Discussion – ''source of inflow'' - for P&A in the overburden

Agenda and background

- Introduction/Egil Thorstensen, PAF leader
- Flow unit, storage unit or buffer sand?/Frode Uriansrud, Equinor
- Subsurface Isolation Strategy/Mark Davison, Shell
- Decision making/Laurent Delabroy, AkerBP
- Required data?/Geir Kjeldaas, ConocoPhillips
- Conclusion/Egil Thorstensen, PAF leader

Reference to some relevant presentations held on the PAF P&A conference (we just keep talking…)

- 2014/''Evaluation of flow potential in the overburden''
- 2015/''Huldra PP&A project – from five to one double barrier –''
- 2015/''Risk-Based Abandonment of Offshore Wells''
- 2018/''Discussion of acceptance criteria for risk-based P&A design''
- 2018/''Understanding leakage rates in permanently abandoned wells by studying natural hydrocarbon seepages''
- 2018/''Varg P&A experience and learnings''
- A series of presentations discussing plugging material and permeability

Introduction

We know how to P&A a RESERVOIR

- NORSOK D-010 Standard
  - Dual barriers
    - Preferably independent from each other
    - Cross-sectional, to restore the cap rock
    - Located at a depth where formation integrity is higher than potential pressure below
  - Length and material of barriers described in standard and regulations

But what about the overburden?

- What exactly is a "Source Of Inflow" (SOI)?
  - Definition in NORSOK D-010 is identical to that of a reservoir
  - Identification? Content? Size? Properties? Flow potential? Permeability?
- Is it sensible to apply the same requirements to every SOI?
  - Allow risk-based approach? Is ''risk based'' risk or consequence?
  - Thermogenic vs biogenic gas?
  - Barriers designed for zero flow, or is it sufficient to restore natural seepage rates?
  - How do we differ between SOI and cap rock/seals?
- Regional and global standards are not aligned
- Not knowing can be costly

NORSOK Standard
D-010
Rev. 4, June 2013

Well integrity in drilling and well operations

3.1.53
source of inflow
a formation which contains free gas, movable hydrocarbons, or abnormally pressured movable water
(same definition as reservoir)

Flow Unit, Storage Unit or Buffer Sand?

Frode Uriansrud, Equinor

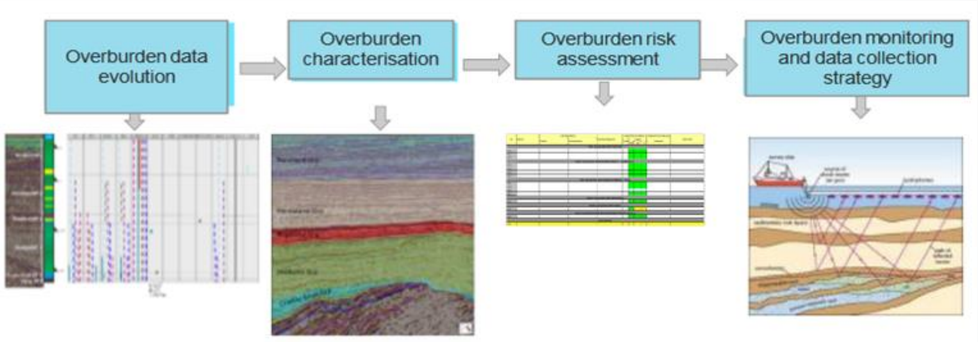
New concepts?

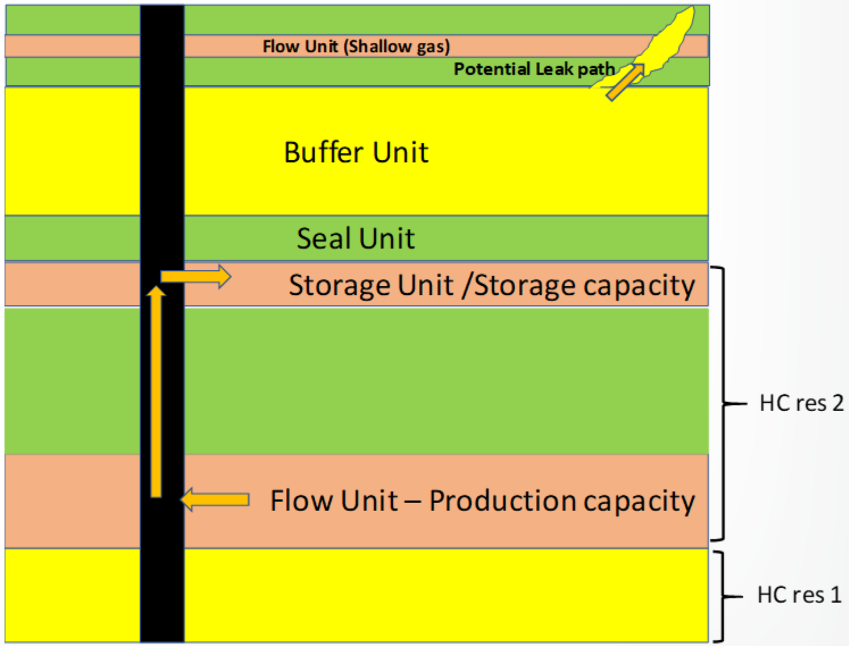
- Driven by experiences, challenging well design and well cost together with more detailed internal requirements and guidelines we have started to investigate the overburden (OB) of our producing fields the last years in much more detail than before

- Focus for the OB- studies are data collection for describing and understanding the OB and to find new ways to optimize design for field lifetime according to the geological setting

- This has over time led to a new focus on the challenges and possibilities the permeable zones within the OB may represent

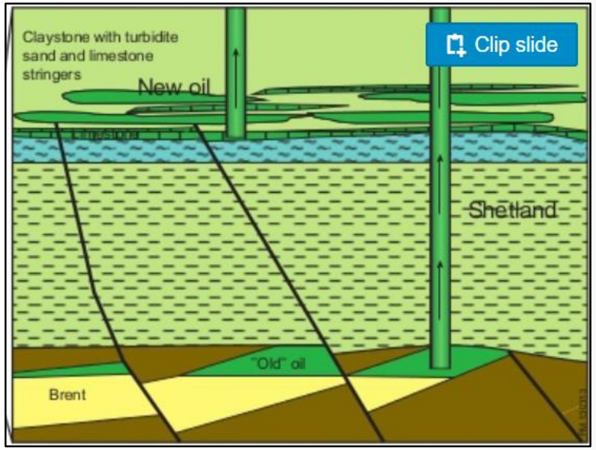
- Some of these ideas and concepts cannot be introduced to old fields due to their present wellbore schematics, but for others –and definitely for new fields, they might represent new opportunities for more robust and cheaper well design solutions



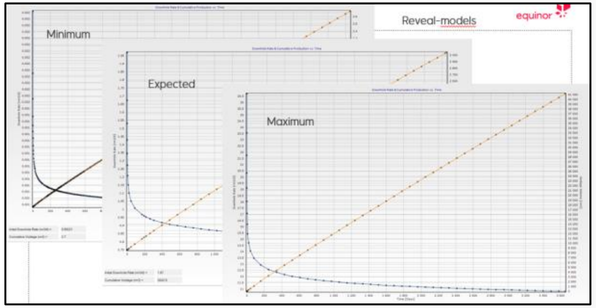


Flow Unit

- With the term «Flow Unit» we mean any form of permeable lithology (fractured network or matrix permeability) which can deliver flow into a wellbore: basically a reservoir
- With more focus on permeable intervals in the overburden the last years, we have started to find, evaluate and map out these zones in more detail then before
- The focus now is to get an as-realistic-as-possible production capacity range-estimate for these intervals as they can represent a threat to our barriers during various drilling, production and PPA operations
- Petec delivers now an estimated range of production capacity from these zones to D&W which uses these numbers to check the potential impact on all surface- and downhole- barriers
- The upside of this work is the potential for finding new zones of economic interest. Several fields are now looking into the possibility for test-production of interesting intervals during P&A of upcoming wells



GF Shetland /Lista discovery



Estimated production capacity

Storage Unit and Storage Capacity

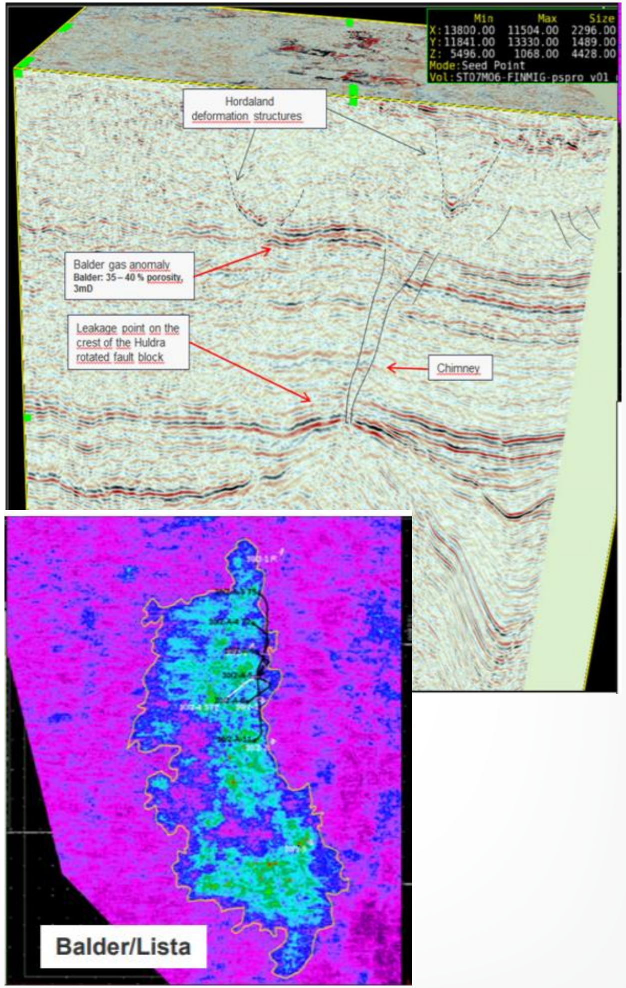
- If a zone in the OB is so permeable that it can flow water or HC *into* a wellbore it is obvious that it can also *receive and store* fluids until it is:
  - a) filled to the pressure which lead to sealing-failure or
  - b) in pressure-balance with the Flow Unit (-s) it is in communication with

- If it can receive and store the volumes it is exposed to, without breaching the caprock, for infinity, then we have defined a Storage Unit

- It is important that we get a reliable estimate, based on tests and models, for its Storage Capacity

- When a Storage Unit is defined, could it be considered a conceptual Barrier Element, both on well and field level?

Example natural storage unit



Buffer Sand?

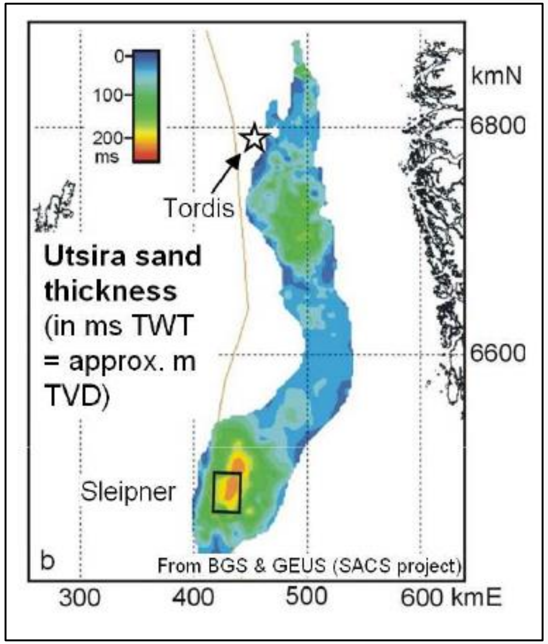
- If, by unknown reasons, the main barrier elements should fail in a wellbore there exists many places another **safe-guard** that we had not yet discussed / utilized. This is for instance the large sand-bodies in the Oligocene and Miocene sections of the North Sea

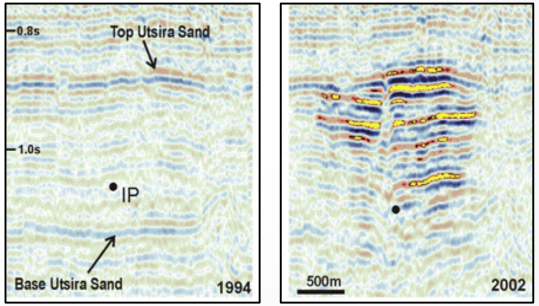
- We utilize these sands (Utsira, Grid, Vade, Skade, etc.) today for controlled injection of a variety of e.g fluids, cuttings, CO2. We have had successes and some failures on the way

- Models of injection studies shows that these shallow sands will quickly distribute the incoming fluids from most deeper reservoirs and the resultant pressure increase will in most cases, be marginal due to the enormous storage capacity. These sands do also have caprocks, and the system is likely to hold for a very long time giving us significant time to handle a deep barrier-leakage into them. Knowledge of the placement of existing, shallow well barriers is obviously an important issue here if you consider utilizing these shallow sands

- Such a concept, which is not considered to be part of the initial barrier elements, could it be defined as a Buffer Sand?

- Example: 2/4-14 blow out was into a buffer sand (not equipped to be a storage unit)
- Capacity of the buffer sand allowed time for a kill operation
- Kill was completed before the buffer capacity was exceeded
- As the flow stopped the sand have now proven to be a storage unit for the actual volume, but it is still a only buffer unit for the underlaying flow unit



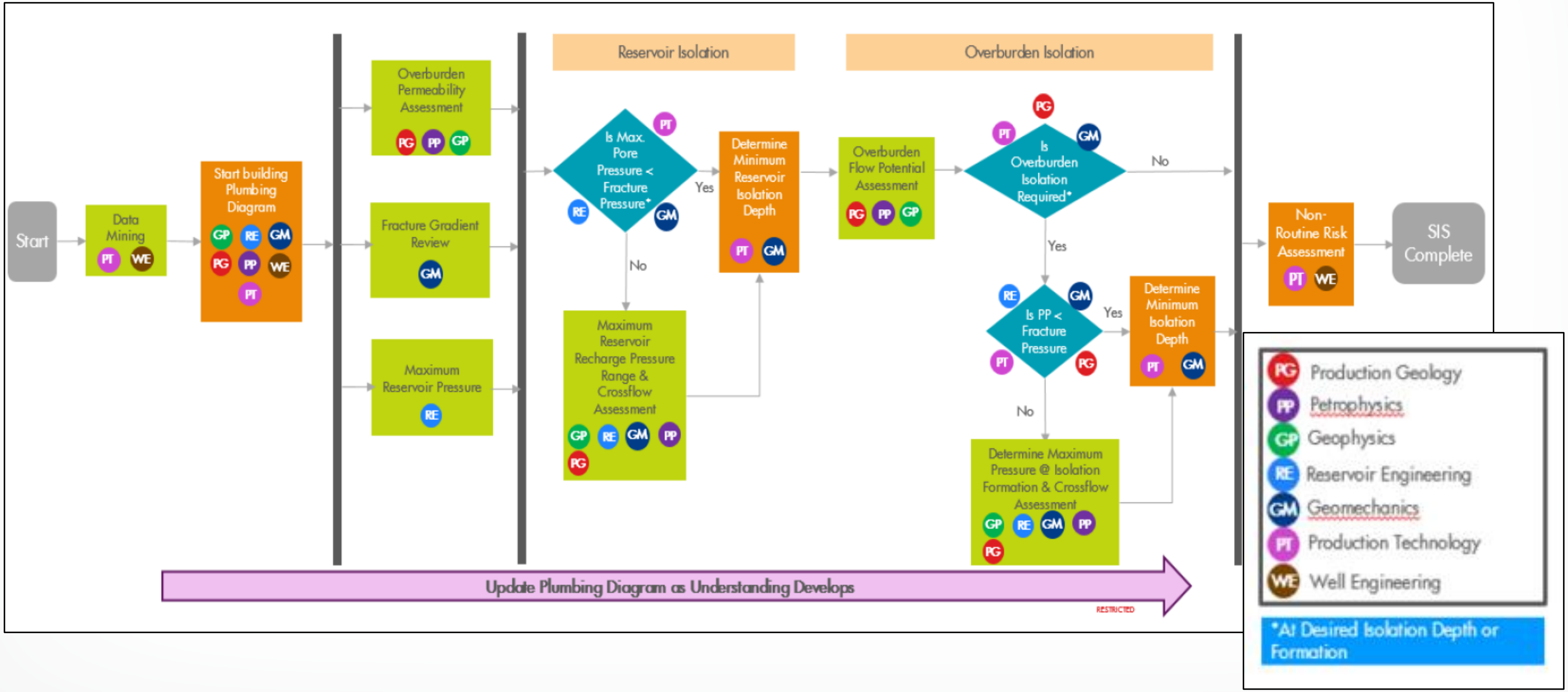


Subsurface Isolation Strategy

Mark Davison, Shell

Subsurface Isolation Strategy (SIS)

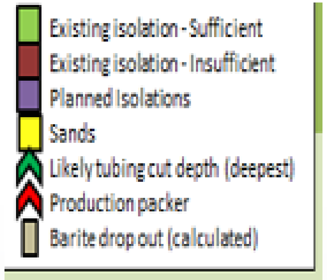
Suggested workflow for data and information required to construct a SIS

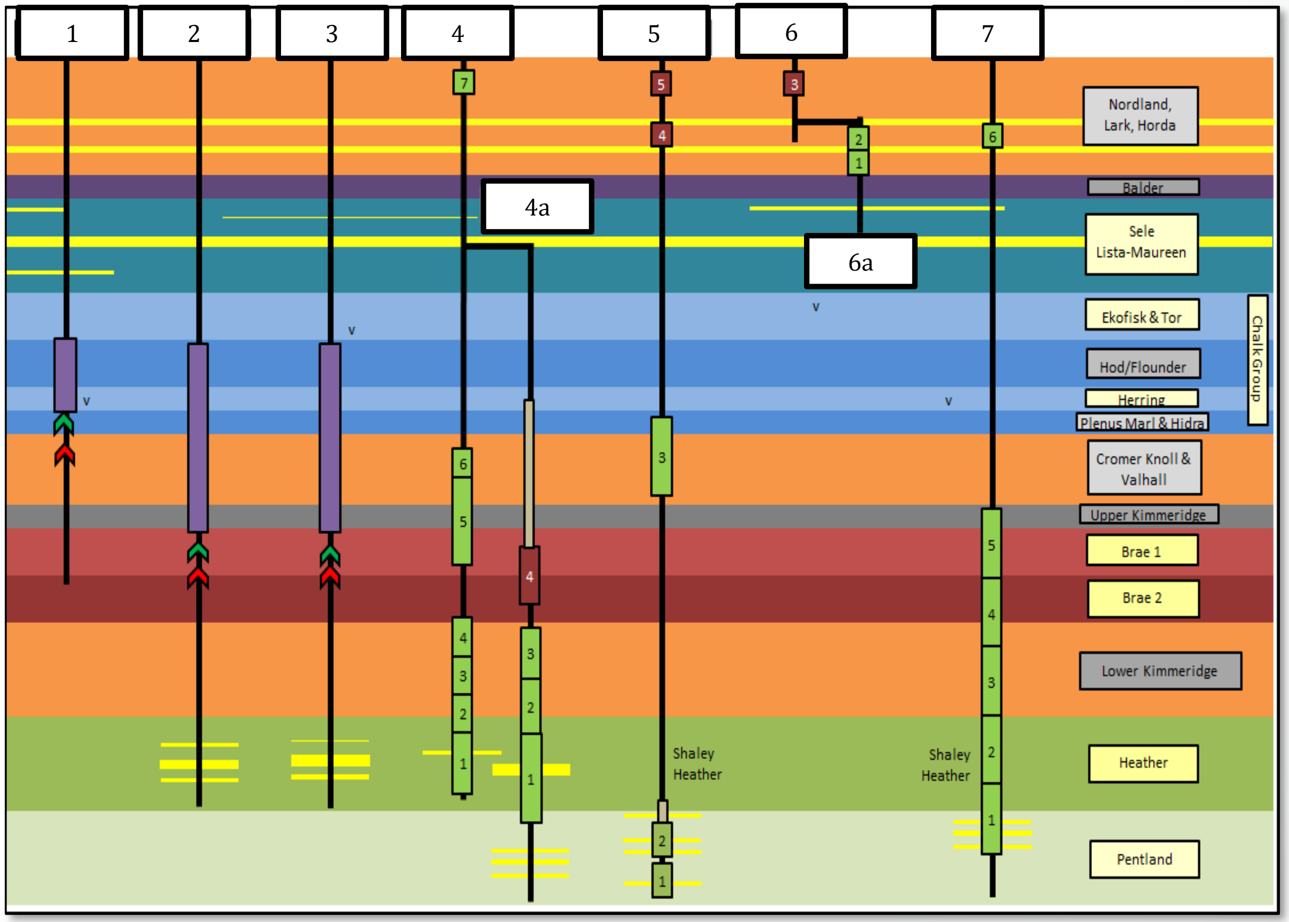


Subsurface Isolation Strategy Workflow

Plumbing Diagram

- SIS defines barrier placement strategy for 'routine' wells
- 'Non-routine' wells are where SIS cannot be implemented
- Plumbing Diagram basis for risk assessment of alternative solutions

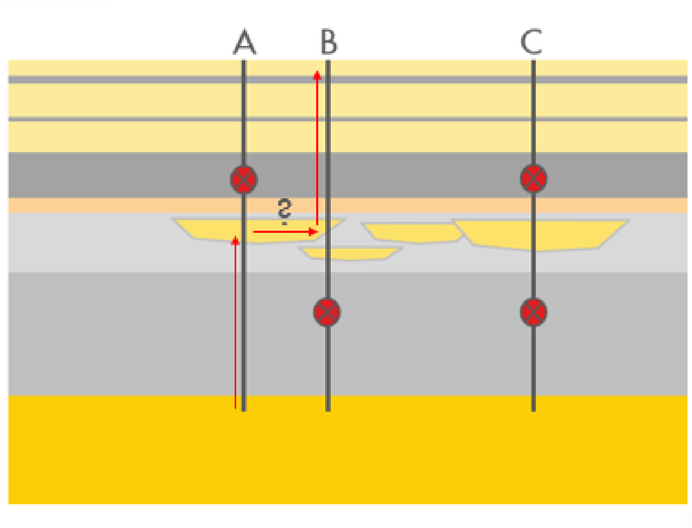




Plug Placement and Cross-Flow Analysis

- As part of a field subsurface isolation strategy (SIS), the plumbing diagram illustrates the well status, well barriers and permeable formations in the subsurface

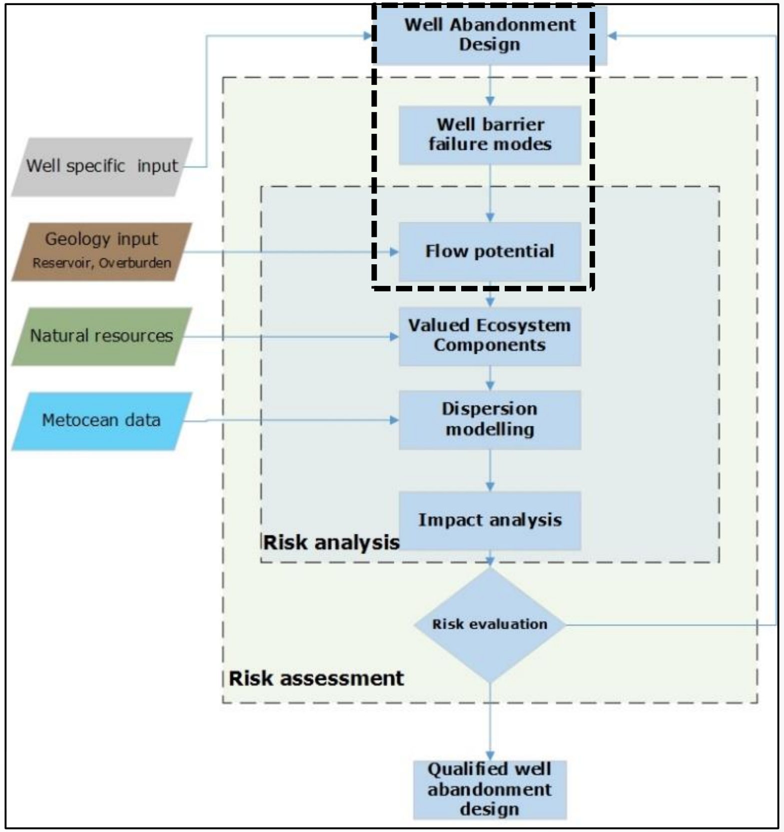
- ALARP risk assessment of the flow potential for P&A wells requires understanding of the barrier integrity and opportunity for cross-flow, storage and containment within the subsurface



Discontinuous overburden sands

Reservoir

DNV Risk Assessment for Well P&A



Containment and ALARP Assessment Tools

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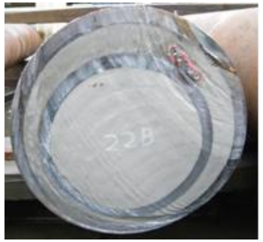
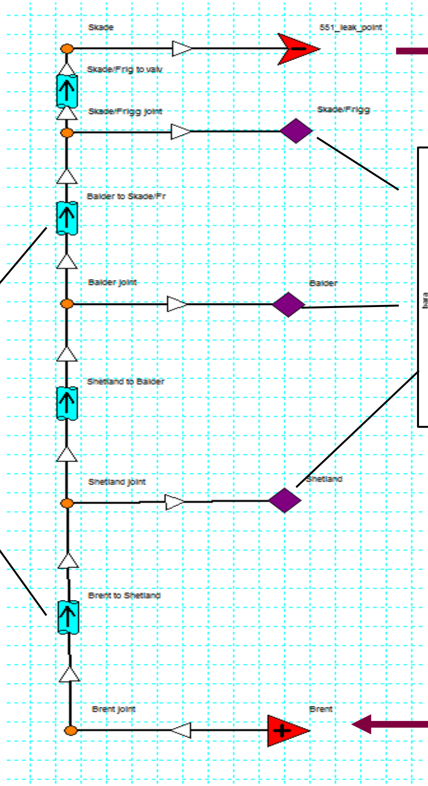
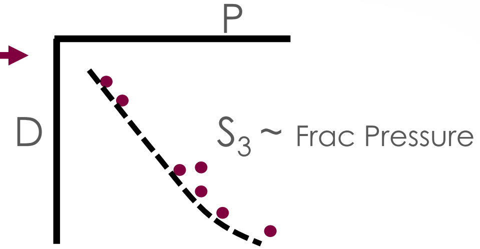
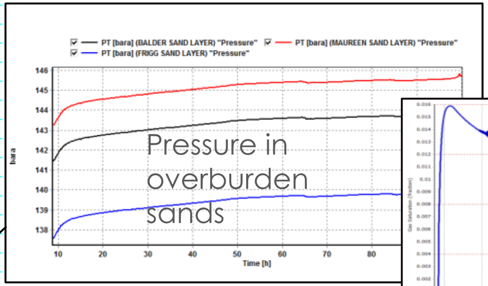
Assessing impact of different P&A scenarios for barrier placement and containment

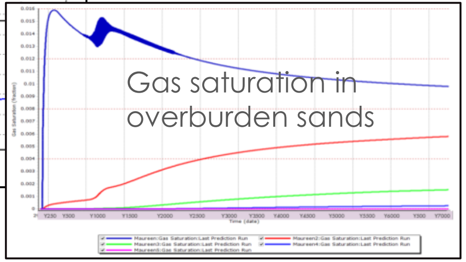
Flow through cement in annuli

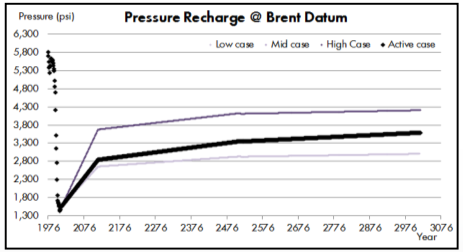












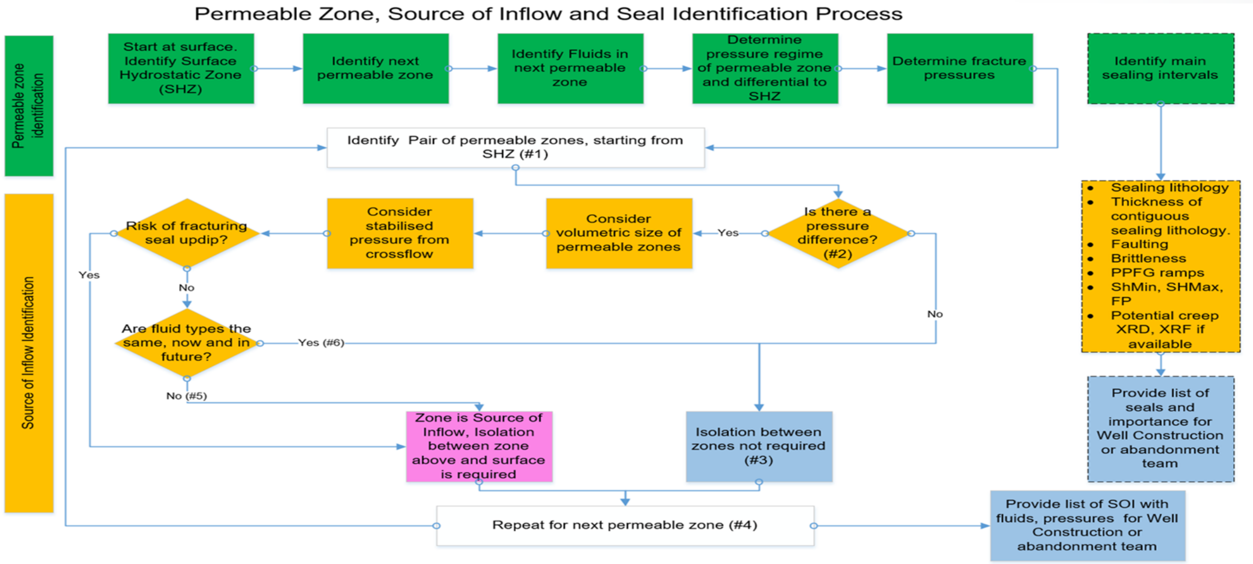
Decision making

Laurent Delabroy, AkerBP

Decision Making

Step 1: Permeable zone, Source of Inflow and Seal Identification Process

- Standardised approach, nomenclature and methods – covers whole cycle of well from planning to abandonment
- “How to” Guide, together with Overburden Description document supports existing Zonal Isolation requirements
- Flowchart to illustrate approach – easy to tailor to simple or complex situations
- Improved well integrity and isolation
- Reduced cost and risk



Notes
#1 First pair of zones includes the surface Hydrostatic zone
#2 Adjust for fluid gradient to assess if it is overpressures relative to overlying zone
#3 Flow to surface is not permitted, and top of first over-pressured permeable zone is treated as the top of SOI 1
#4 If no new SOI identified, next permeable zone analysis is to the top of the current SOI or zone
#5 Hydrocarbon/Water contact is not considered a SOI boundary
#6 Refer to table 1 in Identification guidance chapter for further information on potential crossflow of different fluids

Decision Making

Norsk olje&gass

Step 2: Barrier(s) Requirements

Statement of Requirement (SOR) issued by Subsurface describing

- Classification of each permeable zone
- Identification of seal above each source of inflow
- If applicable, expected fluid in permeable zone
- Number of barrier(s) required, as per NORSOK D-010, 4.2.3.1 Table
- Shallowest allowable depth of the barrier(s)

4.2.3 Well barrier requirements

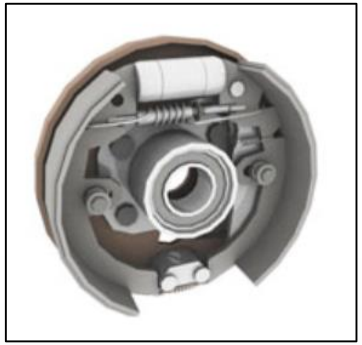
4.2.3.1 Function and number of well barriers

The following number of well barriers shall be in place:

Minimum number of well barriers	Source of inflow
One well barrier	a) Undesirable cross flow between formation zones b) Normally pressured formation with no hydrocarbon and no potential to flow to surface c) Abnormally pressured hydrocarbon formation with no potential to flow to surface (e.g. tar formation without hydrocarbon vapour)
Two well barriers	d) Hydrocarbon bearing formations e) Abnormally pressured formation with potential to flow to surface

m MDRKB	M TVDRKB	DPZ	Description (NORSOK)	Expected Fluid	Lithology	Stratigraphy	Thickness (m)	Max PP (s.g.)	FG (s.g.)	Temp. (°C)	Isolation Req.	Shallowest Plug Setting Depth (m TVDRKB)
210 - 750	210 - 750	No source of inflow										
2360 - 2600	2360 - 2600	DPZ #1	c	Water	Sandstone	Hordaland Gp	240	1,47	1,97	92	1 well barrier	1254
2954 - 3012	2954 - 3012	DPZ #2	c	Water	Sandstone	Forties	58	1,50	2,00	106	1 well barrier	1684
3282 - 3646	3282 - 3646	DPZ #3	c	Water	Limestone	Tor	364	1,52	2,03	128	1 well barrier	1862
3940 - 3982	3940 - 3982*	DPZ #4	e	Water	Mudstone + 5% risk of Sandstone stringers	Åsgard	42	1,64	2,07	139	2 well barriers	2532
4015 - 4155	4015 - 4155	DPZ #5	d	Oil	Sandstone	Gyda	140	1,54	2,06	145	2 well barriers	2692
4155 - 4185	4155 – 4185**	DPZ #6	e	Water / Oil	Sandstone	Eldfisk	30	1,54	2,06	146	2 well barriers	2702
4185 - 4225	4185 - 4225***	DPZ #7	e	Water / Oil	Sandstone	Ula	30	1,54	2,06	148	2 well barriers	

One solutions fits all?



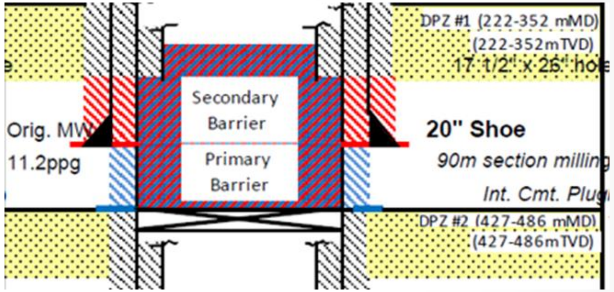
Specifications	Formula 1 car	Citroen 2CV
Top Speed	380 km/h	80 km/h (on a good day)
Brake material	Carbon-carbon	Rusty steel
Brake cost	15,000 $	200 $
Max temp during braking (C)	1200 C (gold melts at 1063 C)	100C ?
Manufacturing time	6 months	2 mn?
Braking power	5G	0.6 G
300 km/h – 0	4 sec	N/A
200 km/h – 0	2.9 sec / 65 m	N/A
100 km/h – 0	1.4 sec / 17 m	55 m from 80 km/h

Decision Making

Are current requirements always suitable?

- **Question 1**: Is it reasonable to apply a one-fits-all philosophy to barrier lengths, and have the same requirements for a barrier against an HPHT reservoir as for one against a shallow hydrostatically-pressured permeable zone with very limited flow capability?

- **Question 2**: What method can best match risk with suitable barrier length requirement?
    - Learnings from the nuclear industry: define leak acceptance criteria
    - Completely impermeable barriers do not exist – Cement, shale, rock etc. all have a certain permeability
    - Leakage calculators
        - Several calculators have been developed (Oxand, IRIS/UiS, DNV, Astrimar..)
        - Already used or being tested by several operators (ref SPE 177612, for instance)



Example: Valhall seal 2:

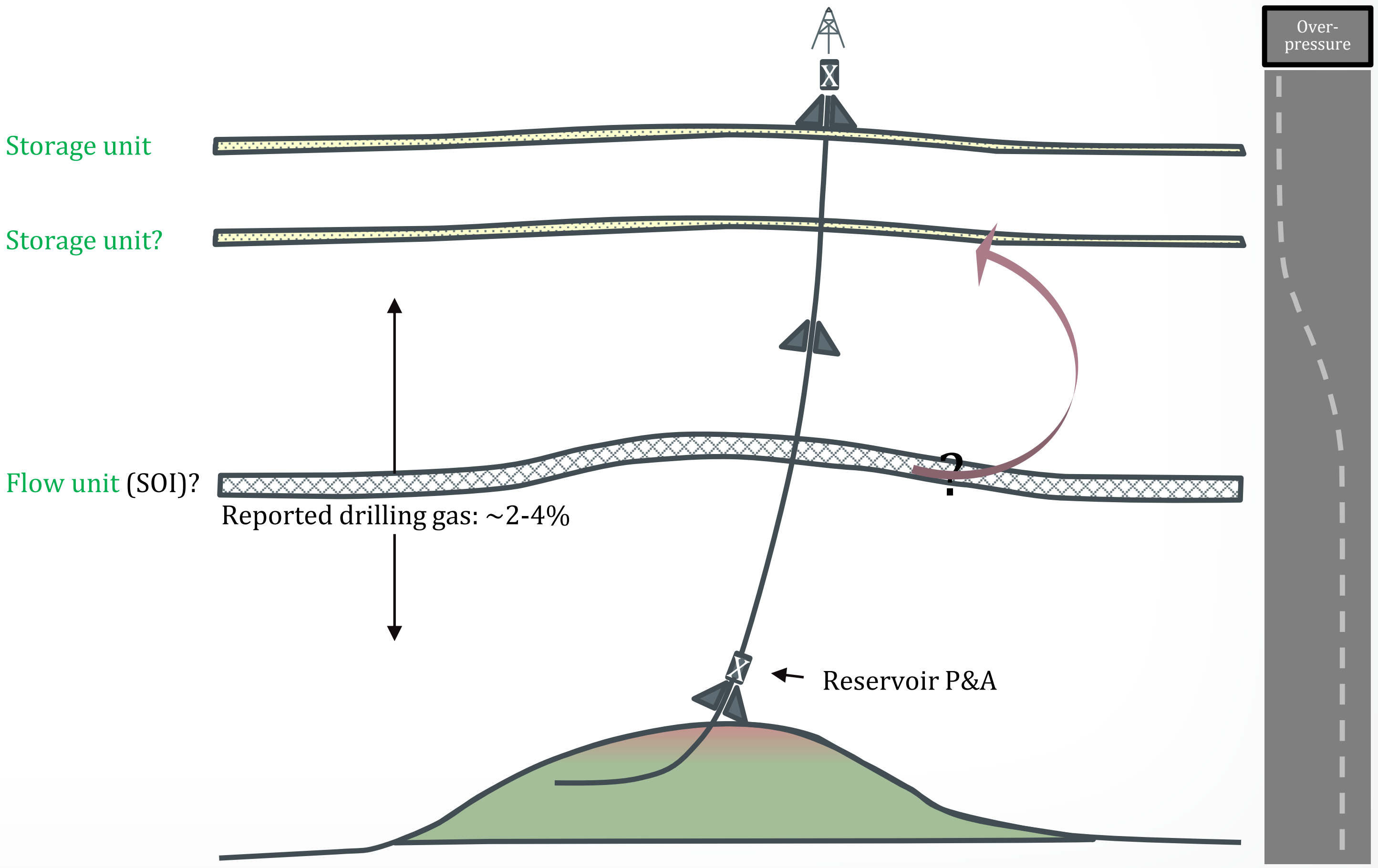
- Limited seal 2 thickness
- Well bonded annulus cement in OH, poor/no cement in casing/casing annulus, as per log (realistic?)
- Poor match between cut & pull predictions based on log response and actual experience
- Limited, risky and time-consuming remediation options
- About 33% of time spent to P&A a well is related to installing barriers in shallow, low-risk section → poor risk vs reward equation

Data required – to characterize flow, storage or buffer unit?

Geir Kjeldaas, ConocoPhillips

ConocoPhillips operated example

- Flow unit/SOI? Positive indicators:
  - Abnormally pressured formation water
  - Permeable zone exists
  - Gas observed while drilling
- Flow unit/SOI? Negative indicators:
  - No gas cloud
  - No kicks observed in overburden
  - No seismic brightening of zone
- Available data:
  - Standard MWD data
  - Standard drilling gas data
  - Standard "mud logging" data
- Potential consequence
  - No plugging *may* lead to very limited cross flow to shallower zones



Analyze of situation vs. NORSOK definition of SOI…

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NORSOK D-010, rev.4 states (4.2.3.1)
Minimum number of well barriers - One well barrier :
"Abnormally pressured hydrocarbon formation with no potential to flow to surface (e.g. tar formation without hydrocarbon vapour)"

Minimum number of well barriers - Two well barriers :
Hydrocarbon bearing formations

3.1.53 source of inflow

a formation which contains free gas, movable hydrocarbons, or abnormally pressured movable water
(same definition as reservoir)
NOTE Hydrocarbons are movable unless they are residual or have extremely high viscosity (i.e. tar).

Example field situation:

Overpressure?	Gas in formation?	Flow potential to surface?
☑ Overpressure is known from both sonic logs and historical well and geological data	☑ Gas logs show increase in drill gas when passing a regionally known storage unit Level is very low, no indication of producible reservoir. Only biogene gas until ~2500ft below permeable zone in overburden	? Data required

Resultant action:

Plug zone according to guidelines for flowable zone – **2 plugs**

A few open questions leads to many more..

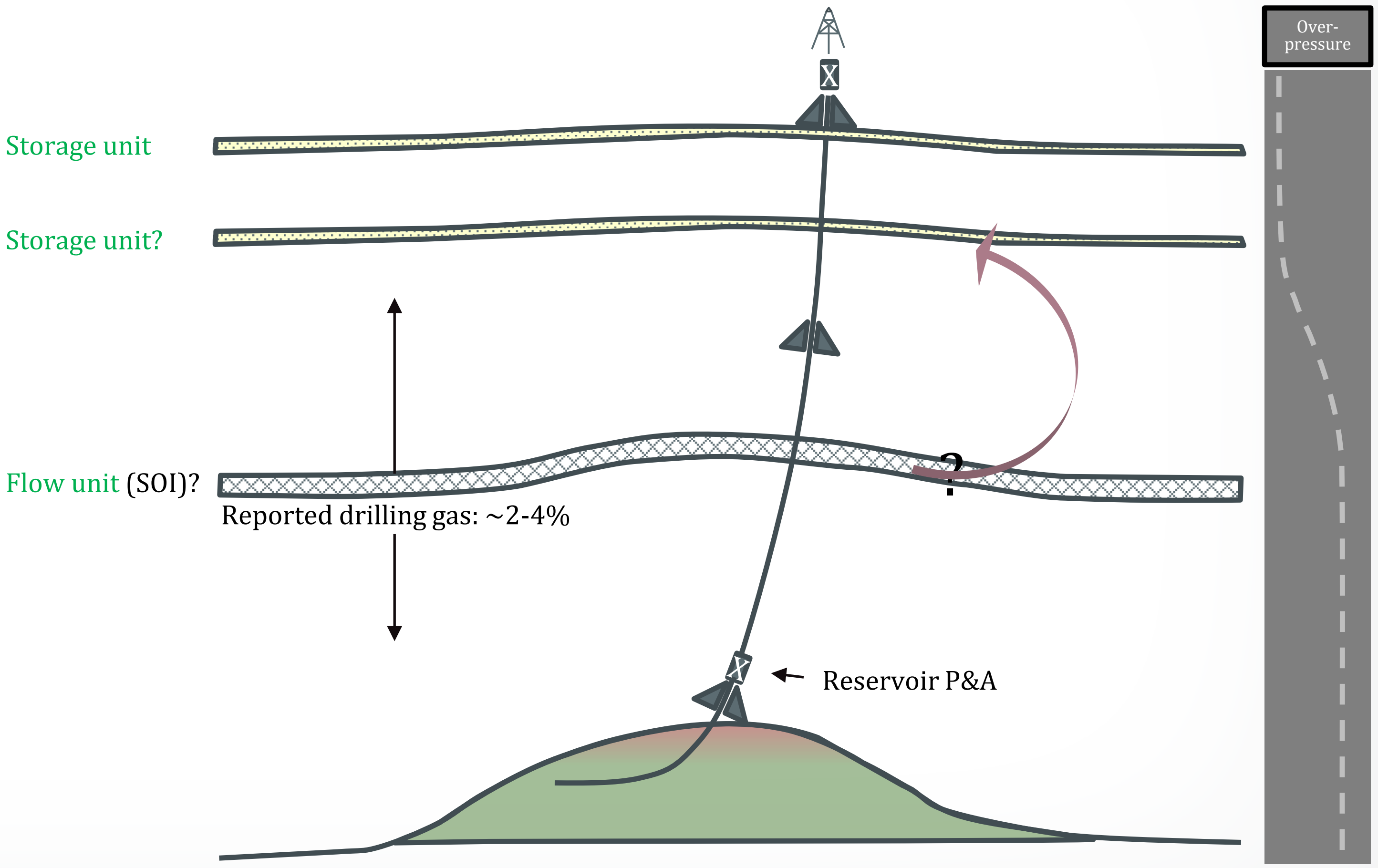
- Data required to decide if it is a flow unit?
  - Logs?
  - Production test
    - Exposed area?
    - Draw down pressure?

- If it is a flow unit
  - Where is my top of reservoir?
  - Where/what is my cap rock?

- Possible to design for storage unit?

- If no to all above
  - Still ok to design for cross flow?
  - Vent flow, platform safety?

- If no reasonable risk exists?
  - Acceptance criteria?



PAF common conclusion and recommendation

Conclusion

- **As demonstrated through the presentation there is no common terminology today**
- **Overburden description needs to be:**
  - **Improved**
  - **Aligned**
  - **Properly integrated in standards and regulations**
- **Requirements for barriers in the overburden need to be**
  - **Risk-based**
  - **Reasonably achievable**
  - **Effective**
- **Not knowing is costly**
- **Standards should be reasonable**

Recommendation

- **Operators and Regulators in the region need to work together to achieve common understanding and develop appropriate guidelines for the PP&A of the overburden**

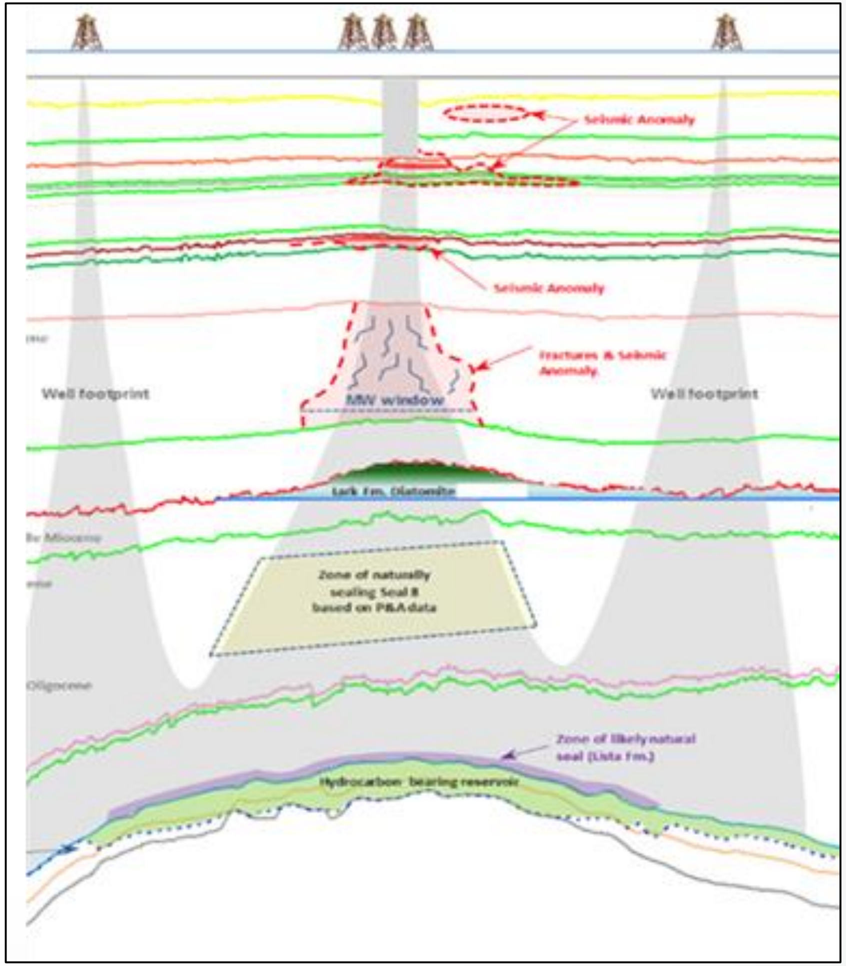


Illustration: Reservoir and overburden in a North Sea field