

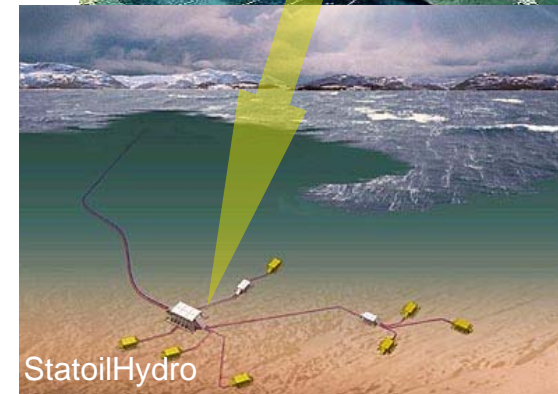
Assessment of Sustained Well Integrity on the Norwegian Continental Shelf

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Norwegian Continental Shelf Development Trends

- The industry goes **subsea** and **towards the artic**
- Remote operations and control
- Integrated operations
- **HPHT** (Kristin, Victoria, ...)
- **IOR** and extended field life cycle
- **Re-use of well infrastructure** for low cost drainage points

- **Sustained field integrity needs to be documented**

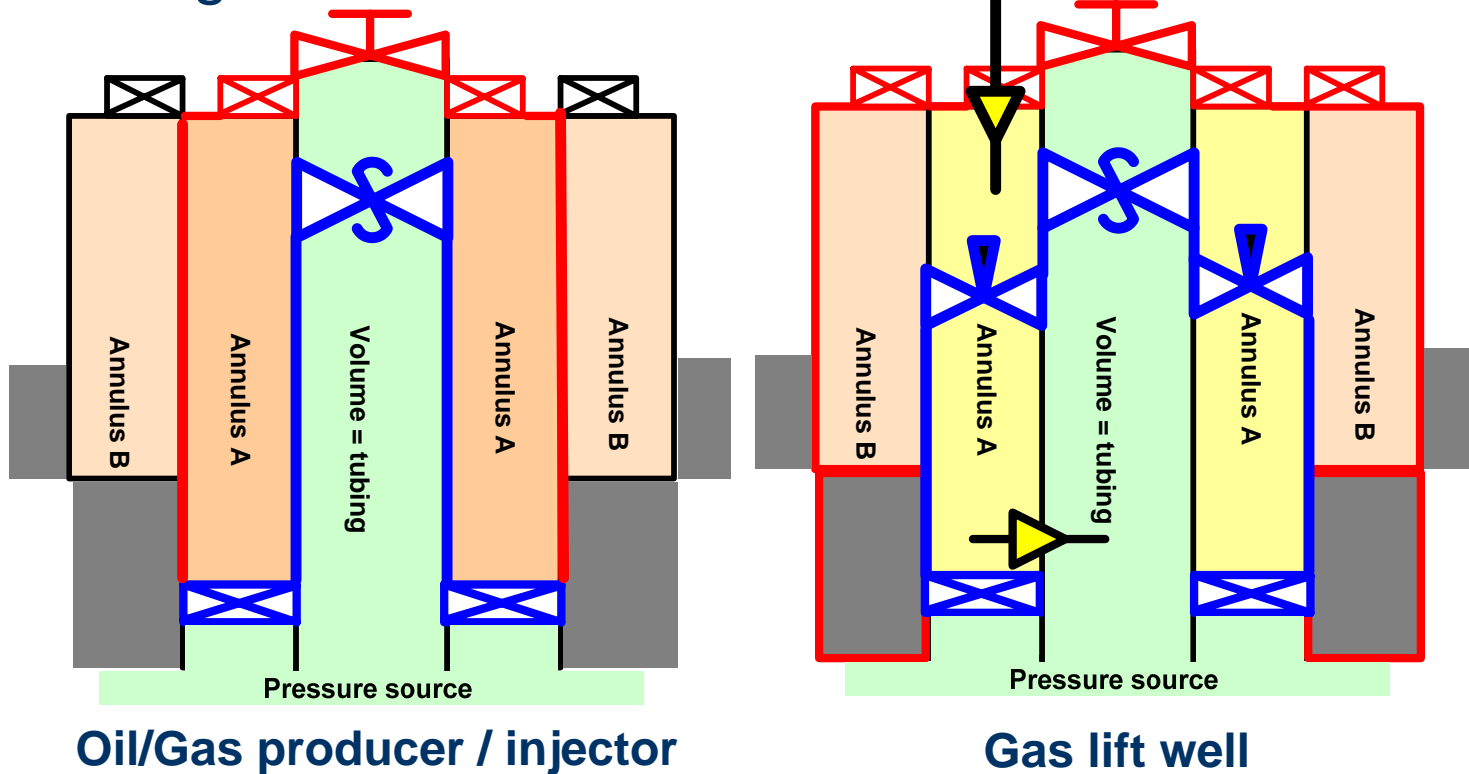


Barrier Requirement

Well Integrity

*“The application of technical, operational and organizational solutions to reduce the risk of uncontrolled release of formation fluids throughout the **life cycle** of a well” (NORSOK)*

- Two barriers are required to **prevent** hydrocarbons reaching surface



— Primary barrier **— Secondary barrier**

Well Integrity

④ What percentage of the wells have had at least one leak?

- ~20-30%

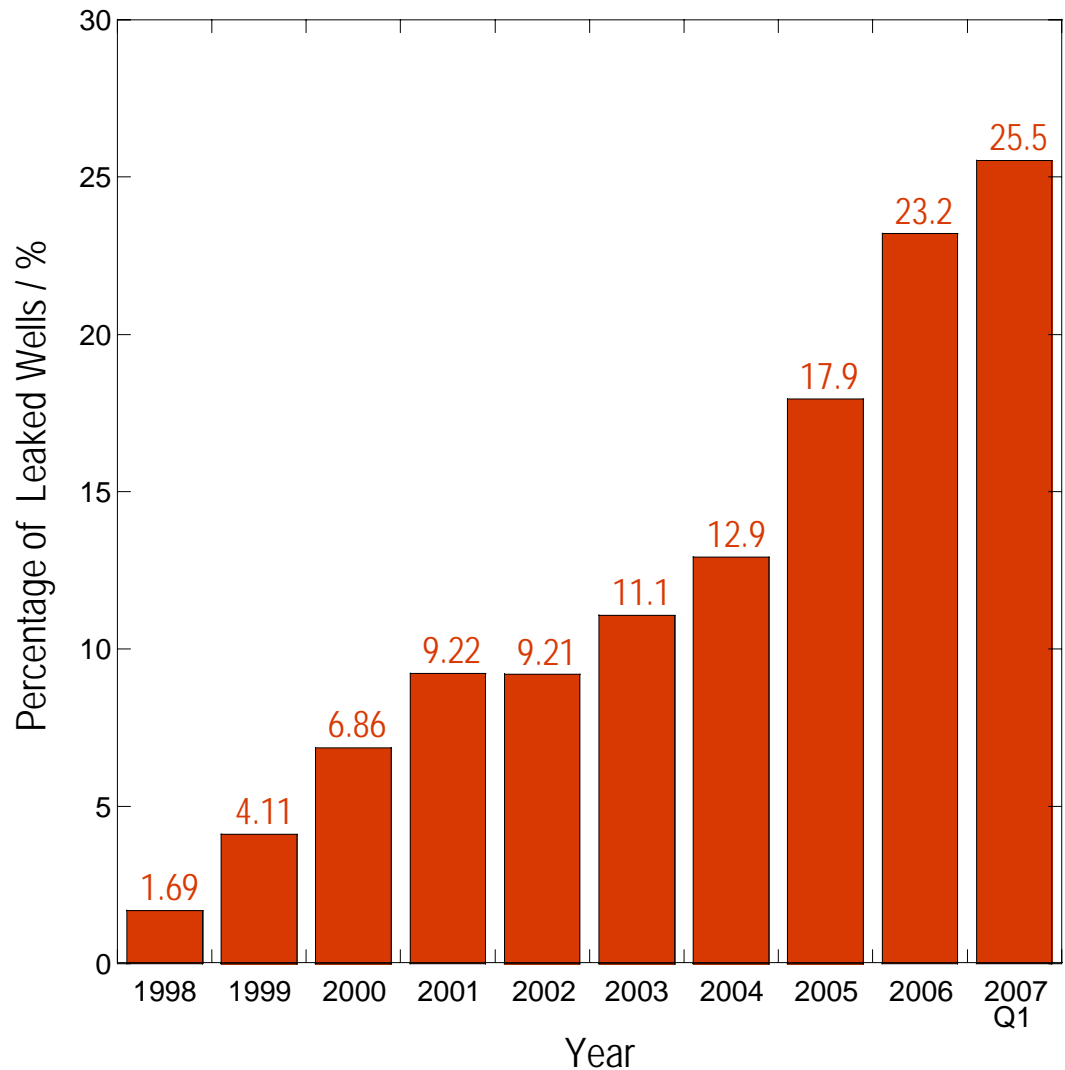
④ Why is Well Integrity important?

- Safety
- Environment
- Production
- Reputation
- Asset Value



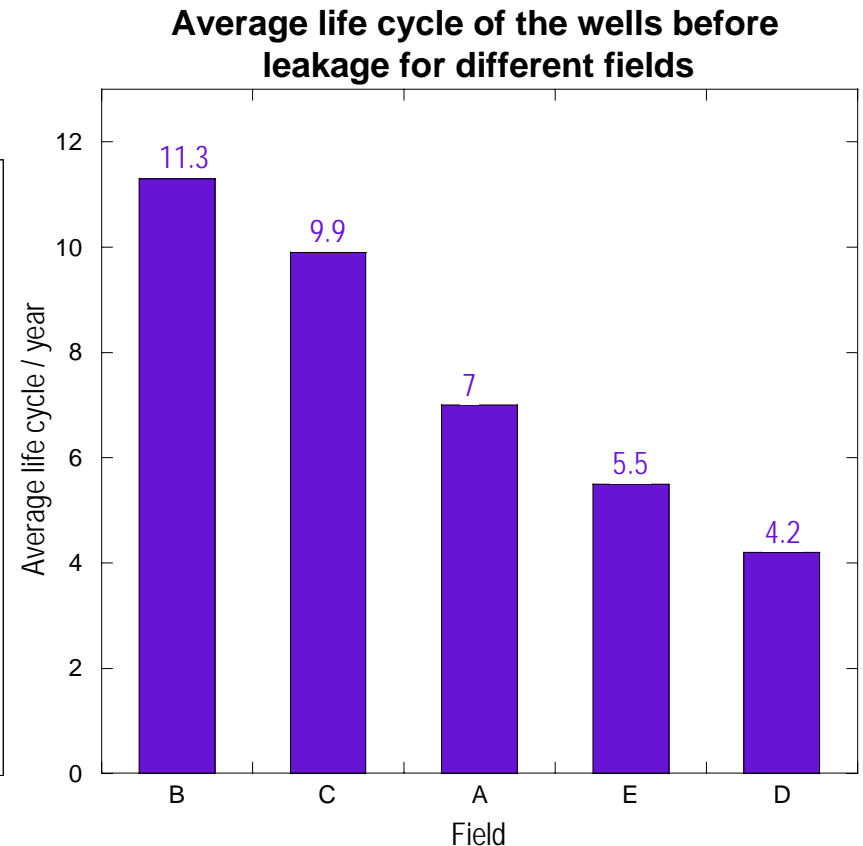
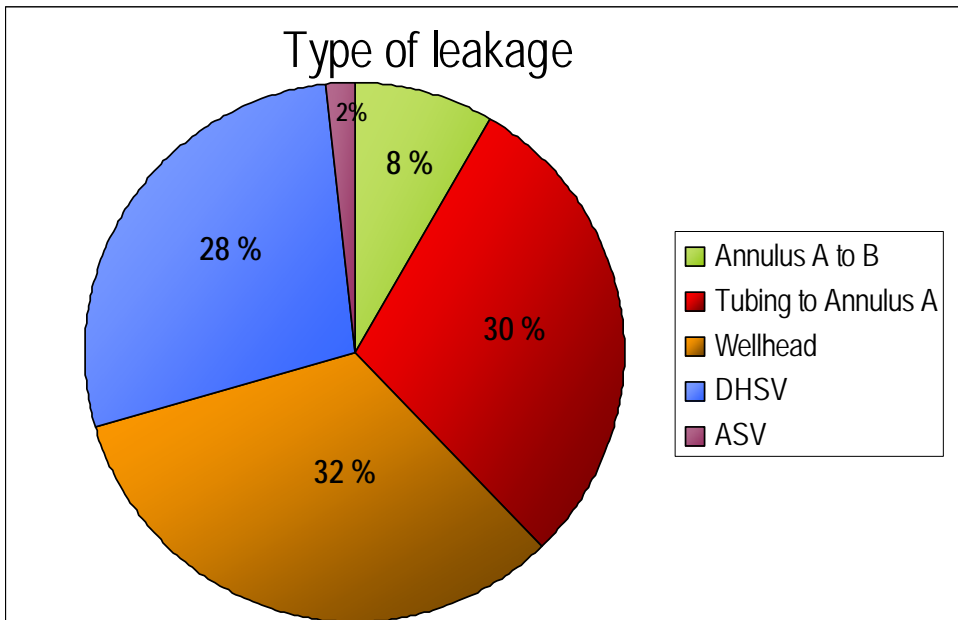
SINTEF Well Integrity Study on NCS

- Two SINTEF studies on well integrity for one operator's 8 fields with a total of 217 wells
- Leak history from 1998 to first quarter 2007 has been mapped and studied
- **The number of leaks can be due to:**
 - Aging of the wells
 - Number of wells
 - Improved reporting/awareness
 - Operating outside the design envelope



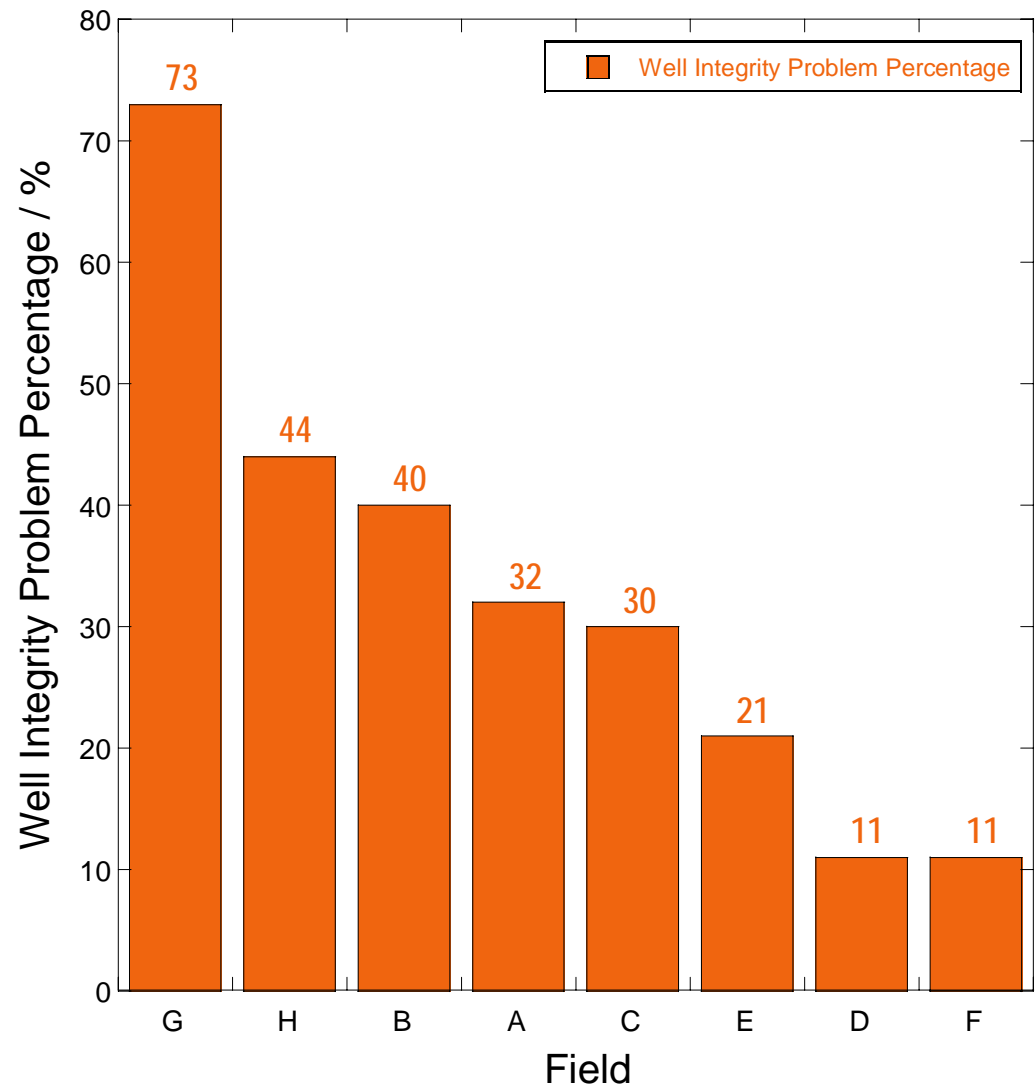
Well Life and Type of Leaks

- There were three main types of leakages
- The Well Life Cycle varied for the different fields



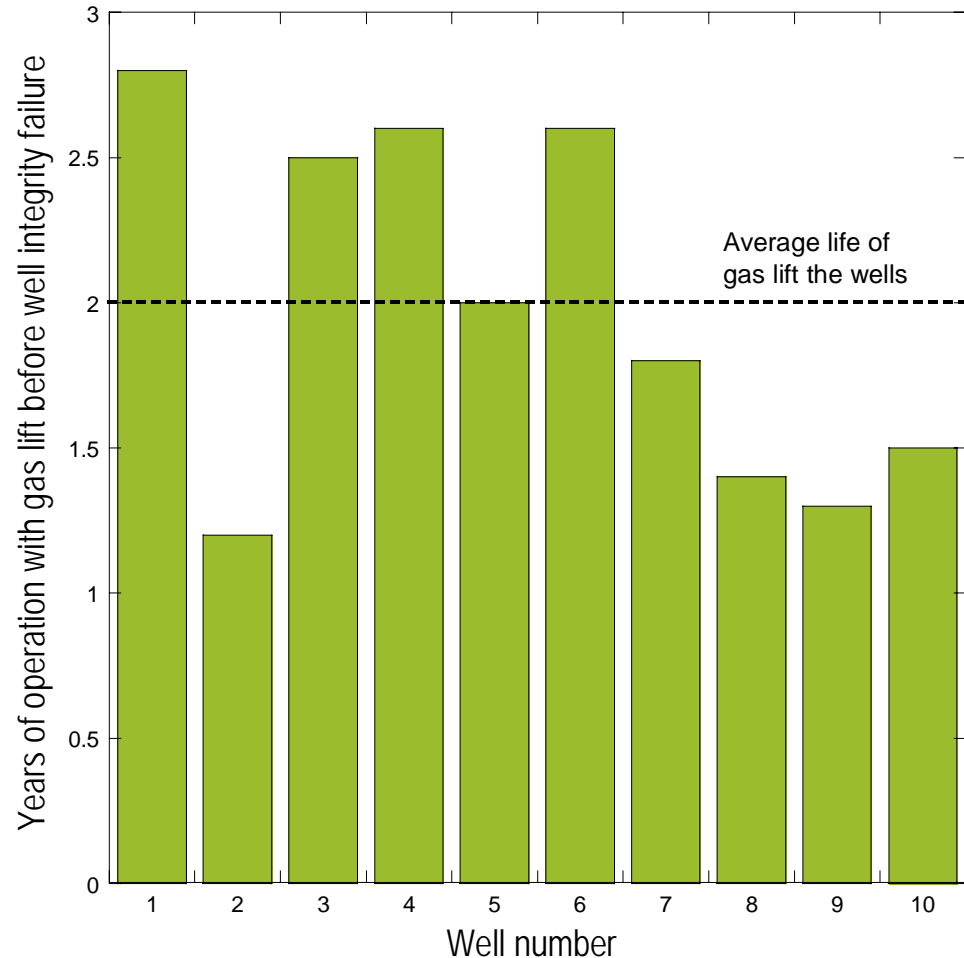
Well Integrity Field situation

- Variations from field to field
- Important differences such as:
 - Gas lift wells
 - Platform vs Subsea
 - Material choice
 - Etc...
- Cannot assume that each field will have same type/amount of problems
- Finding the root causes is a complex problem due to lack of exact data
- Data scattered between difference disciplines



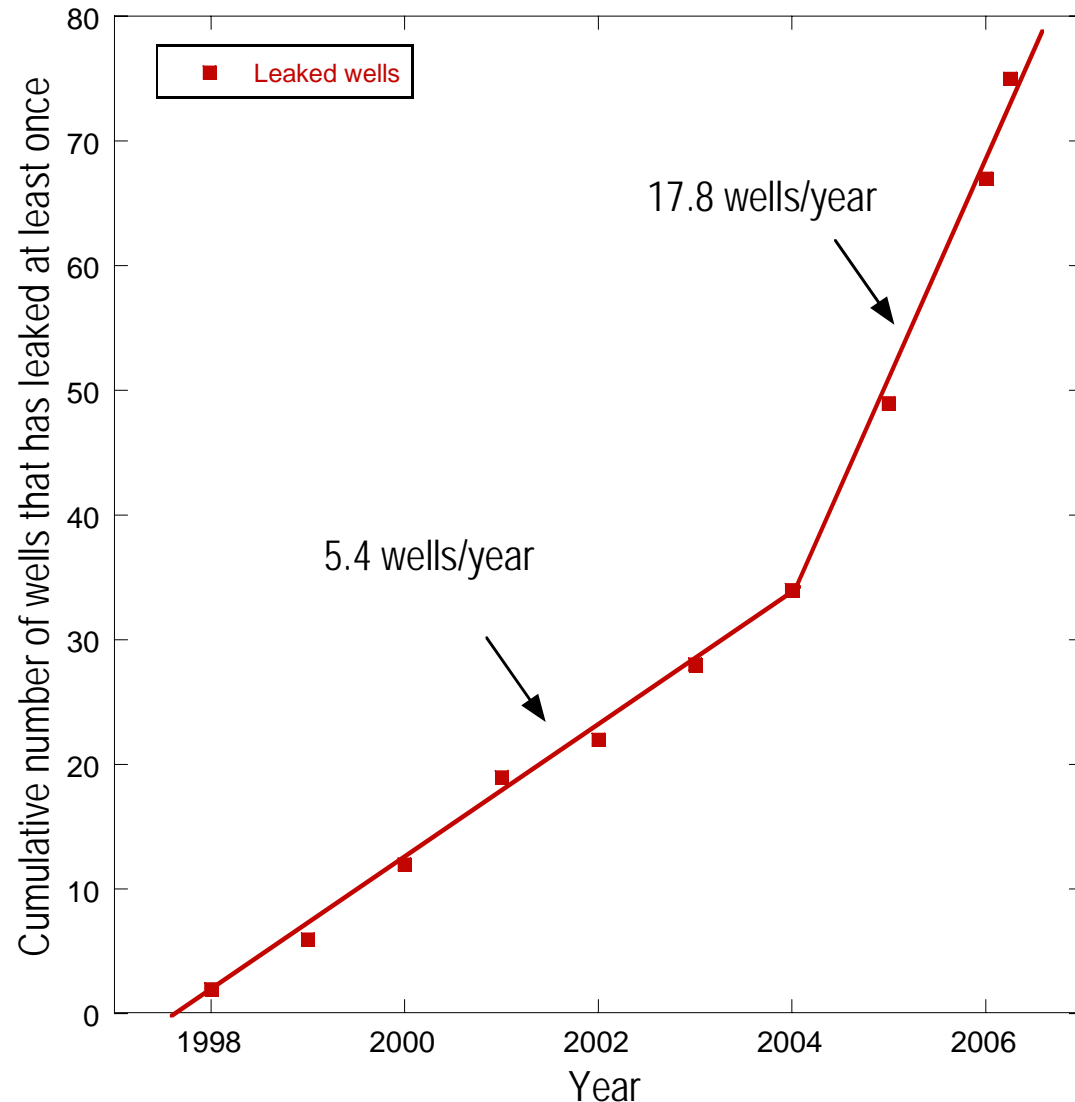
Gas Lift Wells

- Wells completed with low grade steel casing and 13 Cr tubing
- Depletion made it necessary to use gas lift
- Wells were designed for dry gas
- Operational conditions with wet gas and more corrosive CO₂ than design criteria
- **Operating outside the design envelope lead to very short lived wells**
- Average of 2 year operations before leakage occurred after gas lift was introduced



Look and you shall find

- Up to 2004 the trend was 5.4 wells per year with well integrity problem
- After 2004 the number was 17.8
- In 2004 personnel was hired to look at well integrity situation
- Plausible reason:
Increased awareness and focus on reporting!



Norwegian Petroleum Safety Authority Well Integrity Study on NCS

- The Norwegian Petroleum Safety Authority (PSA) did a study in 2006
- Study involved
 - 7 operators on NCS.
 - 406 wells out of 2682
- **18%** of the wells showed to have had some form of well integrity weaknesses & uncertainties
- **7 % of the wells completely shut in due to integrity issues**

(ref: <http://www.ptil.no/.../nettPSAWellintegritysurveyphase1reportrevision3006.pdf>)

Costs of production loss due to well integrity problems

- The NCS produce **1.5 billion barrel** per year
- That amounts to **\$120 billion** (assuming \$80/barrel)
- **A 7% loss in production equals**
 - **\$8.4 billion**or
 - **The cost of constructing 200 wells** (@ \$42 million/well)



The Problem Wells of the 90's (PSA Study)

■ According to the PSA study:

- Wells drilled in the 1990s are over-represented regarding well integrity problems

■ Possible reasons

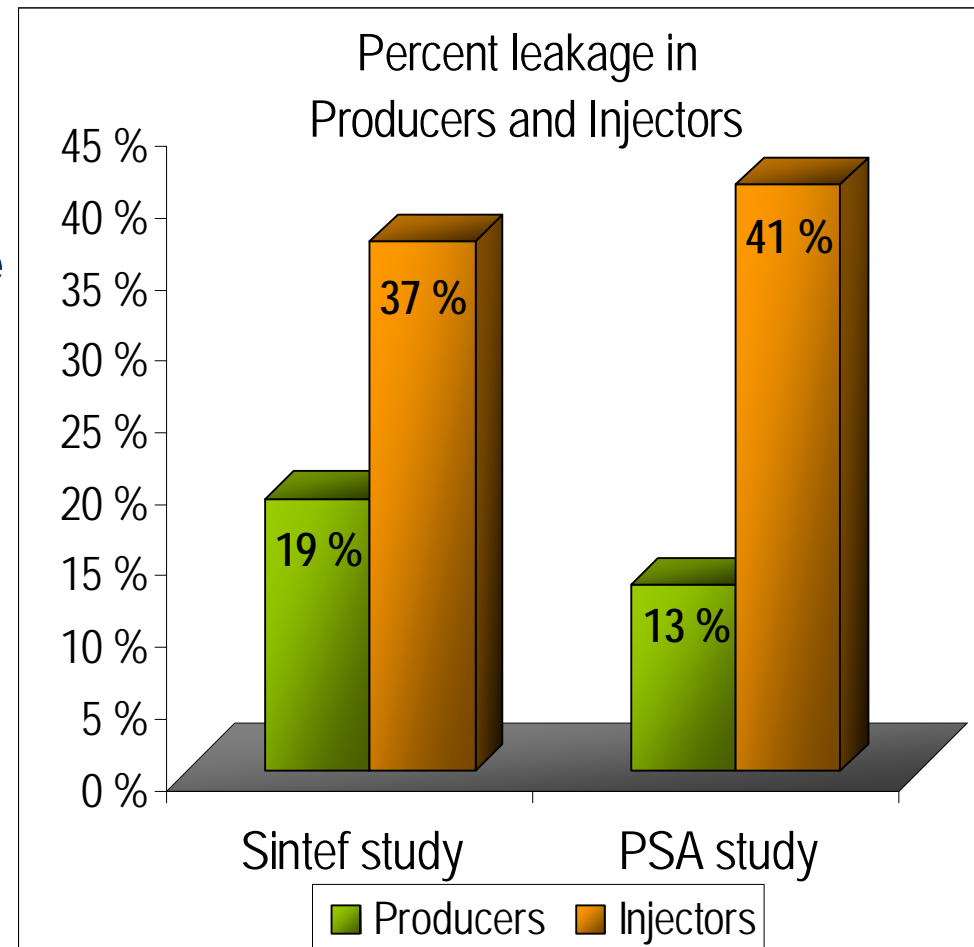
- High level of activity during this period, in combination with cutbacks and focus on costs
- More technological advanced wells

(ref: <http://www.ptil.no/.../nettPSAWellintegritysurveyphase1reportrevision3006.pdf>)



Producers vs Injectors

- Injectors were found to be much more prone to well integrity failures
- **Injectors 2 to 3 times more likely to leak than producer wells**
- The two studies were conducted on different fields with only limited overlap
- The assessment of the Well Integrity situation in NCS seems therefore confirmed by the two studies

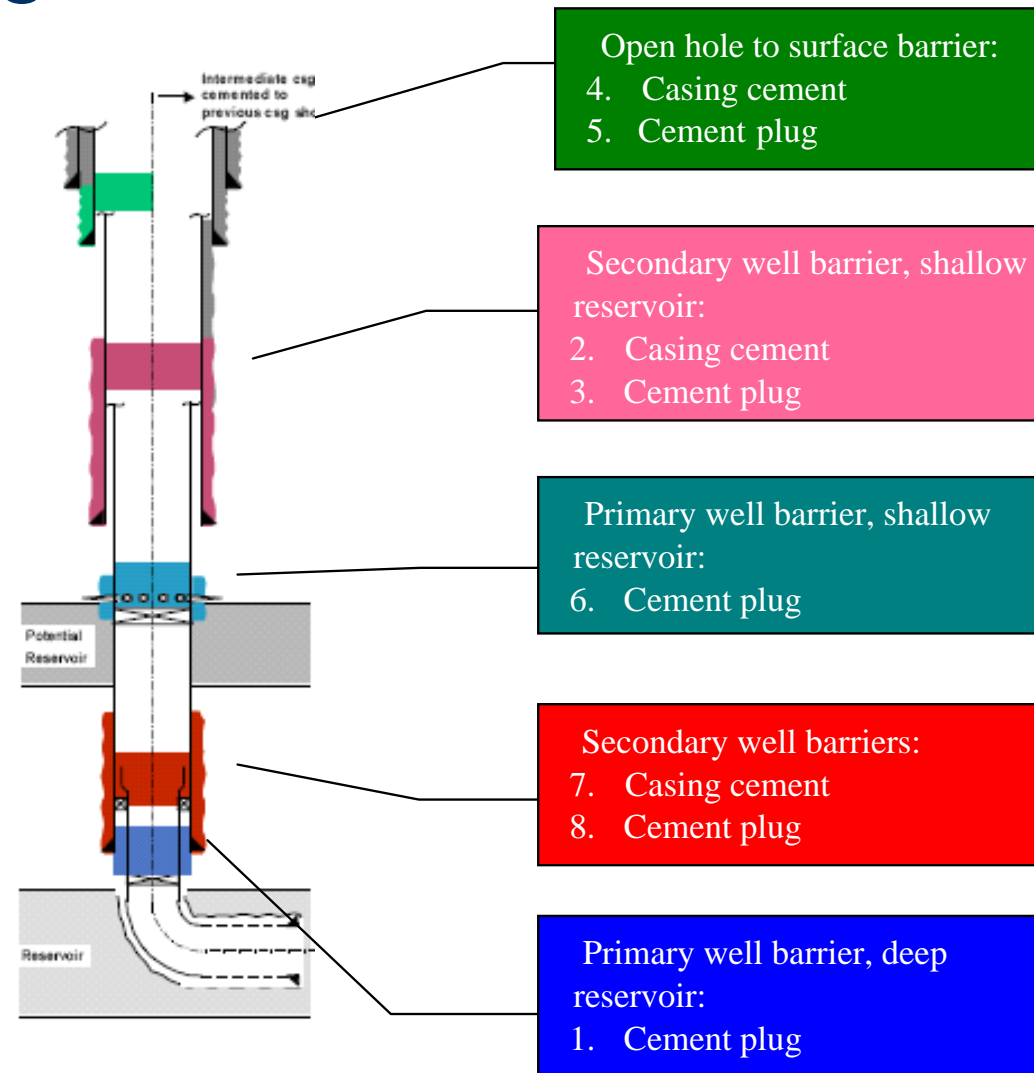


Well Integrity and CO₂

- Why is well integrity important in connection to CO₂?
 - Injection wells are more prone to leak
 - Gas lift wells more prone to leak due to CO₂ and H₂O
- IOR/EOR CO₂ wells
 - Risk of CO₂ blow out
 - Producer wells needs to handle possible large amount of CO₂
 - Control CO₂ migration path in the reservoir and assure safe storage
- Long term
 - Abandoned wells need to withstand CO₂ degradation
 - Need to map carefully all well trajectories and perforations

Abandonment Regulations NOROSK

- No specific methodologies to evaluate well integrity after permanent well abandonment
- Existing guidelines on permanent well abandonment intended for typical oil and gas wells and **not for CO₂-brine environment**



NORSOK

Current Status

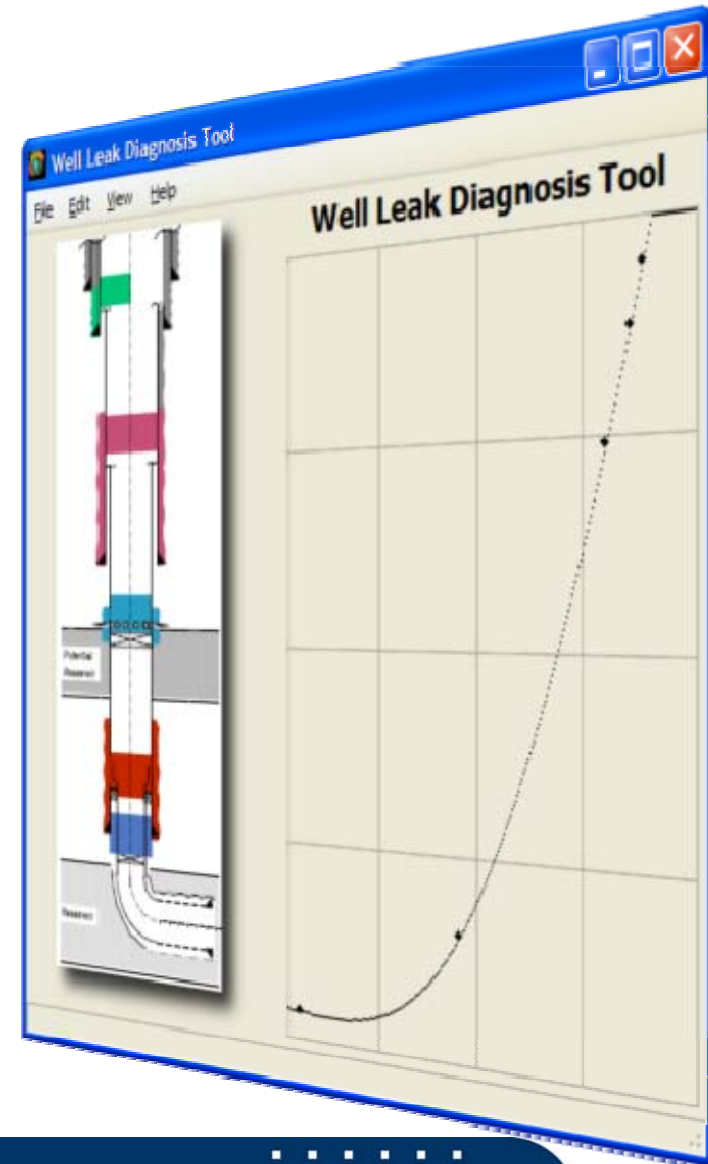
- ☑ Petroleum Safety Authorities follows the situation carefully
- ☑ Operators are focused on the well integrity issue
- ☑ Management tool for Mapping the Well Integrity are being used/rolled out (different *WIMS* systems)
 - ☑ Major improvement for operator to **know** the status and risk of the wells
 - ☑ Makes analysis and data mining much easier
 - ☑ A platform to build on

Focus for the future

- Areas with improvement potential
 - Audit the losses due to well integrity
 - Localisation of the leakages
 - Inspection of pulled equipment
 - Hand-over of well information between different field life phases
 - Essential well information that is *user-friendly* and *up-to-date*
 - Analyse the data to find root causes and corrective actions
 - Cross-disciplinary and cross-field experience exchange
 - Regular well condition monitoring
 - Improve design and best practise based on operational experience
 - CO₂ well integrity
 - Competence & training

Well Integrity - R&D focus

- An R&D project has been started at SINTEF to study
 - Leakage mechanisms
 - Develop models and software to analyse/localize leakages
 - Risk assessment of passing design life
 - Influence of CO₂, Arctic and HPHT on well integrity
 - Well Integrity and new technology or advanced wells
 - Subsea well integrity
- Project funded by Norwegian Research Council
- The project will also facilitate Workshops
 - First Workshop probably in September 2008



Thank you for your attention!

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