Waterflood Evaluation using Communication Analysis Tool

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Outline

- Typical waterflood workflows
- The dilemma
- Communication analysis tool
- Field case study
- Conclusions
Recap: Review Conventional WF Profile

- Waterflooding provides approximately double the primary reserves

- Majority of oil production in the World comes from WF

- Key Mechanisms are:
  - Pressure Maintenance
  - Displacement / Sweep

- Waterflood decline period accounts for majority of waterflood life (volumetric sweep efficiency becomes key factor governing WF recovery)
Logical Work Flow for Waterflood Analysis

Key Questions:

- What is the OOIP?
- How much oil is left?
- Where is remaining oil?
- How do we optimise recovery?
- Is it economic?
Routine Waterflood Surveillance

Field level analysis
- Composite plots
- Decline analysis
- RF vs. HCPVI
- Conformance plot
- $(Q_0, Q_{fld}, W_p)$ vs. $I_w$
- Watercut / GOR / WOR analysis

Well pair analysis
- Time lapse
- Bubble maps $(Q_0, Q_{fld}, W_p, I_w)$
- Hall Plots
- Static reservoir pressure data
- Communication Analysis
What Controls Waterflood Recovery?

- $E_d$ is the microscopic displacement efficiency
  ~ 60 to 65%

- $E_v$ is the volumetric efficiency
  - Volumetric sweep ranges between 10 to 80% for most floods
  - Low Volumetric Sweep Efficiency ($E_v$) is the main reason Waterfloods fail
  - Low sweep efficiency usually means high water cycling and high unswept oil volumes

- Communication Analysis will give indication of pattern $E_v$ by examining cause and effect

**Estimating Volumetric Sweep Efficiency**

$$Recovery = E_{vol} \cdot E_d$$

**Target for Waterflood optimization**

- High $E_v$
- Low $E_v$
The Dilemma

- Combination of RF vs. HCPVI, analogy, decline analysis indicates field or area upside but...

- Where do we:
  - place wells?
  - perform workovers?
  - convert producers to injectors?

It’s a plumbing problem
Communication Analysis (SweepSCAN™)

We want to identify key wells that communicate

Map view

Use all available DYNAMIC data (prod/inj/pressure) to identify high permeability, channelling, baffles, barriers
Communication Analysis (SweepSCAN™)

- **Objective**
  - fluid flow between well pairs
  - magnitude of communication
  - water cycling

- **Different variables used for correlation**
  - Water Injected
  - Liquid produced
  - GOR
  - Gas Injected
  - Gas Production
  - User defined variable
Field Example – Manyberries Sunburst Field (Canada)

Manyberries Sunburst Q
- OOIP = 25 MMSTB
- RF_{current} = 41.5% OOIP
- 81 Wells

Manyberries Sunburst JJ
- OOIP = 15 MMSTB
- RF_{current} = 33% OOIP
- 37 Wells

Manyberries Sunburst O
- OOIP = 14 MMSTB
- RF_{current} = 17% OOIP
- 33 Wells
Recovery Factor vs. HCPVI Plot

- Slope of the curve indicates waterflood efficiency
- Compare RF vs. HCPVI plots between fields with consistent geology and compare performance to avg. trend of field
- Group individual patterns into high, medium, poor performers (compare to avg. trend of field)

Cumulative Recovery (% OOIP) vs. Water Injected (HCPV)

- Good performance
- Average performance (unit performance)
- Poor performance (low)
- Early break over point (< 20% recovery)
- Low Sorw, excellent sweep Ev
- Favorable geology
- High Sorw, water channeling, poor areal/vert. sweep
- Unfavorable geology

Plot

- Slope of the curve indicates waterflood efficiency
- Compare RF vs. HCPVI plots between fields with consistent geology and compare performance to avg. trend of field
- Group individual patterns into high, medium, poor performers (compare to avg. trend of field)
Field Example – RF vs. HCPVI

- Sunburst Q and JJ fields track each other and are expected to recover +40% OOIP

- Sunburst O field breaks over earlier and appears will only recover ~25% OOIP
  - Has poor waterflood efficiency in comparison to analogues
  - Channelling or cycling of water to one or more producers? Communication Analysis will pinpoint which wells are problem wells.
SweepSCAN Analysis Manyberries Sunburst Q

Shows relatively good communication in most injection patterns
SweepSCAN Analysis of Sunburst O

- Less communication between injectors and producers
- Liquid production not correlate with injection changes at most wells

Shows good communication
Analyse Pressure Trends and Couple with Prod/Inj Response

Sunburst O Pressure Data

- Wells with high pressure – good communication with injector
- Wells with low pressure – poor communication with injector
Field Example – Sunburst O

- We see areas with high pressure and areas with low pressure

- Looking at water injection and water production bubble map, it is evident that a lot of the water injected is being produced by 1 producer - cycling
Case Study – Weyburn Midale – WF Conformance Optimization

- Weyburn Midale beds discovered in 1955
- Delineation drilling defined field limits 1956 - 1957
- Unitized for waterflood 1962 - 1963
- IOR techniques implemented 1985 - 1992. Including infill drilling, horizontal drilling and injection modifications (line drive)
- Miscible Flood starts in 2000
- Naturally Fractured Reservoir
Using SweepSCAN Analysis to determine poor areas of WF

- Use communication analysis software to select water shut off candidates
- Use injection and production data to determine areas of low waterflood volumetric sweep efficiency
- Quickly pinpoint areas that have upside potential!
A Closer Look at Selected Pattern

- Well produces at very high watercut
- Water injection rate tracks production wells water production rate
- High permeability pathway between injector and producer resulting in poor sweep to other producers
- Pattern would benefit from water shut off treatment - directing waterflood support to nearby producers
Weyburn Water Shut Off Treatment

Gel Treatment Dates/Volumes:

**Injector A**
- November 26-30, 2008: 7250kg polymer, 497m³ gel solution

**Injector B**
- January 12-22, 2011: 6225kg polymer, 661m³ gel solution

Waterflood Diagnostics indicates a volumetric sweep efficiency of around 53% in 2008. Evident that SE region is unswept
2008: Injector A
- 3 hours to breakthrough to producer C
- 16 hours to E

2011: Injector B
< 9 hours to breakthrough
To producer D

Flow of Polymer/Gel
Producers that show increase in Pressures and Oil Rates after Treatment
Oil Rate vs. Cumulative Oil Produced

The diagram illustrates the trend of Oil Rate (m³/day) versus Cumulative Oil (m³) produced over time, with lines indicating Oil Rate (P), 2008 Injection, 2011 Injection, and Producing Well Count.

A table below the graph shows:

<table>
<thead>
<tr>
<th></th>
<th>Prior to Gel injection</th>
<th>After Gel Injection</th>
<th>Incremental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Est. Oil Recovery (thousand Sm³)</td>
<td>840</td>
<td>1,180</td>
<td>340</td>
</tr>
<tr>
<td>Est. Oil Recovery (MMSTB)</td>
<td>5.3</td>
<td>7.4</td>
<td>2.1</td>
</tr>
</tbody>
</table>
North Sea Experience

- 3 completed projects in UKCS for majors
- Ideal technique for mature UKCS fields
- Complex reservoirs, e.g. multi-layered, faulted
- Supplements static geological model
- Has indicated poorly swept areas for infill well opportunities
- Communication analysis results supported by tracer test results
Conclusions

- **SweepSCAN™** is a powerful tool and workflow that provides valuable insight into the unknown plumbing of a reservoir
- Reduces risk in reservoir characterisation at start of evaluation
- Simple map view facilitates easy communication between disciplines/teams to improve decision cycle time
- Can be used successfully in multi-layered reservoirs
- Fast - Identifies optimisation target locations in days not months

Thank You
Questions