From pilot to field implementation – the main challenges

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Content

- Status EOR NCS
- Pilot plans
- Decision process EOR – from pilot to full field implementation
- Summery

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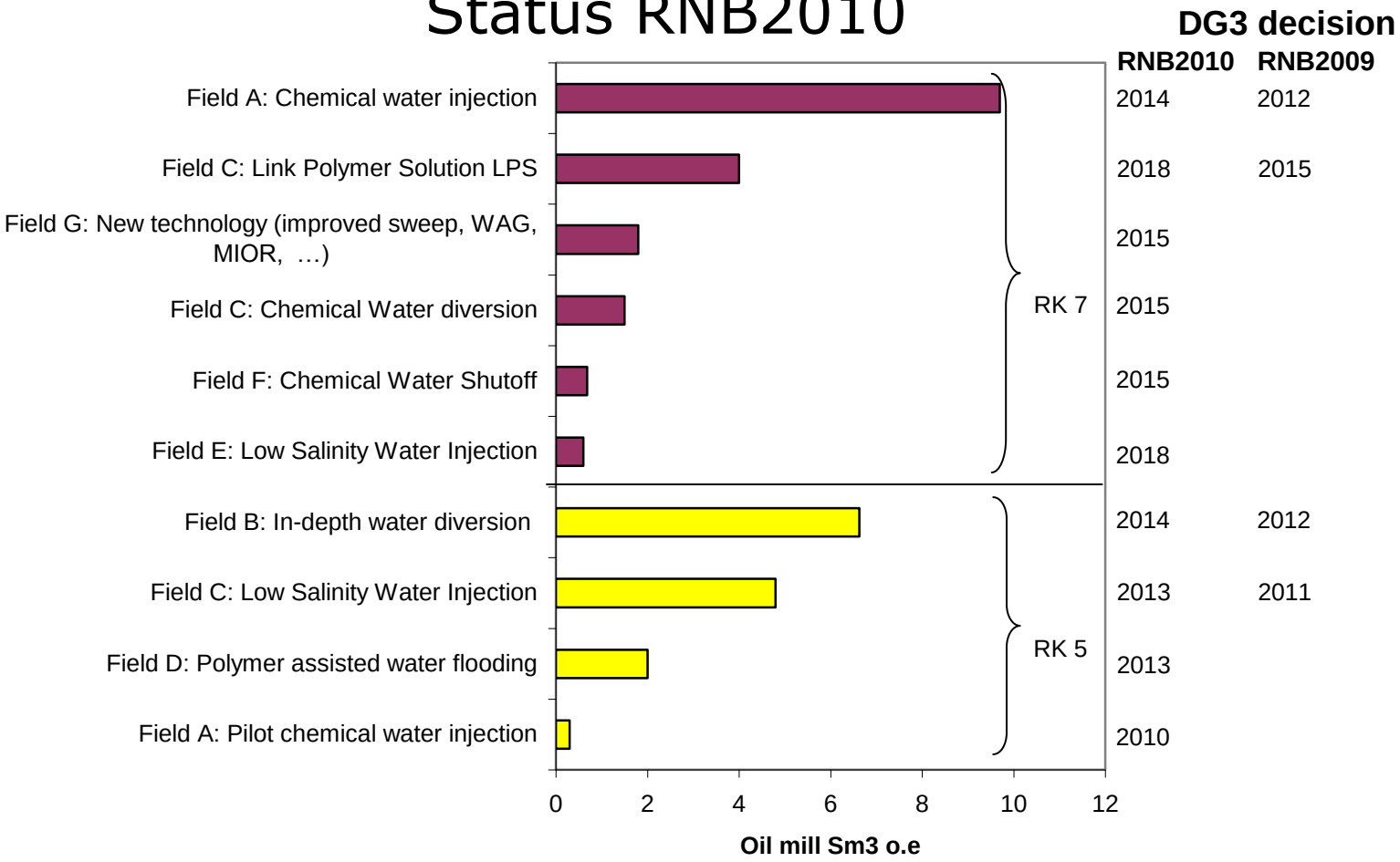
EOR – Advansed water injection Status RNB2010



- The four largest EOR-projects have postponed DG3 with 2 years or more since fall 2008
- One field reported a EOR volume of 2 MSm3 in RNB2010, but the project is now terminated.

EOR Pilot Plans 2010

Felt	Pilot	Decisions
Field A	Injection test diverging chemicals	DG4: Q2 2010
Field A	Two well pilot. diverging chemicals.	DG3: Q1 2010 DG4: Q3 2010
Field B	Injection test. Silicate	DG4: Q2 2010
Field B	Two well pilot Silicate	DG4: Q2 2011
Field C	Single well chemical tracer test (SWCTT) LoSal	DG4 2010
Field C	Two well pilot diverging chemicals - BrightWater	DG4 2010
Field C	Injection test Link Polymer solution (LPS)	DG4 2010
Field C	Two well pilot or several Single well tracer test LPS	DG4 2011

- Many pilot plans and other EOR activities in 2010 and 2011.

- It is important that field licences follow the plans and make decisions. For all these fields EOR is time critical

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Possible Pilot Workflow

1. Identify the uncertainty
2. Study how uncertainties can be addressed and which are irredusible.
3. Can uncertainties be reduced significantly within a reasonable time by using the Pilot? Are there alternatives to the pilot to reduce uncertainty?

4. Defining the data collection program and the success criteria for the Pilot

A 'pilot' should not only be a demonstration project, but a method for actively reducing the uncertainty in the full field project as well as to optimize the main project

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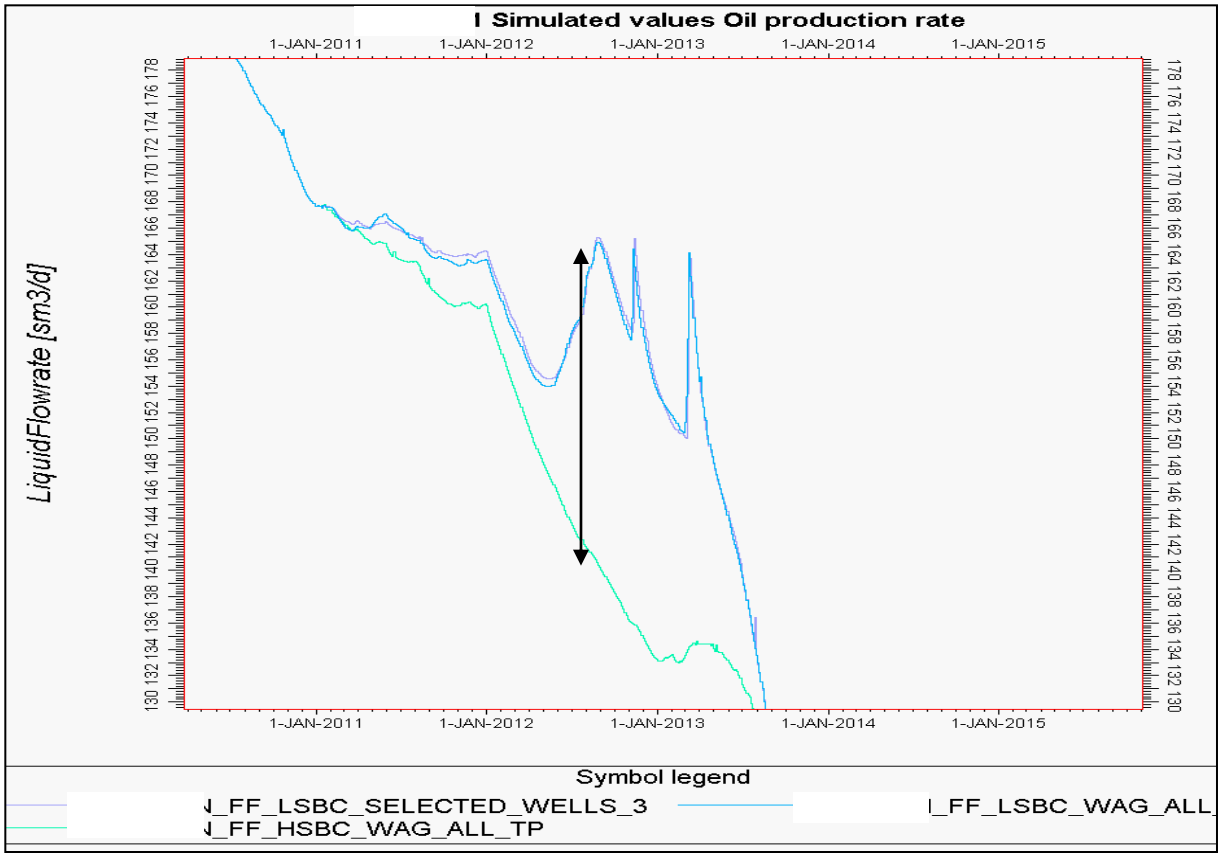
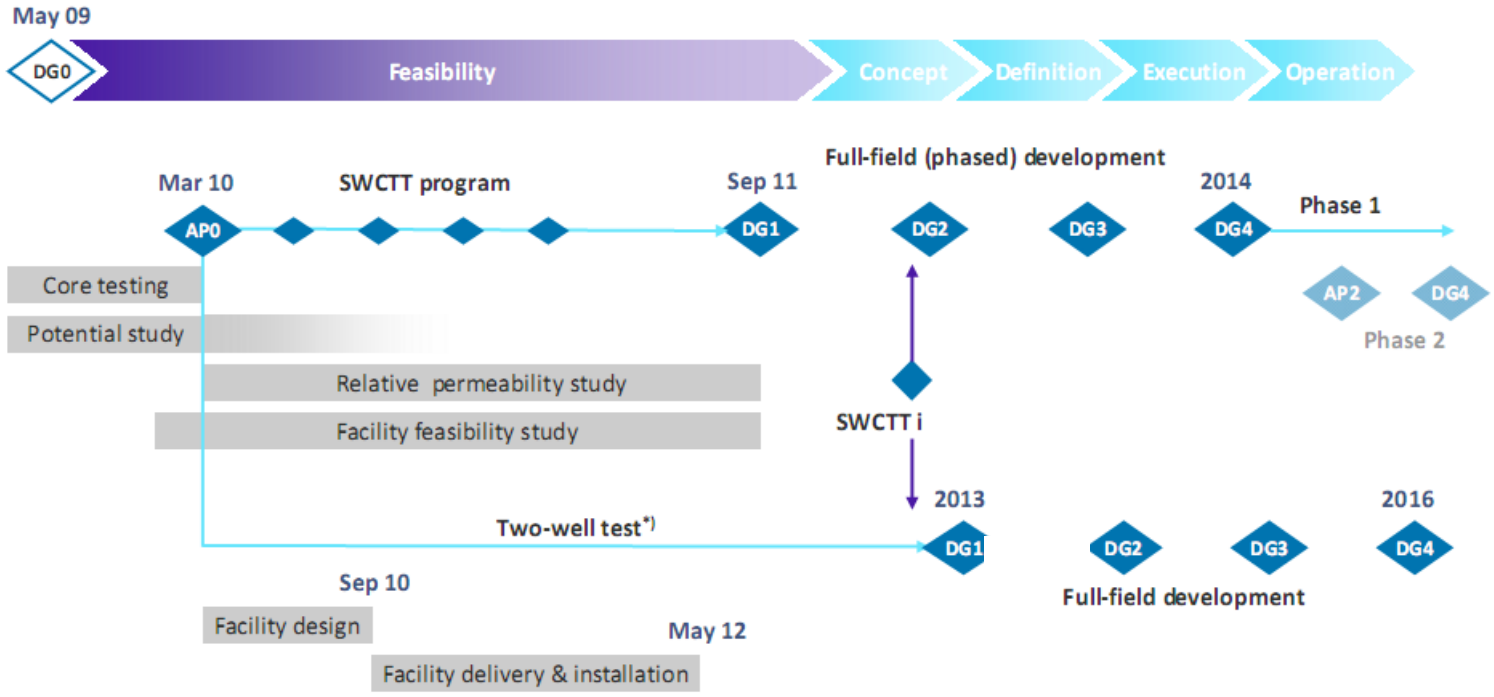
Example potential LoSal pilot



- Injection start 1.1.2011
- Maks. differense in oil-rate 2013: 25 Sm^3/d (18%)
- Max red. i vannkutt: 3%

Plan LoSal Field C



Project focus is on understanding and making the correct decision.

Data collection program: Two-well test

Pros

- Large effect on reservoir uncertainty if successful (proves both mobilisation and production)
- A successful pilot covers investment (partly at least)
- Gives operational experience
- RO plant solution has possible post-uses even if project is stopped

Cons

- Unclear if test is will be conclusive
- Large investment upfront
- Delayed field implementation (2 yr)
- Challenging to find good test areas
- Probably only test in one formation

The next step is to evaluate the two different scenario.

Data collection program: SWCTT series

Pros

- Allows to investigate more than one formation
- Lower uncertainty in measurement of mobilisation compared to two-well test
- Relatively low investment level for qualification
- Saves 2 years to field implementation

Cons

- Will not reduce uncertainty as much as a successful two-well test could
  - Proves mobilisation but not increased production
- Implies decision on FF implementation at higher risk (possible?)
- Reduced production during testing
- Requires well intervention
- Do we have enough wells?

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Example - Evaluation data collection program LoSal
Single well chemical tracer test program gives the highest NPV

	2-well pilot 1 year	2-well pilot 2 year	2-well pilot 3 year	SWCTT 4 test 1 year
Field implementation - DG4	2016	2017	2018	2014

- A conclusive test is uncertain with a 2-well pilot. Most likely that a 2-3 year test is needed.
- By drilling a well closer to the injector the 2-well pilot can be reduced to one year.
- The largest uncertainty is the reduced potential with a delayed full field implementation.

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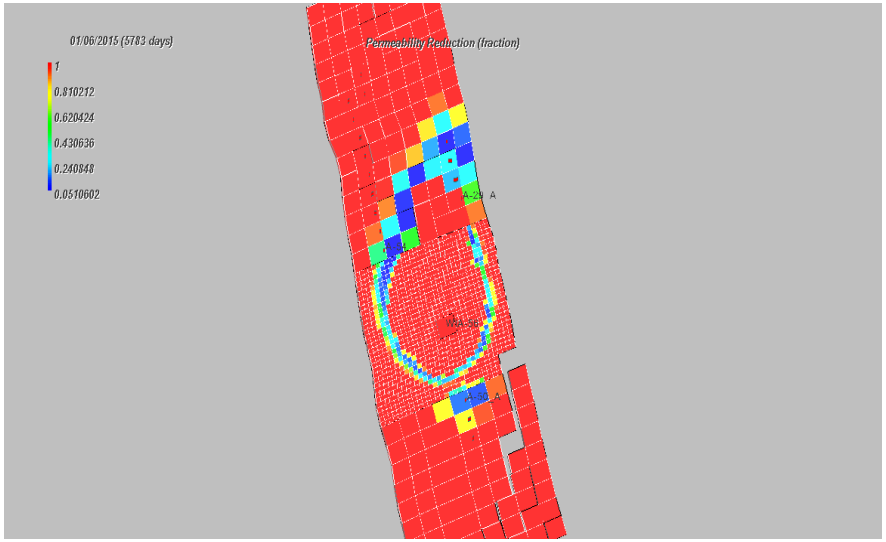
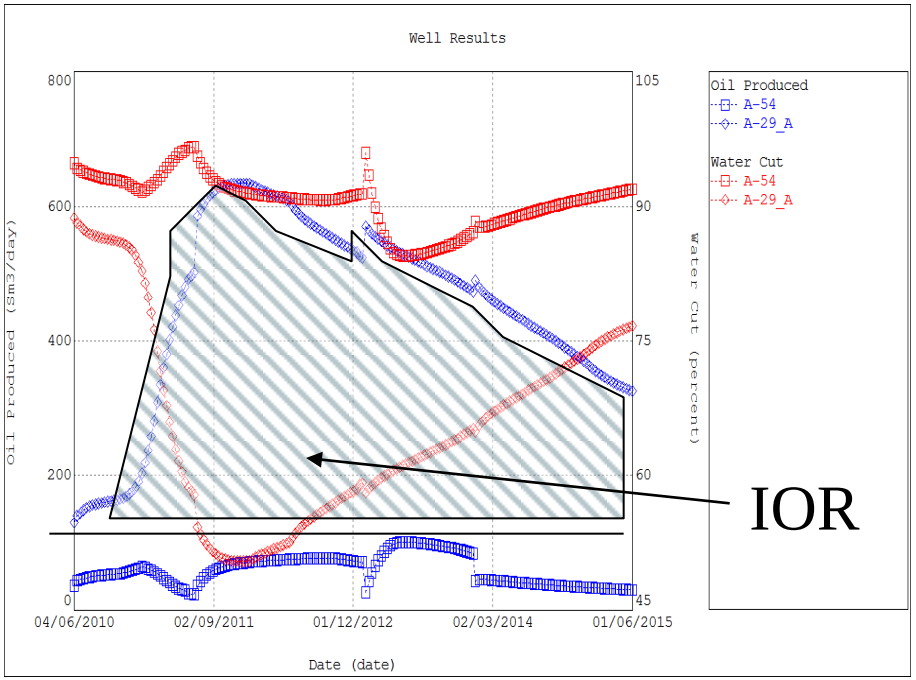
Example BrightWater 2-well pilot

Permebilty reductions set up by BrightWater





- Injection 9 days – start 1.1.2011
- Responce after 1 year
- Increase in oilrate – 200%
- Oil increase – 0,2-0,4 MSm3 within 5 years

- BrightWater has small upfront CAPEX investments; minimal modifications. 'Learn as you go'; well by well decision

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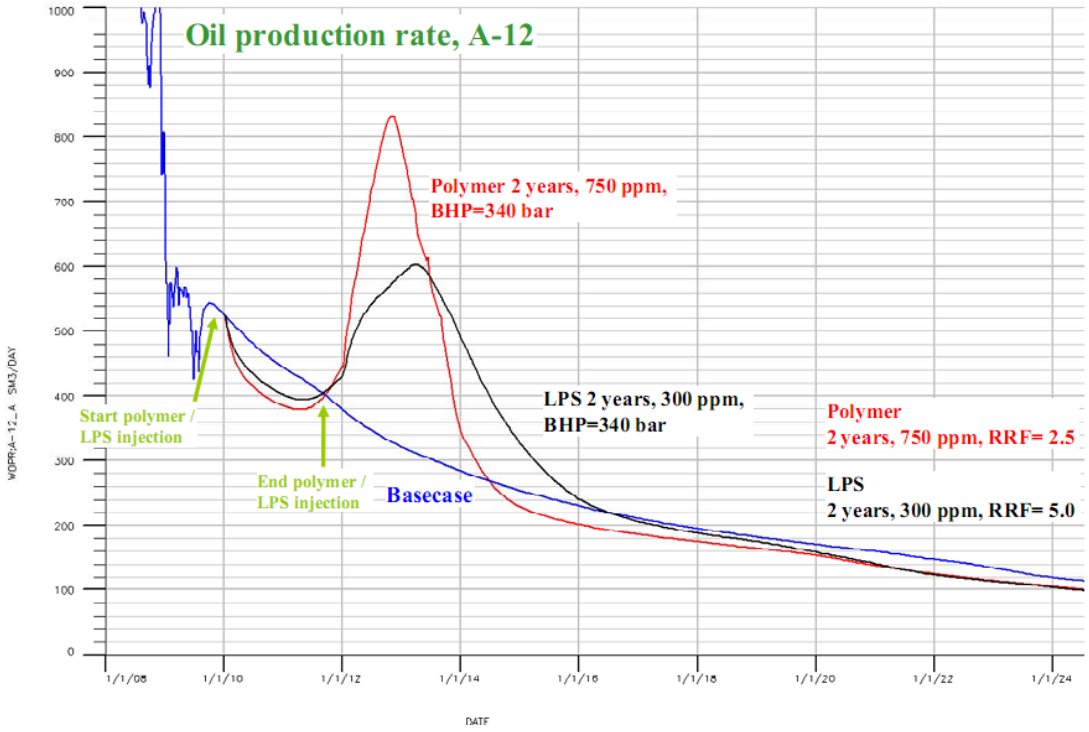
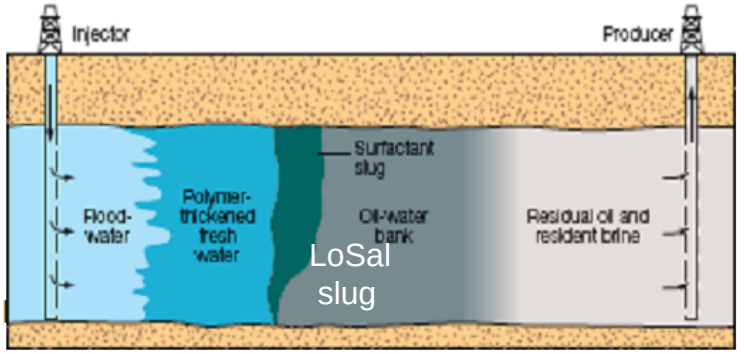
Example Polymer/Link Polymer solution
Potential pilot Field C



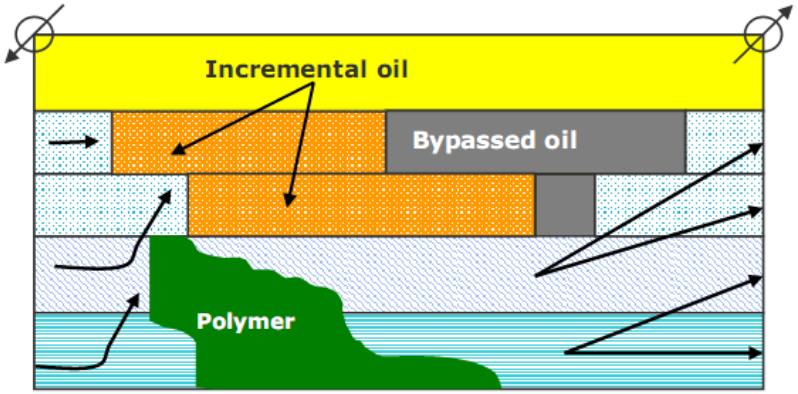
- Significant increase in oilrate (50-100%) after 2,5 years
- Increase of 0,2 MSm3 within 4 years
- Pilot economically robust.
- A challange to evaluate microscopic effect of LPS

Combined LowSal and surfactants or polymers

- Surfactants
  - Reduce oil-water interfacial tension
  - Reduce capillary forces
  - Improve microscopic recovery efficie



- Polymers
  - Increase water viscosity
  - Improve mobility ratio
  - Improve sweep efficiency



Advantage of the combined EOR methods
- Low salinity reduces surfactant and polymer retention
- Same effect with less amount of chemicals
- Low cost surfactants can be used at these salinities

Kilde: Statoil, CIPR

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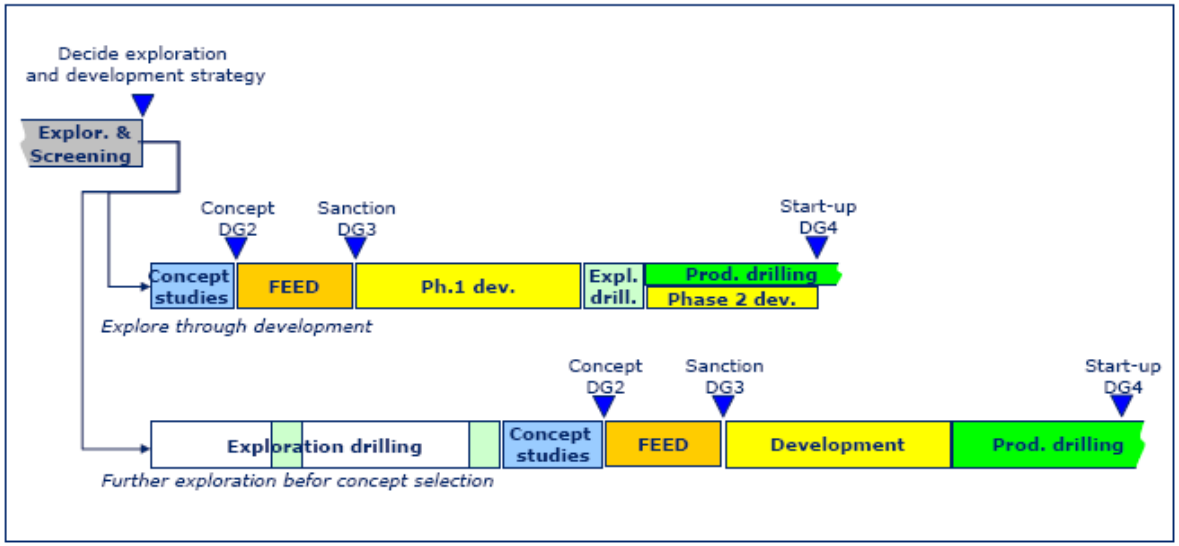
Decision of the IOR-pilots before full-field implementation should be seen in context with other similar decisions under uncertainty

Example: Decision of a new appraisal well



Despite the uncertainty in the volume + -50%, it was considered that the appraisal well would not provide sufficient information to impact the concept selection

What is the value of the information and what is the probability that information from the pilot will change the decision?

Example decision process large EOR project Polymer injection in deep-offshore Angola field

- Background
  - Base case development is with water injection , with 4 subsea injection lines and 31 injectors. Maximum water injection rate will be 375 000bwpd. Desulfated sea water is injected at start, but produced water will be reinjected later in the life of the project.
  - Increased recovery estimated to 3-7 percent based on lab and reservoir simulation

- This field meets many favourable criteria for polymer injection:
  - Medium viscous oil 3 to 7cP
  - High permeability : multi darcy
  - Clean sand meaning low polymer adsorption
  - Low temperature : 50°C which is ideal for conventional hydrolysed polyacrylamides (HPAM)

- When referring to existing polymer operations, the major challenges are related to the salinity of the water and the deep offshore configuration (both geoscience and architecture/logistics).
  - Limited up-front Capex. Opex include chemicals and logistics.

- After a full design of the injection strategy (polymer selection – concentrations – stakes …) a phased approach has been retained with
  - an injectivity test in April 2008 – 1 single well – short duration – to address the risk of plugging the formation
  - A full line polymer injection for around 1 yr to ensure longterm injectivity, long term operability of the polymer facilities and potentially reservoir performance. 7t/day of polymer will be injected.

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Environmental challenge

- Chemical flooding has a large potential for increased recovery both reducing residual oil and increasing the mobility of oil, sweep. Extensive use internationally but limited use on the Norwegian shelf

- The challenge by chemical flooding:
  - Often red chemicals that are mixed with water.
  - For some chemicals, it may be back produced to the platform.

- The following chemicals considered:
  - **Silicate** is a green chemical. It must be injected LoSal water before and after injection of Silicate. Consequences for injectivity by contact with salt.
  - **Bright Water** is a red chemical that is expected to remain in the reservoir. The questions are the requirements that are put to BrightWater to be approved by SFT.
  - Injection of **Polyacrylamid** and **LPS** are characterized as being red. There is a possibility that the chemicals will reach the producers. The question is what requirements must be set to regularity etc to get an approval by SFT for use in Norway

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Summery

- A 'pilot' should not only be a demonstration project, but a method for actively reducing the uncertainty in the full field project as well as to optimize the main project

- Decision of the IOR-pilots before full-field implementation should be seen in context with other similar decisions under uncertainty
  - What is the value of the information and what is the probability that information from the pilot will change the decision?

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