PRM on Johan Sverdrup - an unique Opportunity
Force seminar 2017 – Stavanger, Maximilian Schuberth
Agenda

- Introduction to the Johan Sverdrup Field

- Ambition for a world class recovery rate

- Permanent Reservoir Monitoring (PRM) on JS – an unique opportunity

- Summary
Introduction to Johan Sverdrup

License Partners:

- Statoil (Operator) 40.0267%
- Lundin Norway 22.6%
- Petoro 17.36%
- Aker BP 11.5733%
- Maersk 8.44%

General

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoir apex</td>
<td>~1800 m</td>
</tr>
<tr>
<td>Water depth</td>
<td>~110 m</td>
</tr>
<tr>
<td>OWC</td>
<td>1922 - 1934 m MSL</td>
</tr>
<tr>
<td>Pressure</td>
<td>Hydrostatic</td>
</tr>
<tr>
<td>Thickness</td>
<td>4 – 146 m (Well Observation)</td>
</tr>
<tr>
<td>Age</td>
<td>Late Triassic to Early Cretaceous</td>
</tr>
</tbody>
</table>

Reservoir Facts

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>25-30 % Porosity, High NTG</td>
</tr>
<tr>
<td></td>
<td>Multi Darcy permeability</td>
</tr>
<tr>
<td></td>
<td>No gas cap</td>
</tr>
<tr>
<td>Area/Volume</td>
<td>~200 km² area</td>
</tr>
<tr>
<td></td>
<td>Recoverable volumes 2 – 3 bbl</td>
</tr>
</tbody>
</table>
Johan Sverdrup - the giant value creator

TOP 5

70 %  50 YRS.  2 – 3 bn  660 000

One of the largest oil fields ever on the NCS

Ambition - recovery

Production horizon

Resources

Production capacity

bbl

bopd
Johan Sverdrup - the giant value creator

70 %
Ambition - recovery

Drainage Strategy
Water Flooding

IOR Projects
WAG Injection
Infill Drilling
Potential advanced IOR methods

Reservoir Surveillance
PRM
Well Monitoring
Reservoir Surveillance

Geophysical reservoir monitoring is part of the overall field surveillance and drainage strategy.

Permanent seismic cables will be installed on the seafloor.

PRM is the optimal solution, allowing:
- High Quality
- Flexibility
- Short Turnaround
Time lapse Concept

Base

Monitor

Pictures from Sascha Bussat, Statoil
Time lapse Concept
Time lapse Concept

Monitor

Pictures from Sascha Bussat, Statoil
Time lapse Concept

4D Difference

Streamer

Difference with better repeatability

PRM

Pictures from Sascha Bussat, Statoil
Time lapse Concept

1985

1999
Feasibility – Petro-Elastic Modeling

Converting reservoir properties to elastic rock properties

- Reservoir Model
  - Porosity
  - Pore Pressure
  - Saturation, GOR
  - NTG

- Seismic Domain
  - $V_p$ Compressional Velocity
  - $V_s$ Shear Velocity
  - $\rho$ Density
Feasibility – Petro-Elastic Modeling

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- Pore Pressure
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Fluid Substitution
- Dry Rock Model
- Pressure Model
- Fluid Model
- Mineral Model

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Seismic Domain
- \( V_p \) Compressional Velocity
- \( V_s \) Shear Velocity
- \( \rho \) Density

Synthetic Seismic
Feasibility – Petro-Elastic Modeling

PEM provides a way to model expected 4D effects (or seismic amplitude changes), which can be used as input to:
- survey design,
- hypothesis testing (e.g. IOR, well placement)
- and ultimately model calibration.

Blue:
Water replacing Oil /Gas

Red:
Gas replacing Water/Oil
Oil replacing Water
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Mean Al ratio
Time 3 - Baseline

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Defining a PRM Layout

Aspects controlling the layout of the PRM system.

<table>
<thead>
<tr>
<th>Areal Coverage</th>
<th>Survey Design</th>
</tr>
</thead>
</table>
| **Field development plan**  
  *e.g.* schedule of wells, drainage strategy |  |
| **Installation window**  
  *e.g.* time of the year, other installations ongoing |  |
| **Cost-Benefit**  
  *e.g.* expected value to cost of additional length (or area) |  |
| **Seismic detectability**  
  *e.g.* reservoir thickness, structure |  |
PRM Layout

- Total field area about 200 km²
- PRM outline 125 km²
  - 400 m cable separation
  - 335+ km of cable
PRM on JS – An Unique Opportunity

Production

Time

Early
Decline
Tail

Production at max. process capacity
Cost effective Access
Recovery of challenging resources

Early Calibration of the model
Aquifer & Gas cap monitoring
Well Management
PRM on JS – An Unique Opportunity

As a comprehensive monitoring solution, the PRM system on JS provides a link between IOR methods, and of course the general drainage.

It can monitor them alone and their interaction, throughout the life of the field.

Its various monitoring applications can provide an improvement for business cases of IOR methods.
Possible applications include:

- Overburden Surveillance
- Seismic PLTs
- Production optimisation
- Well placement
Summary

- Technical feasibility of the PRM system on Johan Sverdrup has been shown.

- Substantial efforts went into designing the areal coverage and cable spacing.

- The derived layout is a good balance between cost, monitoring focus areas and installation constraints.

- As a monitoring solution, it can positively contribute to the business cases of IOR methods.

- Through monitoring, PRM contributes to IOR effectiveness, thus can ultimately be considered an IOR method itself.
Thank you!

We also thank the partners for permission to present this work:
PRM on Johan Sverdrup - an unique Opportunity

Maximilian Schuberth, Statoil

www.statoil.com