Introduction to flow diversion technologies

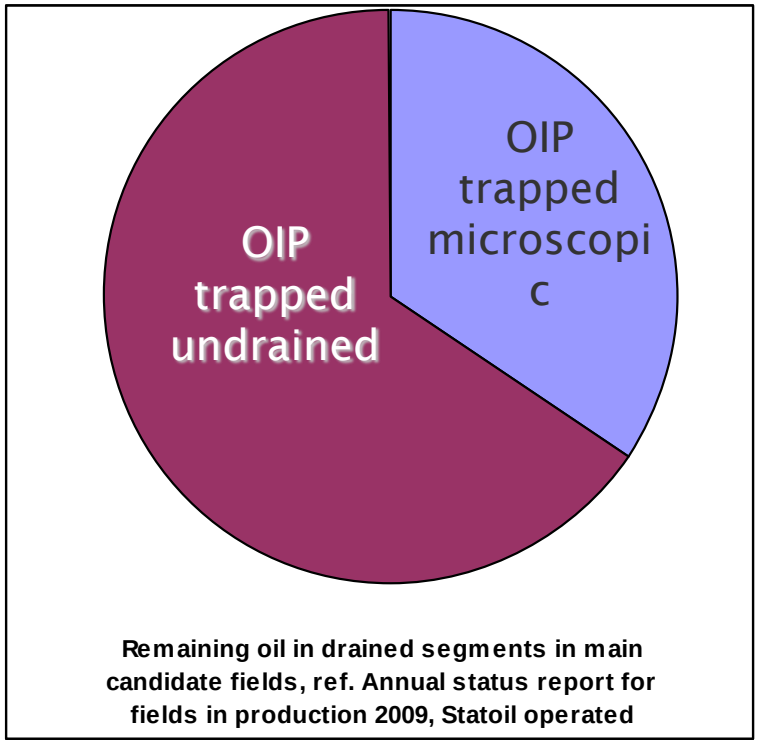
Force workshop, Stavanger, January 20. 2010

Outline

- Motivation
- Chemical flow diversion
- Applications and plans in Statoil

Motivation

- Efficiency of water injection processes is limited by permeability contrasts
- In Statoil operated fields with water injection, ~2/3 of oil in drained segments is mobile
- Improved sweep efficiency by diverging the injection water constitutes a significant IOR potential



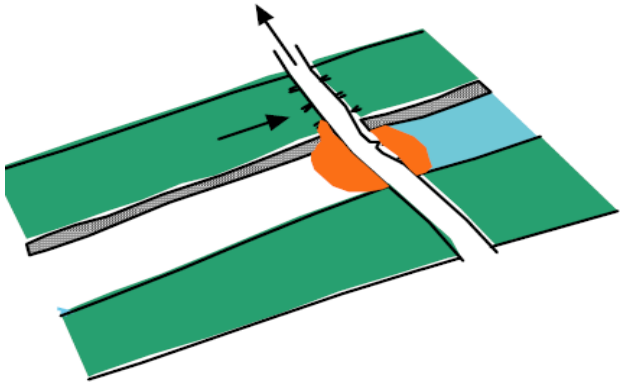
Remaining oil in drained segments in main candidate fields, ref. Annual status report for fields in production 2009, Statoil operated

Flow diversion by injection of chemicals

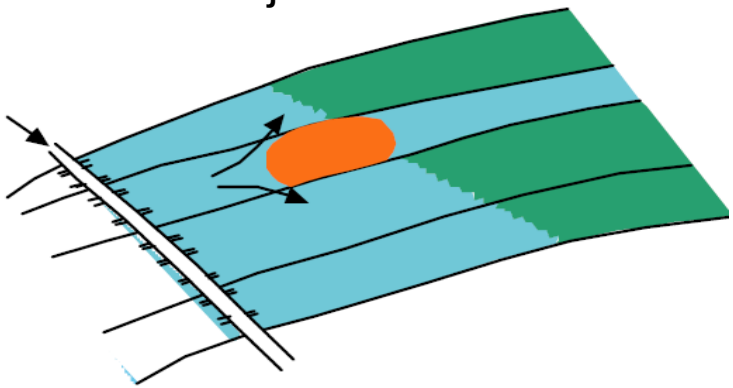
1. Profile modification
   - Near wellbore treatment of production or injection wells
   - Mainly applied for prod wells

2. Deep flow diversion
   - Flow restriction placed some distance from injection well, typically 1/3 of inter-well distance
   - Applied in injection wells

Oil Producer



Water injector



Profile modification by chemicals

- Type:
  - Water shut-shut off, or
  - Rel.perm-modification treatments (RPM / DPR)
- Beneficial conditions
  - Commingled production / injection with limited cross flow
  - Permeability contrasts
  - Limited length of perforation interval to be treated
- Mechanical treatment may in some cases be an alternative

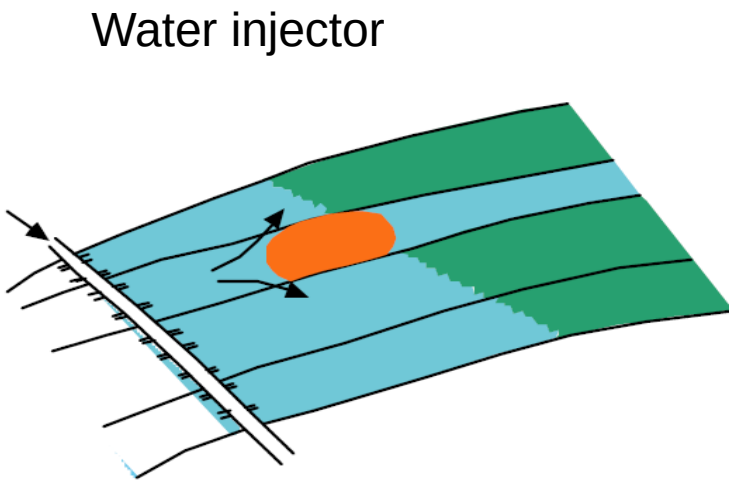
Chemical water shut-off treatments in Statoil by 2006

Well	Evaluation	Result	Comments
A, 1990	Failure	Water prod unchanged	Too little volume of gel Gel system: Xanthan + Cr
B, 1993	Moderate success	Small increase in oil prod	Thin gel; total WSO not the goal. Gel system: Silicate
C, 1994	Success	Red water prod, incr oil prod	Thin gel; total WSO not the goal. Gel system: Silicate
D, 1996	Success	Qw red 1000 Sm^3 / day Qo incr 400 Sm^3 / day	Dual injection. Problem with removal of packer Gel system: Injectrol
E, 1996	Mechanical shut-off	Watercut reduced from 92% to 75%	Failure in mixing. Plug set. Gel system: Maraseal + straddle
F, 1997	Moderate success	Small increase in oil prod	Thin gel; total WSO not the goal. Gel system: Injectrol
G, 1997	Moderate success	Low oil rate, high water rate	Increased prod from lower intervals Gel system: DGS + patch flex
H, 1999	Success	Watercut reduced from 100% to 5% Oil production 300 Sm^3 / day	Deep penetrating cement squeeze System: SqueezeCrete
I, 2000	Moderate success	GOR reduction, Oil production increased by 300 Sm^3 / day	Temporary chemical plug Gel system: H2Zero
J, 2001	Moderate success		Repair of tubing leakage in scrams completion Gel system:
K, 2004	Success	Water rate reduced by 800 Sm^3 / day	DPR / RPM treatment Gel system: Emulsified gel, mGel (gen 1)
L, 2005	Failure	No effect observed	DPR / RPM treatment Gel system: Aquacon HP, polymer/micro-gel system
M, 2006	Failure	No effect observed	Reduce water cut and sand production Gel system: Emulsified gel, mGel (gen 2/3)

Deep flow diversion

Can have a significant potential when:

- Displacement process efficiency is limited by permeability contrasts and flow through ”thief” zones
- Pore volume of thief zone should not be moderate compared to the total oil zone volume
- Cross flow from thief zone to surroundings exists



Some chemical technologies for deep flow diversion

Technology	Blocking mechanism	Field tests	HSE class
Sodium Silicate	Permeability reduction by geletion and precipitation. Triggered by T, pH and divalent cations	Some, mainly profile control	Plonor
Bright Water^{tm}	Massive pore blocking by particle expansion and agglomeration triggered by temperature increase	Several successful fields tests, incl. offshore	Red
LPS / CDG	Micro-gels giving flow diversion on pore scale (HPAM + x-link, low C)	Some field tests in China, ambiguous conclusions reported	Red
Abio gel	Permeability reduction, mainly by adsorption of micro-gel particles	Several successful field tests	Yellow
Preformed Particle Gels (PPG)	Relatively large particles, mainly applied to fractures or fracture-like features	Several successful field tests	Red / black
Stargel ^{tm}	Pore blocking by micro-gels of very narrow size distribution	Gas storage wells in France (no results yet).	Yellow / Red

Thank you

Presentation title

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Preconditions for deep flow diversion

- Detailed understanding of inter-well communication and efficiency of water injection process
- Water injectors in or very close to oil leg

- Key elements to know:
  - Volumetric sweep efficiency of injection water
  - Remaining oil volumes and distribution
  - Remaining oil saturation in swept areas
  - Break-through time between injection and production wells
  - What is determining / limiting volumetric sweep efficiency