Risk-based design of through-tubing P&A in wells with gauge cable

SPE Aberdeen Well Decommissioning
20-21 April 2022

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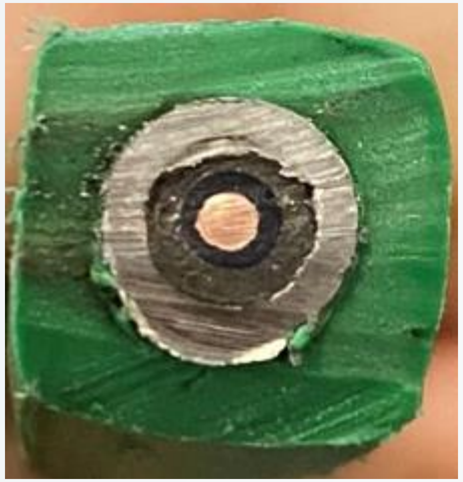
Thanks to A. Agnew, T. Jenkins, S. Ghanbari, D. Davies

Project overview

- Although through-tubing abandonments are becoming standard industry practice, there has been a lack of sufficient information for Harbour Energy to support a robust risk assessment to enable through tubing cement jobs on wells that contain gauge cables.
- We engaged with Heriot Watt University to model leakage risk in through-tubing abandonment scenarios with gauge cable as part of the abandonment barrier.
- We developed models for four candidate wells in the southern North Sea that were suitable for through tubing abandonment, apart from the completion containing downhole pressure and temperature gauges.
- Several industry papers have addressed through tubing abandonments with gauge cable with examples of wells that have been abandoned with this method in the North Sea:
    - SPE-178840 – Cement placement with tubing left in hole during plug and abandonment operations
    - SPE-199866 – Case study for rig-less subsea well abandonment
    - SPE-203459 – Self-sealing cement system as an abandonment solution for wells with gauge cables: A case study from the North Sea, UK



Project challenges

- Through-tubing cement plugs with gauge cable left in the well are not common practice and at this time have not been done by Harbour Energy
- Well Decommissioning guidelines state:

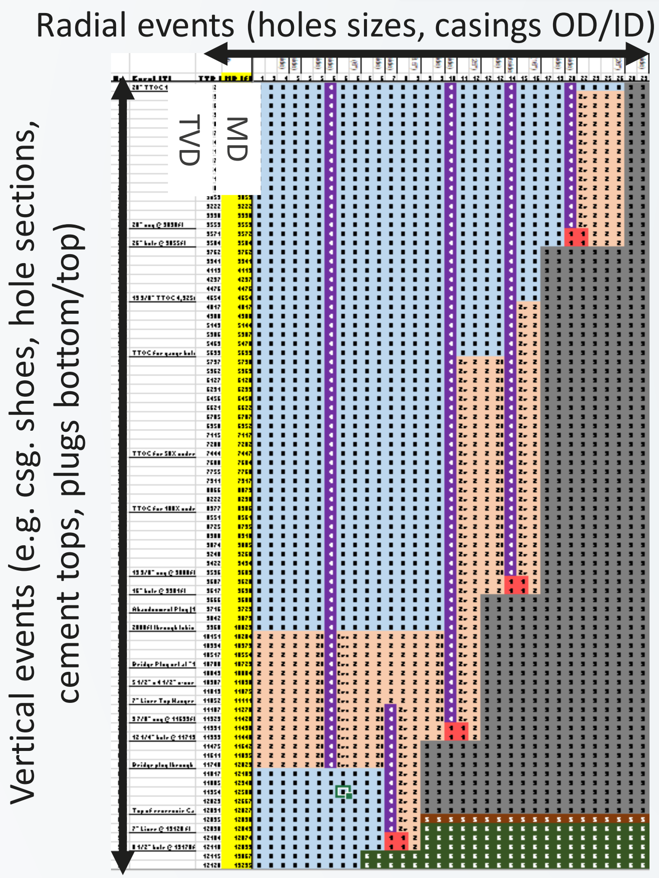
> **3.6.2 Penetrations Through Permanent Barriers**
>
> Provided the isolations outlined in these guidelines are achieved, cables and control lines can form part of permanent barriers. Assessment of potential leak paths and the plugging thereof should be conducted. A rigorous risk assessment process should be followed and documented and should consider:
>
> - Penetration type e.g. ESP cable, gauge cable, chemical injection line, control line.
> - Potential leak paths e.g. encapsulation, cable material, hydraulic line, bonding of barrier material.
> - Encapsulation material e.g. plastic type, damage during installation, interfaces between materials.
> - Degradation e.g. plastic encapsulation shrinkage, metal corrosion, barrier material interface, with consideration of temperature and fluid environment.
> - Leak path failure modes, and well specific risk profile, which may include cross-flow modelling.
> - Alternative isolation material requirements including seal-healing properties.

- Focused on three areas of investigation to address this challenge
  1. Risk-based modelling and optimisation of P&A barrier system to assess incremental risk of incorporating gauge cable into barrier
  2. Gauge cable encapsulation degradation
  3. Investigating the bond between gauge cable encapsulation material and cement interface and internal leak paths

Risk-based well P&A modelling framework

- Provides long-term performance modelling of P&A system for risk-based comparison of alternative design scenarios to support cost-saving via fit-for-purpose, well specific P&A design

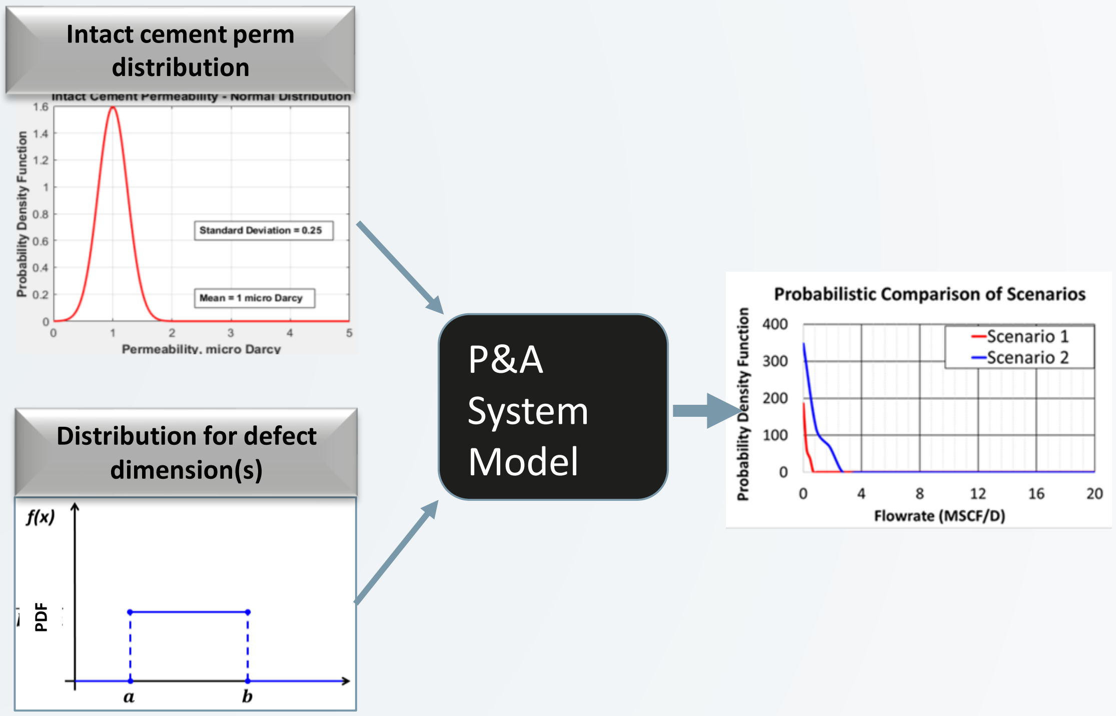
1- P&A System Model



- Grid-based numerical modelling approach.
- Well components and any possible integrity defects (micro-annuli, cable encapsulation degradation, channels or fractures in cement, casing leak) all explicitly defined.

0	Annular
1	PoorCement
2	GoodCement
3	InactiveCells
4	Casing
5	CapRock
6	Formation

2- Probabilistic Add-ons



✓Probabilistic evaluation and comparison of alternative P&A design scenarios.

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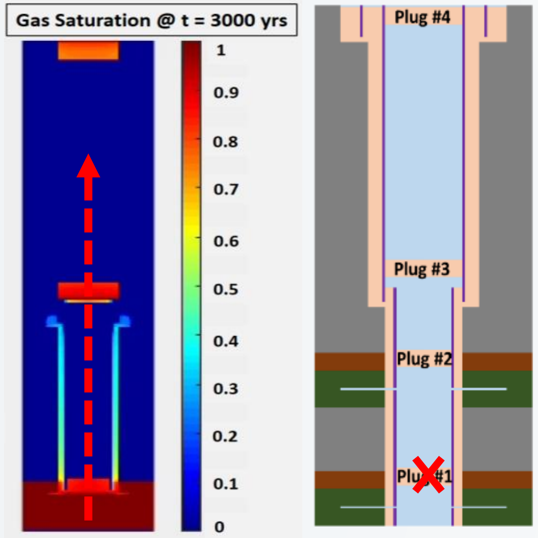
Key applications of the well P&A framework

- **Fieldwide (multi-well):** Probabilistic comparison of risk of leakage from different wells, to identify high/low risk wells, for a well specific P&A design
- **Well-based:** Support risk-based, well-specific P&A design by probabilistic comparison of alternative design scenarios
  - Fit-for-purpose, through-tubing P&A design
  - Identifying critical leak paths to support optimal P&A design or remedial operations.
  - Optimise number, location and length of barriers (model also quantifies cross-flow situations)
  - Value of new technologies (e.g. probabilistic analysis of alternative barrier materials)
- For more information see: SPE-200608-PA
- **Field trials:**
  - ***Conventional oil and gas fields*** – supported decision making for fit-for-purpose, robust P&A design of multiple wells
  - ***Carbon Capture and Storage (CCS)*** – an interim solution developed to support understanding of the long-term leakage risk associated with P&A'd legacy wells and field tested



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Overview of the risk-based decision-making approach

1. HWU created individual models for each of the 4 candidate wells.

2. Completed sensitivity analysis to establish critical parameters controlling the well's long-term leakage risk.

3. A probabilistic (Monte-Carlo) approach is then used to assess a range of input values for each of the critical parameters identified to allow probabilistic evaluation over a 3000 year period and comparison of alternative P&A design scenarios.

4. A fit-for-purpose, TT P&A design is then developed for each specific well to
   - reduce the long-term leakage risk associated with gauge cable and its degradation
   - ensure that the expected long-term leakage risk is comparable with a regular Through-Tubing cement job (without gauge cable)

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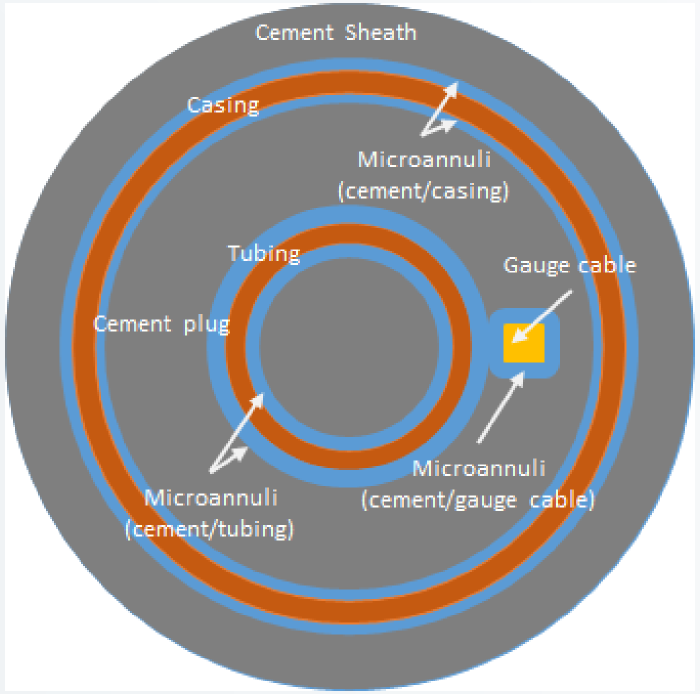
Well P&A system model & integrity defects

- Micro-annuli (MA) is considered as the possible integrity defect for these wells and divided to two groups:
  1. **MA1:** between the cement sheath/plug and the adjacent casing/tubing
  2. **MA2:** around the gauge cable. This can be wider than the MA1 due to possible long-term material loss from the GC

- The following conservative assumptions were considered :
  - Instantaneous recharge to virgin reservoir pressure
  - Micro-annuli exist in all cement/tubular contacts and along the entire section
  - All mechanical barriers are fully degraded (i.e. not included in the model)

- Below ranges and distributions were used for uncertain defect parameters

Uncertain Parameter	Range	Probability distribution
Cement Permeability	0.001mD - 0.02mD	Normal distribution
MA1	0-56 µm	Uniform distribution
MA2 – with intact gauge cable	0 - 22 µm	Uniform distribution
Gauge cable degradation	0 - 2% of gauge cable's size	Uniform and stochastic distribution (next slide)



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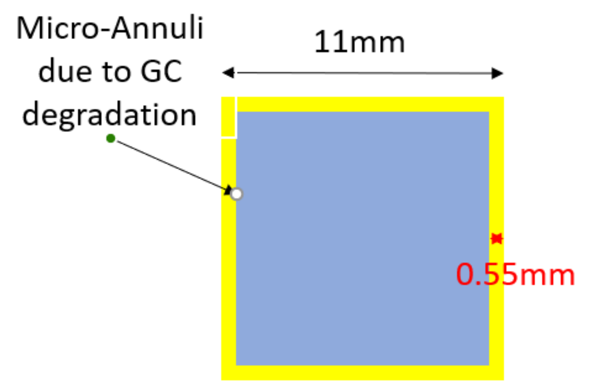
Gauge cable degradation

- Gauge Cable Degradation (GCD) was found to be the most critical (and uncertain) parameter.
- Following approaches are considered to model GCD profile:

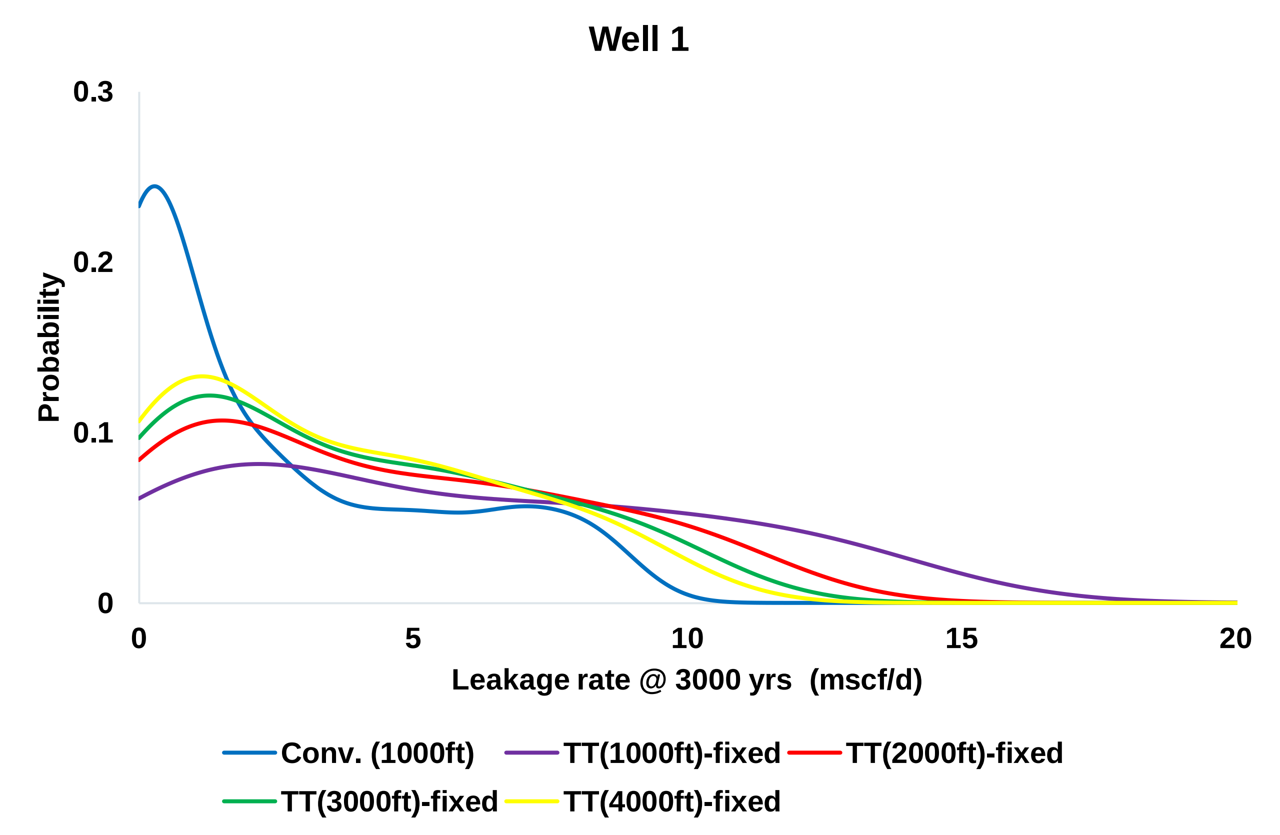
1. **Conservative: Fixed GCD Approach:** a single GCD value along the entire length of the GC, randomly chosen from the defined range (0-2% of the GC's width).

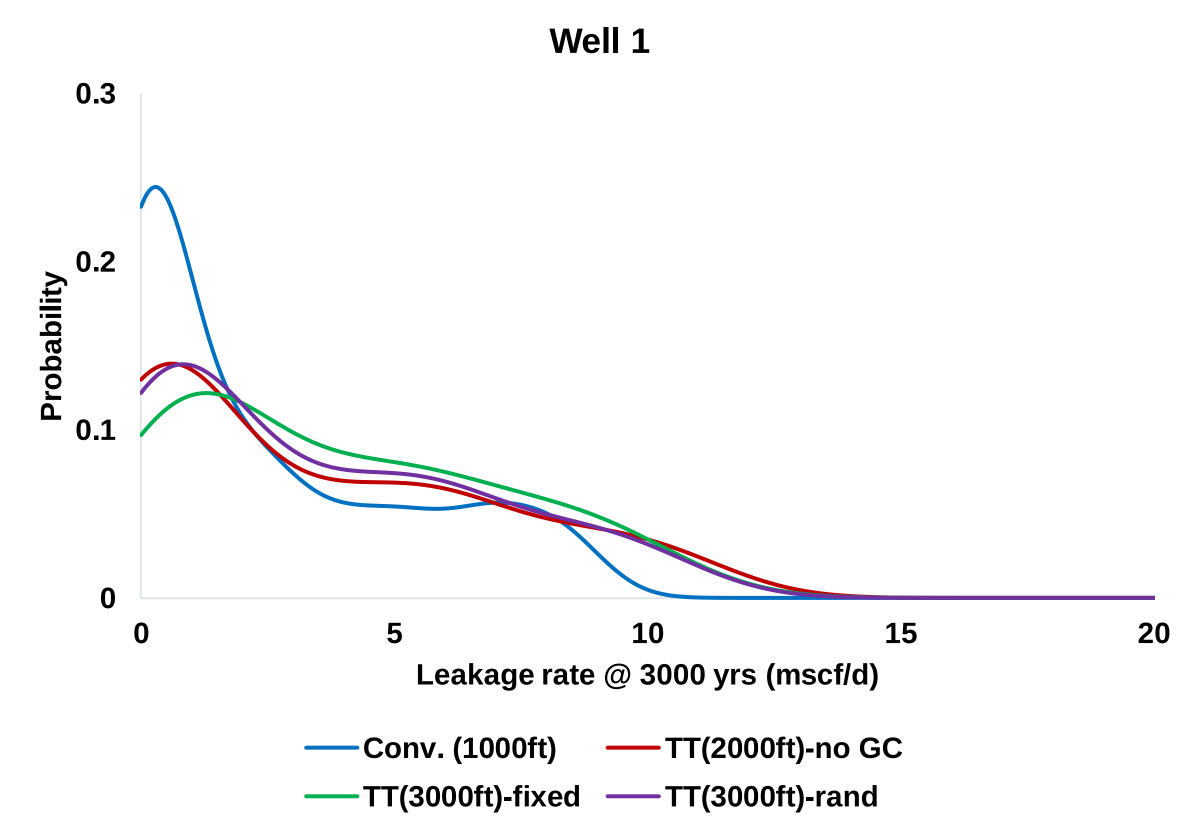
2. **More realistic: Randomly Distributed:** GCD expected to vary with depth due to changes in the localized wellbore environment. This is characterised by discritising the cement plug section with GC to ~50ft intervals and assigning a random GCD value (from 0 – 2% range) to each interval. Better and poorer bonds are present at random intervals.



Note that the degradation % figures represent reduction in cross sectional dimension assuming degradation occurs on the external surface only, e.g. 10% degradation is shown above.

Results – Well 1





- Sensitivity performed on TT plug length (1000-4000 ft) and gauge cable degradation assumptions (fixed or randomly distributed)
- "TT (2000ft)-No GC" is a standard TT scenario with no gauge cable

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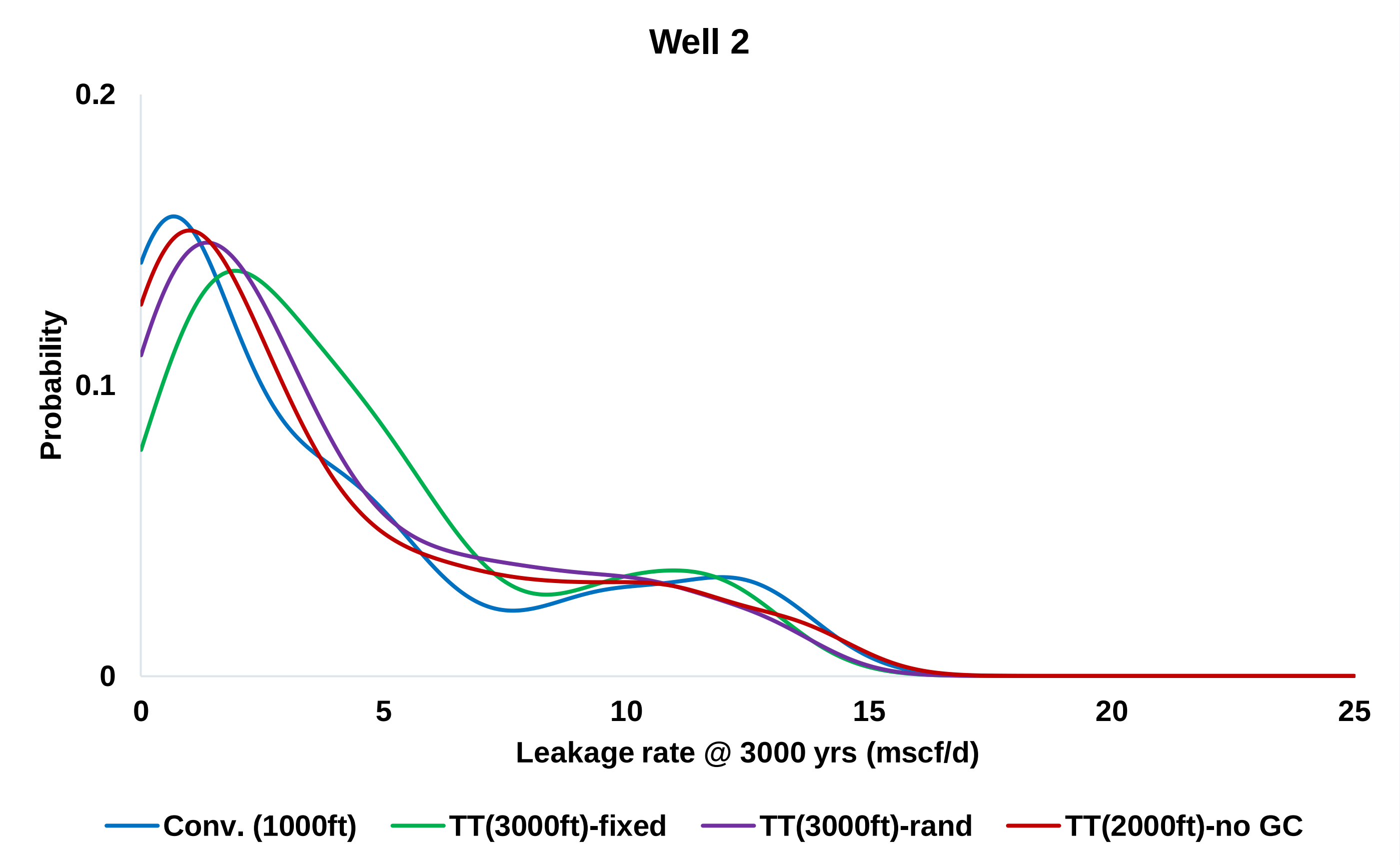
Results – Well 2



	Average leak rate @ 3000 yr (Mscf/d)		
Well	TT 2000ft no GC	TT 3000ft GC (0-2% degradation)	Conventional 1000ft plug
Well 2	3.80	3.89	3.74

- “TT (2000ft)-no GC” represents a standard TT scenario with no gauge cable
- Risk-based approach shows that incremental risk associated with presence of gauge cable is negligible

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Conclusions and considerations

For through-tubing abandonments with gauge cable, considerations would be to:

- **Complete a well-specific risk assessment**
  - A probabilistic approach should be considered to account for various uncertainties to provide extra assurance during the decision-making process
- **Increase length of through tubing cement plug if a gauge cable is present**
- **Utilise an agitator to ensure the best quality cement placement around the gauge cable (minimises potential for micro annuli)**
- **Ensure long-term degradation of the gauge cable is less than 2% (dimensional reduction)**
  - By completing long-term degradation studies of the encapsulation material

Future work

- **Ongoing study into gauge cable degradation for various encapsulation materials**
- **Pressure testing of cement to encapsulation material interface**
- **Collaborate with other operators to share data and build industry consensus**
- **Further develop Well P&A Modelling Framework analysis**
  - Utilise Well P&A Modelling Framework for other field applications
  - Work with other operators during upcoming field applications to identify improvement opportunities
  - Objective is to evolve the framework into a tool for in-house applications
  - R&D Project: comprehensive extension of the Well P&A Modelling Framework for application to Carbon Capture and Storage (CCS) fields to address an important, unmet, industry need

Thank you for your attention
Questions