Ula Field

- Overview
- Field History
- Current WAG Scheme
- Future WAG Scheme
- Summary
Ula Facts

- **Ula Ownership:**
  - 80% - BP (operator)
  - 20% - DONG E&P Norge AS

- **On stream:** 1986
- **Tambar Field tie-in:** 2001
- **Blane Field tie-in:** 2007
- **Oselvar tie-in:** 2011

- **STOOIP**
  - ~1 billion stb (160 mill Sm³)

- **Produced as of 01-01-10**
  - 440 mmstb oil (70 mill Sm³)
Ula Structure

- Elongated four-way salt induced dip closure
- Reservoir dips between 0 and 10°
  - Lower dips at the crest and to the south (0 to 5°)
- A NW-SE fault system bisects the structure
- Shallower oil-water contact in west flank
- Reservoir depth: 3350-3800m
Ula Fluids

• °API ~ 40
• T res ~ 295° F (146° C)
• Pb ~ 2300 psi (159 bar)
• P init ~ 7100 psi (490 bar)
• P res ~ 6300 psi (434 bar)
• MMP ~ 5000 psi (345 bar)
• GOR ~ 500 scf/stb (89 m³/m³)
• Visco ~ 0.35 cp
• Viscw ~ 0.33 cp
• Bo ~ 1.36 rb/stb (@Pb)

• C1 in Injection Gas ~ 68%

Miscible WAG Works Well in Ula
• High SORW (35 - 50%)
• Under-saturated oil
• Pres: 6300 > MMP: 5000 psi
Upper Jurassic, shallow marine sandstones

Reservoir Units

<table>
<thead>
<tr>
<th>Unit</th>
<th>Perm (mD)</th>
<th>Initial</th>
<th>After WF</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A1</td>
<td>1-10</td>
<td>Oil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1A2</td>
<td>1-20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1A3</td>
<td>2-25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1B</td>
<td>5-100</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Fluids

- **Sorw ~ 35-50%**
- **Sorm ~ 5-10%**

- **Oil**
- **Water**
- **Gas/Water**

Baffle between Unit 1A2 & 1A3

- Capable of holding >1000 psi (70 bar)

Baffle in lower Unit 2

- Capable of holding >35 psi

Current WAG

- Upper Jurassic, shallow marine sandstones

Unit 1

Hor. Producers

Current WAG

Unit 3

WAG Injectors

Depth Metres

TVD Metres

Sw_2 V/V
**Oil Rate mbd**

Production increase

Arrested decline

**WI Rate mbd**

WCUT

**GI Rate mmscfd**

GOR scf/stb

- **Online 10 years after discovery**
- **WI starts**
- **Sharp decline WAG Studies**
- **Unit 1 production starts**
- **WAG starts**
- **Tambar More WAG conversions**
- **WAG oil in all producers**
- **Behind floodfront core**
- **First deep horizontal injector**
• Appropriate water handling capacity → upgraded in 1992 and 1994
• Reservoir pressure above minimum miscibility pressure (~5000 psi / 345 bar)

• Appropriate gas handling capacity → 120 mmScfd gas processing (3.4 mill Sm³)
• Gas compression → installed in 1993-1994 for gas lift
• Gas supply → Re-inject gas after export route via Cod Field lost. Tambar, Blane and Oselvar tie-in.
• Conversion of water injectors to gas (WAG) injectors
Current WAG Scheme

Overview  Field History  Current WAG  Future WAG  Summary

• 3 vertical WAG producers up-dip
  ‒ 1 shut-in
• 3 vertical WAG injectors down-dip
  ‒ 1st injector converted in 1997
  ‒ 3 additional injectors in 2001/2002 following Tambar tie-in
  ‒ New WAG injector behind WAG flood front (A09A) in 2006
• 1 horizontal WAG injector in Unit 3
• 1 vertical water injector down-dip
  ‒ Integrity problems with gas injection
• Current injection capacity
  ‒ Gas handling: 120 mmscf/d gas (3.4 mill Sm³)
  ‒ Gas injection: 90 mmscf/d gas (2.5 mill Sm³), limited by wells
  ‒ Water handling: 160,000 bbl/d water (25,400 Sm³)
  ‒ Water injection: 50,000 bbl/d water (11000 Sm³), limited by injection pump
• Large sectors (1km – 2.5 km)
• Sectors identified through tracer program
  – Originally with water tracers (waterflood sectors)
  – Verified with gas tracers (WAG sectors)
• Initial breakthrough times
  – Water: 11 to 55 months
  – Gas: 15 to 35 months
• 3 tracer injections in 2010
WAG Works in Ula

Overview  Field History  Current WAG  Future WAG  Summary

- Historically **5-10 mbd** of WAG oil (800-1600 Sm$^3$/d)
  - 25-50% of Ula production
- Currently ~20 mbd WAG oil, ~60-70% of Ula production
- Total WAG oil: ~**18 mmstb** (2.9 mill Sm$^3$)
- Current scheme, including the contracted Oselvar gas, will recover over **7% of STOOIP**
• 128 bscf of injected gas (3.6 bill Sm$^3$)
  - ~20% recycled gas

• WAG oil produced from all 4 sectors
  - Indicated by gas tracer data and confirmed by well test results
• Limited sweep in lower perm Unit 3
  - Verified by PLTs in injectors while on gas and water injection
  - New injectors target Unit 3

WAG Efficiency:
~7 mscf gas / bbl oil
(~0.8 Sm$^3$ oil / kSm$^3$ gas)
• A-12A recompleted. Came online in June 2009, with higher oil rate than expected, and very high GOR.

• A-15A redrilled close to original A-15, online in November 2009.
  – High initial production rates.
  – Accumulation of mobilized oil
Key to Evaluating Benefits of WAG

- Gas tracer injection and sampling
- PLT in injectors
- Weekly WC measurements
- Monthly well tests
- Continuous THP monitoring
  - Injectivity
  - WAG slug identification
- A09A core in mature WAG sector
- 4D seismic being evaluated
Data acquisition behind WAG flood front

Overview  Field History  Current WAG  Future WAG  Summary

Extensive Data Acquisition Program in 2006
• A09A was drilled in a mature WAG sector
• Reservoir was cored & logged
  - To evaluate effectiveness of current WAG scheme
  - To quantify $S_o$ distribution
• 101 meters of core (100% core recovery)
• Performed extensive study program
  - Over 800 core plugs taken for analysis
  - Routine core & fluid sample analysis
  - Sw and GC, (well site and lab plugs)
  - SCAL m & n, Rw from w/s plugs
  - Log Analysis

Overview
Field History
Current WAG
Future WAG
Summary
Moving to Expanded WAG (XWAG)

- Successful current WAG scheme in Ula
  - Clear indication of mobilized oil production
  - ~ 18 mmstb incremental oil produced
- Extensive data acquisition in A09A to evaluate effectiveness of WAG
  - Clear indication of reduction of $S_{or}$

- Simulation studies on Expanded WAG
  - Indicate potential for a healthy additional incremental recovery
  - Maximize recovery with Unit 3 horizontal injectors
25 XWAG targets screened and ranked according to recoverable resources

7 XWAG targets chosen for recoverable resources, location (sweep)

2 XWAG targets chosen for recoverable resources, location, drillability from existing slots, & good geologic understanding
- 2006: A09A WAG injector drilled & cored behind flood front (10% $S_{orm}$)
- 2007-2008: Increase gas handling capacity with Ula Gas Upgrade (UGU)
  - Gas handling 60 mmscfd $\rightarrow$ 120 mmscfd (3.4 mill Sm$^3$/d)
- 2007: Identify locations & slots for 2 new WAG injectors
- 2007-2008: Investigate passive downhole flow control for uniform injection in horizontal wells
- 2008-2010: Replace water injection pumps $\rightarrow$ 140,000 bbls/d (22k Sm$^3$/d)
- 2008: Commitment to purchase Oselvar gas volumes from 2011
- 2009: Bring back 2 WAG Producers
- 2010: First XWAG type well drilled

Future gas for Ula WAG Scheme: $>$150 bcf
XWAG Plans

Overview  Field History  Current WAG  Future WAG  Summary

- **2 new horizontal injectors** in Unit 3 (2010&2012)
  - Target deeper injection in Unit 3
  - Long, horizontal injectors ~1000m with passive downhole flow control & isolation packers for uniform injection
- Potential for **5 more horizontal injectors**
  - Install new wellhead platform
  - Continue injection in Unit 3 with long, horizontal wells
- Evaluate additional sources of gas for long term
- Full project has potential to increase recovery by ~10% of STOOIP
  - Bring **total recovery to ~70%** through technology
- Enable Ula to produce past 2028

![Diagram of XWAG plans with labeled wells and injection paths.](image-url)
XWAG Challenges and Mitigations

- Commerciality - high early investment and late pay-back
  - Project phasing
  - 3rd Party tie-ins (Oselvar)
- Completion conformance
  - Passive downhole flow control
  - Evaluation of concept needed
- Reservoir response prediction
  - Comprehensive uncertainty analysis to understand range of outcome
- Life of field surveillance plan
  - Surveillance commitment
Summary

• Ula forms a strategic hub in the Norwegian North Sea
  - Successful tie-ins of Tambar, Blane, tie-in of Oselvar in 2011
• Miscible WAG is an effective process in Ula
  - Clear indication of mobilized oil production from WAG producers
  - Clear indication of reduced $S_{or}$ (down to 10%) in WAG flooded zone from A09A core/log data
  - Recovery increased and lifetime extended
• WAG Expansion will realize a healthy additional incremental recovery of ~10% STOOIP
  - Enables production at current levels beyond license period of 2028
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