of North OB
  • Increase injection on NW injectors
  • Watch for producer responses
  • Decrease injection and production in SE area
  • Track performance at pattern level
• Increasing injection required small acid stimulations as most injectors were already choke wide open

<table>
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<th>Inj.</th>
<th>Delta Rate</th>
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<tr>
<td>CST30</td>
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- 3DSL is a 3D streamline simulator that calculates a reservoir snapshot at each instance in time
  - Performs pattern analysis and injector/producer production matching at each time step we choose (monthly, quarterly, etc)
- Based on our geological, well, and production data
- Generates
  - Well allocation factors and patterns
  - Pattern efficiencies and dimensionless curves
  - ROIP and pattern RF maps
  - Waterflood optimization suggestions
- Can be applied to many other fields we operate
- Proposed work
  - Increase injection in 5 northern injectors (needs acidizing)
  - Decrease injection in 5 southern injectors
  - Monitor producer response and pattern production