The Subsurface Isolation Strategy: An Integrated Approach to Well Abandonment Planning

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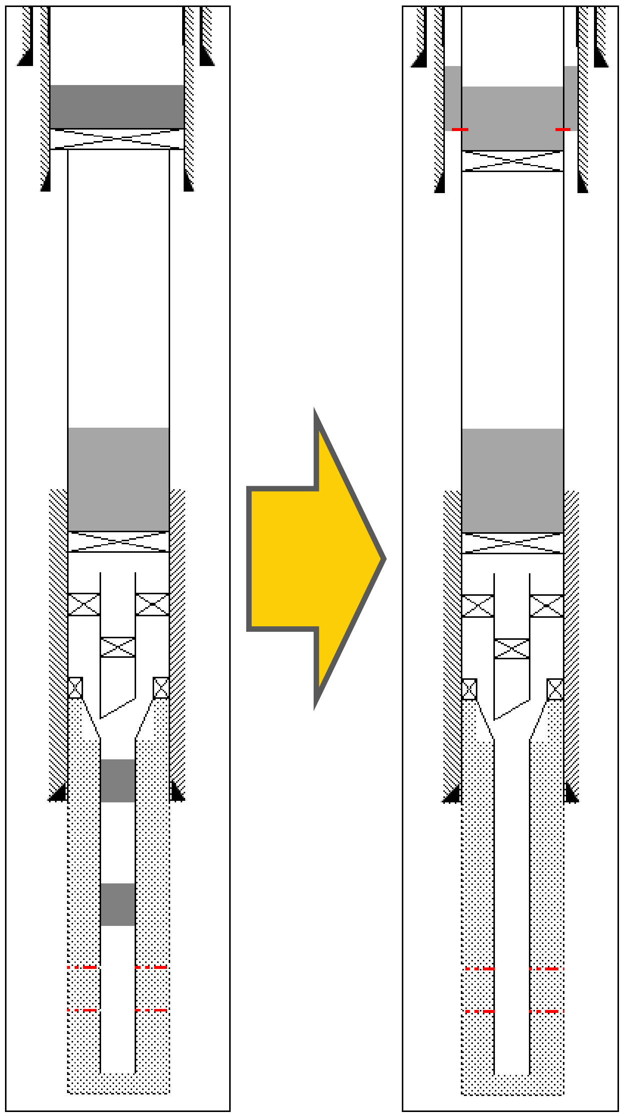
Objectives

- There are currently ~3650 wells on the UKCS to be Plugged and Abandoned (P&A). The estimated cost of P&A is currently estimated to be £19 billion, shared between operators and UK taxpayers.

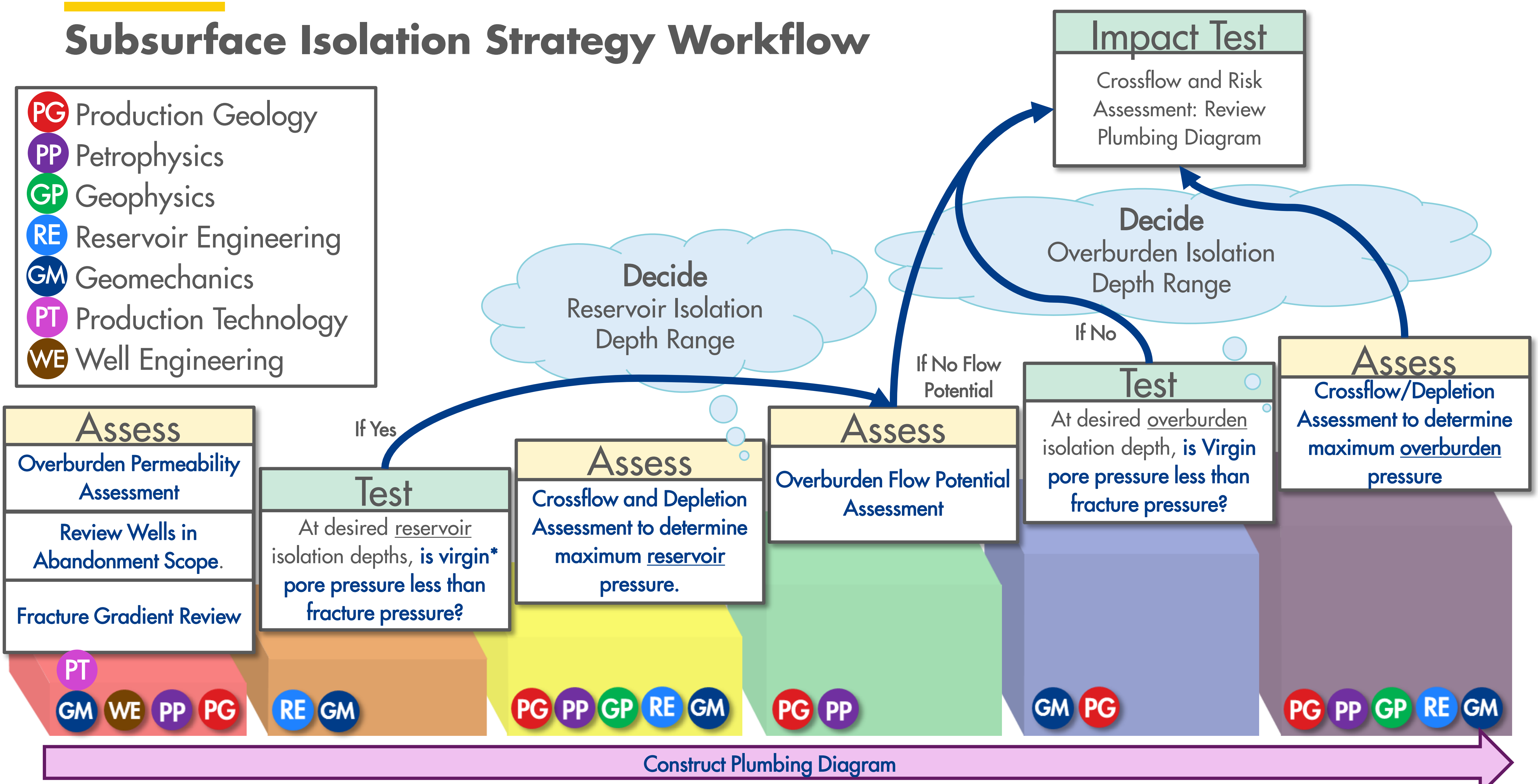
- A strategic initiative to reduce P&A cost whilst meeting current regulations and industry guidelines (*The Offshore Installations and Wells Regulation 1996, O&GUK Guidelines for the Abandonment of Wells, 2015*) is in the integrated preparation of a Subsurface Isolation Strategy.

- An integrated Subsurface Isolation Strategy (SIS) is worked for every field to be abandoned, and addresses two critical decisions which influence abandonment design:
  - Which formations require isolation?
    - Reduction in number of plugs directly reduces P&A cost.
  - Within what depth range should these isolations be achieved?
    - Optimal placement of barriers reduces P&A cost by removing scope (eg, section milling production packers, or fishing).
    - Broadening the isolation depth range can enable further cost savings through added flexibility in P&A execution strategy (eg, to enable "through-tubing" abandonment).

- Across the Shell UK subsea abandonment portfolio, the total reduction in Abandonment Expenditure through integrated Subsurface Isolation Strategies exceeds £80 million, with significant further scope for savings through optimised execution strategy.



Subsurface Isolation Strategy Workflow



* Consideration required for fields with injection (has reservoir been recharged to > virgin pressure?)

Subsurface Isolation Strategy Workflow

Impact Test

- PG Production Geology
- PP Petrophysics
- GP Geophysics
- RE Reservoir Engineering
- GM Geomechanics
- PT Production Technology
- WE Well Engineering

Assess

- Overburden Permeability Assessment
- Review Wells in Abandonment Scope.
- Fracture Gradient Review

PT GM WE PP PG

At des… isolation … pore pr… fract…

RE GM

…ss … epletion … determine … rburden … e

RE GM

<u>Overburden Permeability Assessment:</u>

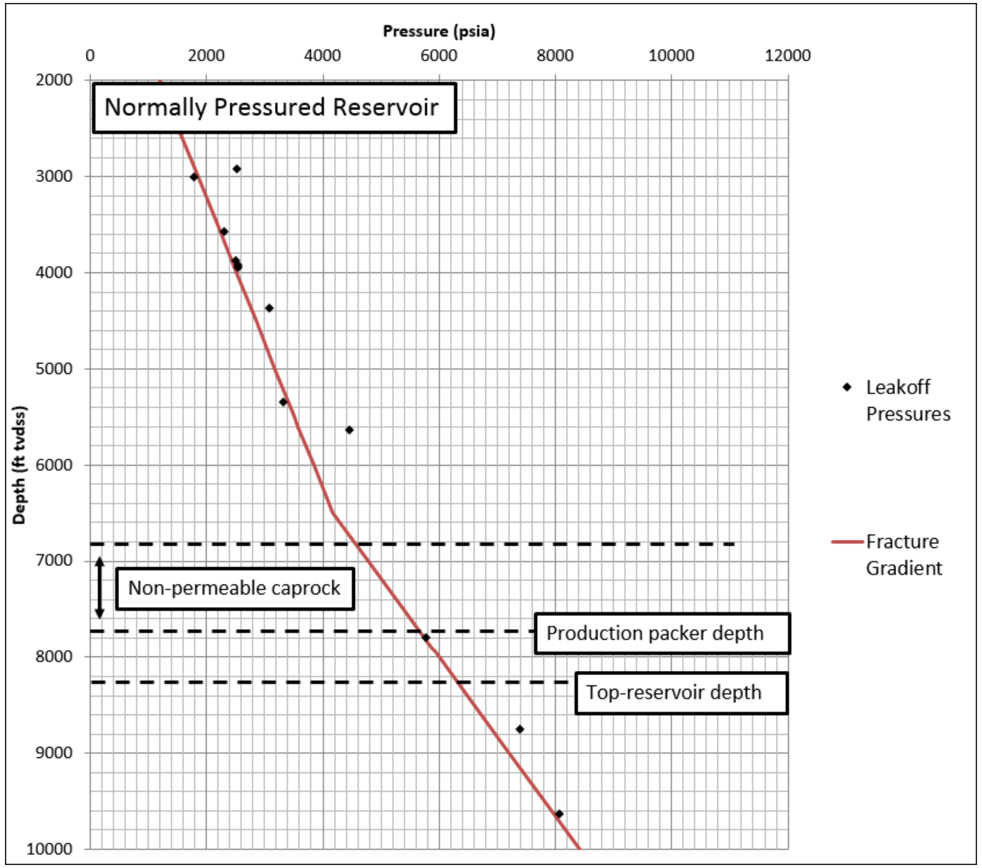
- Isolation cannot be achieved over permeable formations.
- Logging and drilling records evaluated to categorise overburden zones into ‘permeable’ and ‘non permeable’ zones.

<u>Review Wells in Abandonment Scope:</u>

- Isolation may be more challenging or costly at certain depths (due to presence of completion equipment, fish or integrity issues).
- Completion reports and previous well entry reports evaluated to determine isolation depths which could result in added cost or complexity.

<u>Fracture Gradient Review:</u>

- Overburden formation strength evaluated based on available LOT data, if available.
- If the reservoir has been heavily depleted, geomechanical modelling is conducted to assess possible impact on overburden integrity due to induced stress effects.



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If Yes

Test

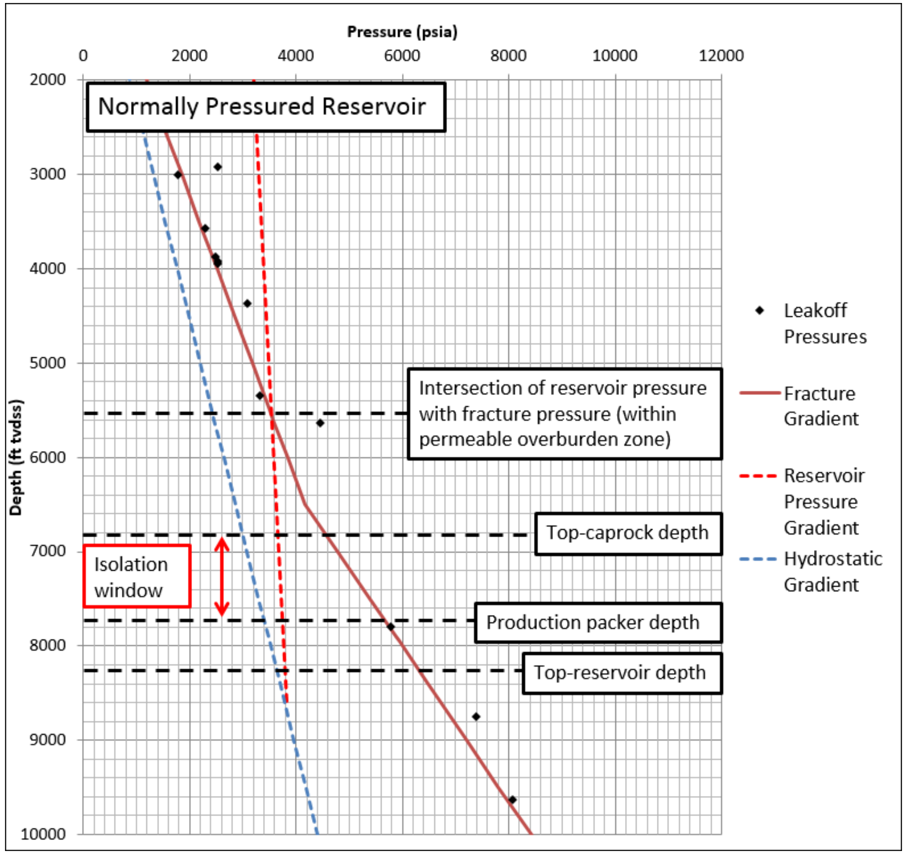
At desired reservoir isolation depths, **is virgin* pore pressure less than fracture pressure?**

RE GM

PG

Isolation Test:

- Assume the reservoir is able to recharge to virgin pressure over the long-term.
- Virgin reservoir pressure is plotted against fracture gradient and overburden/well constraints.
- **If an optimal isolation window exists on each well, provisional reservoir isolation depth range can be provisionally decided.**
- If an isolation window does not exist, a "Crossflow and Depletion" assessment may be carried out, to evaluate likely reservoir recharge scenarios.



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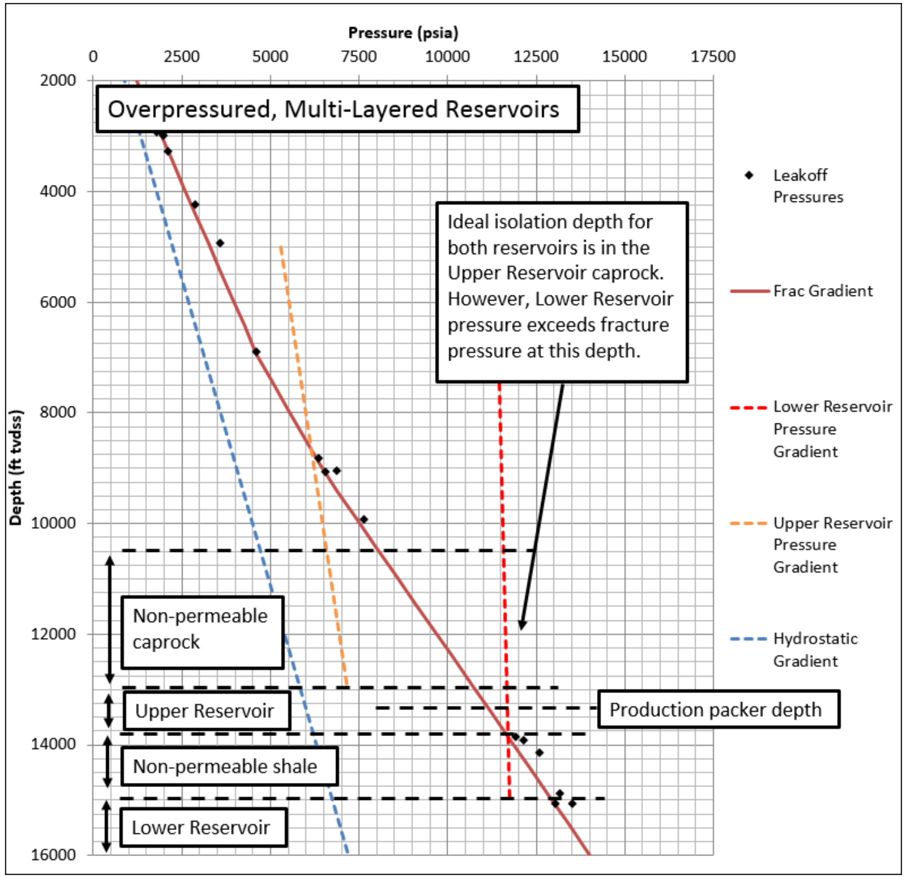

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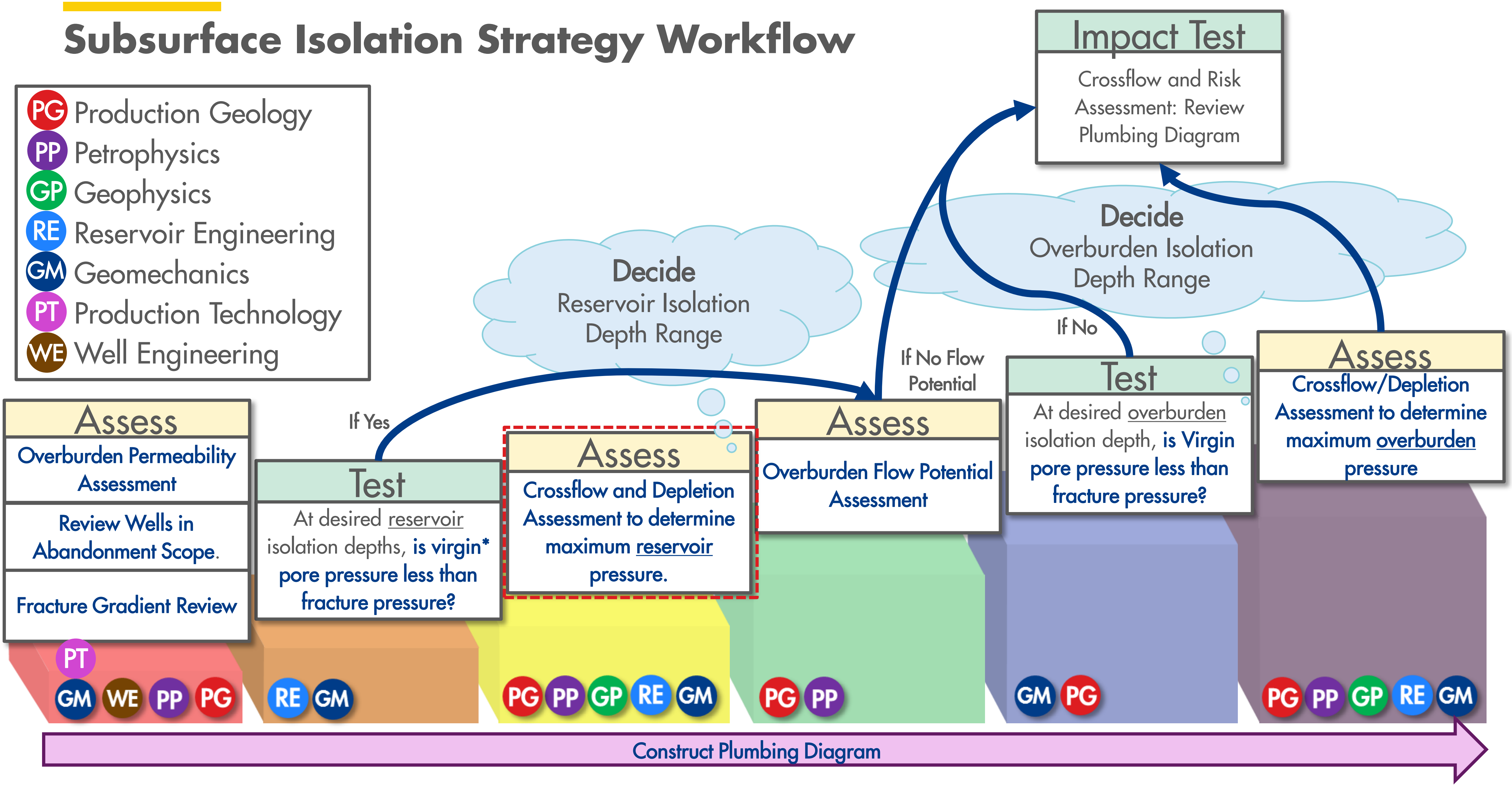
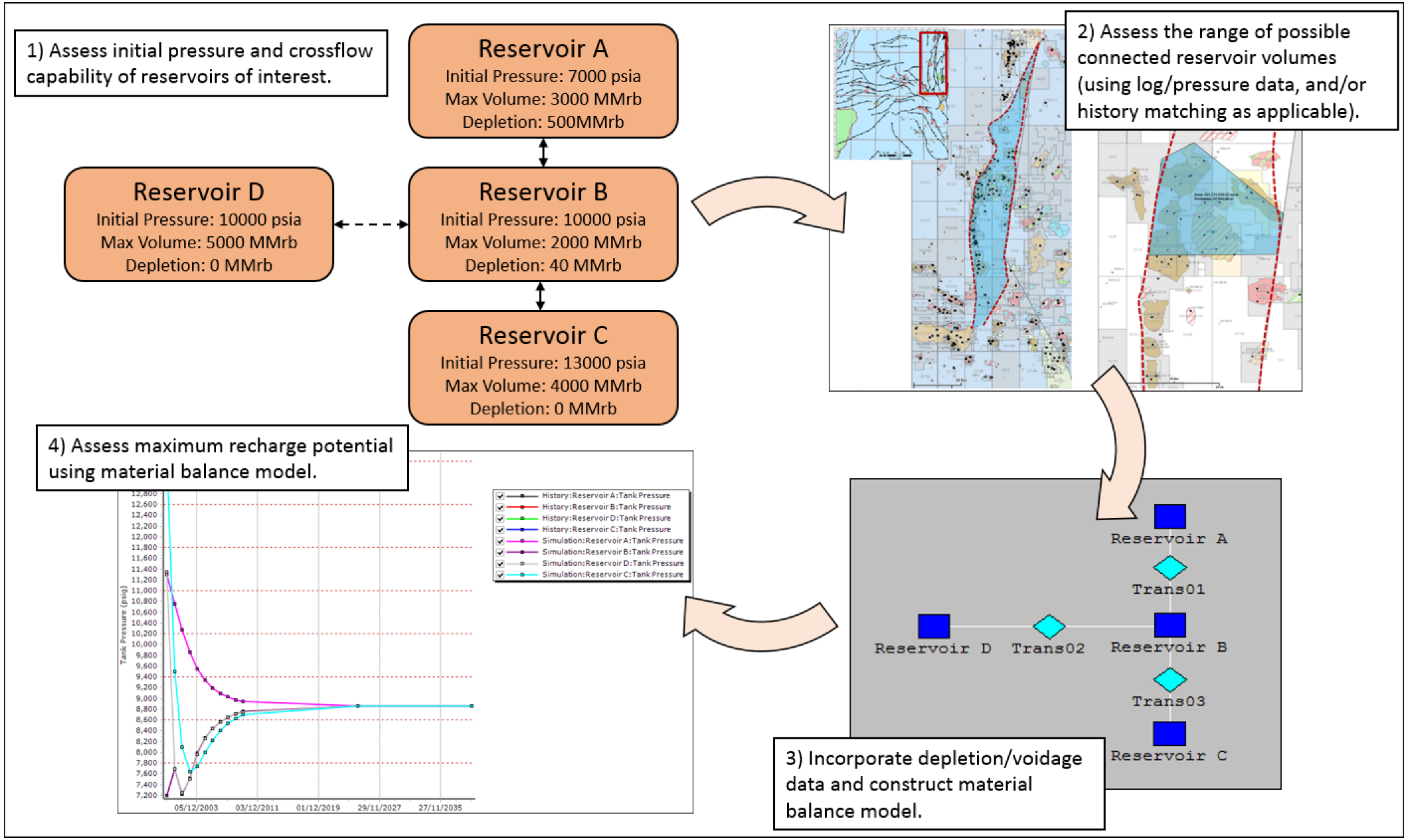


Subsurface Isolation Strategy Workflow

Impact Test



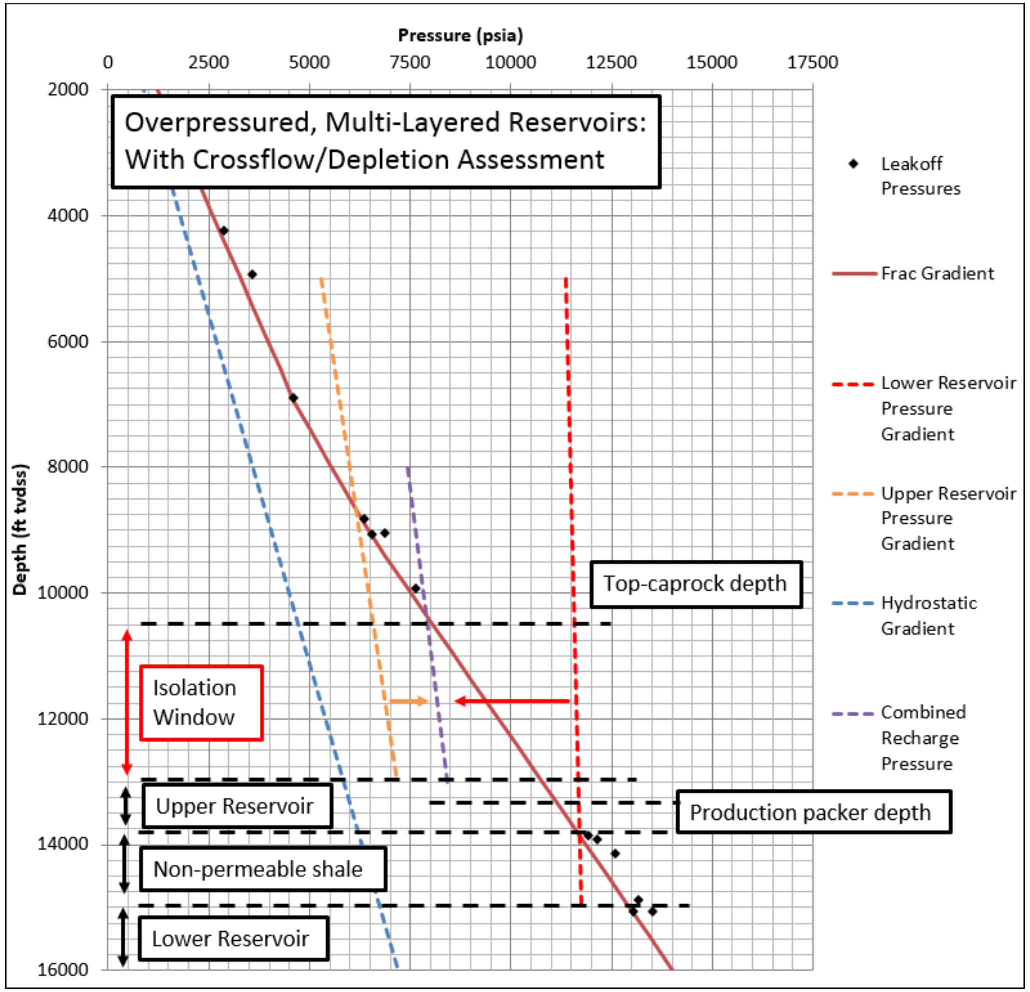
NB: An assessment is required based on available subsurface data on whether recharge pressure can be safely lowered from virgin. The above workflow is indicative only.

Subsurface Isolation Strategy Workflow

Impact Test

Isolation Test:

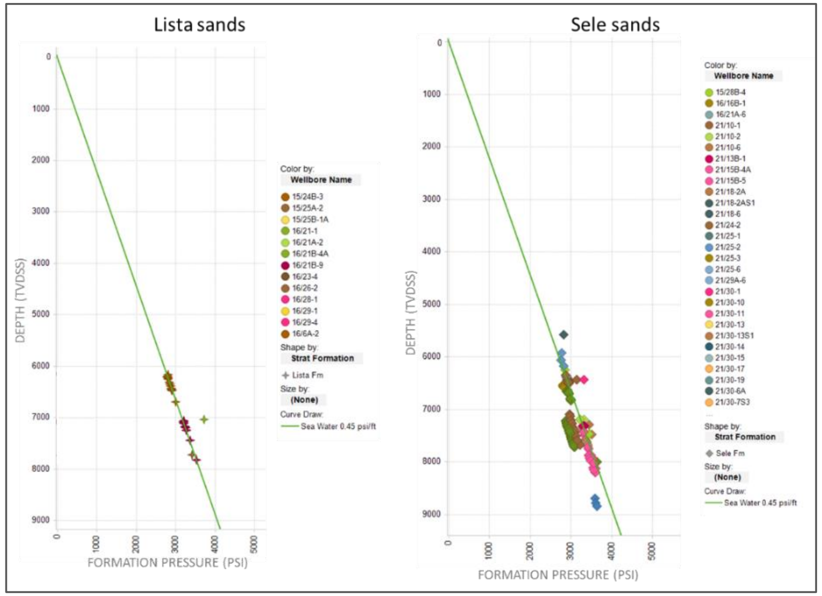
- Following assessment of reservoir recharge pressure, another assessment can be made on whether isolation can be achieved at the optimal abandonment depth.
- In this example, it was assessed that maximum recharge pressure is sufficiently low that it does not exceed fracture gradient within the Upper reservoir caprock.
- Reservoir isolation depth can be provisionally decided at this stage.

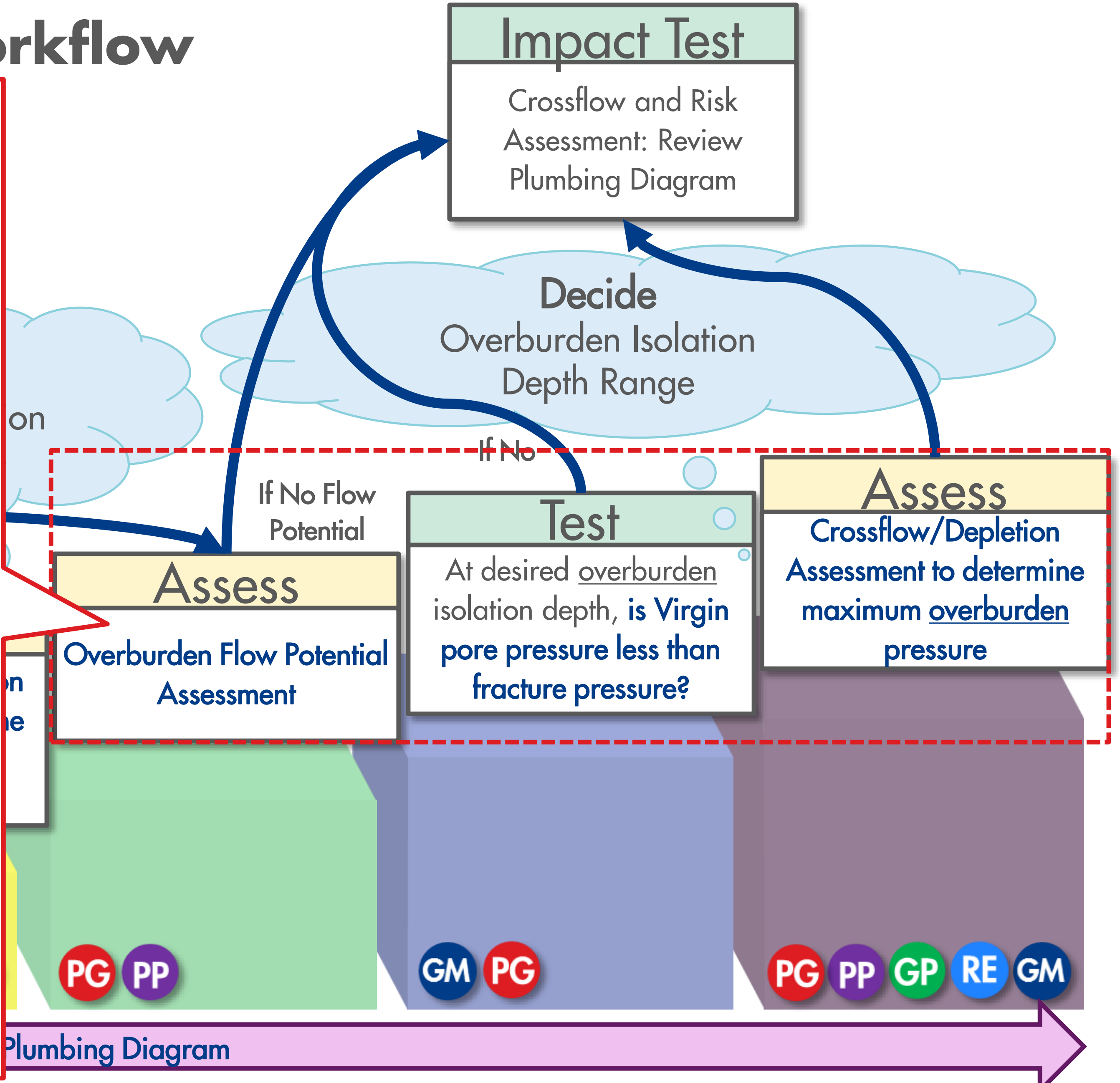


Subsurface Isolation Strategy Workflow

Overburden Flow Potential Assessment:

- Overburden sands which have been identified as permeable are assessed using log/seismic data and drilling records for indications of flow potential.
- A risk of flow potential is applicable in hydrocarbon bearing sands (which have a positive pressure differential to surface), or overpressured water-bearing sands.
- It is possible that there is sparse in-field overburden data. Data obtained from offset fields, or geological trends may assist in assessing flow potential risk.

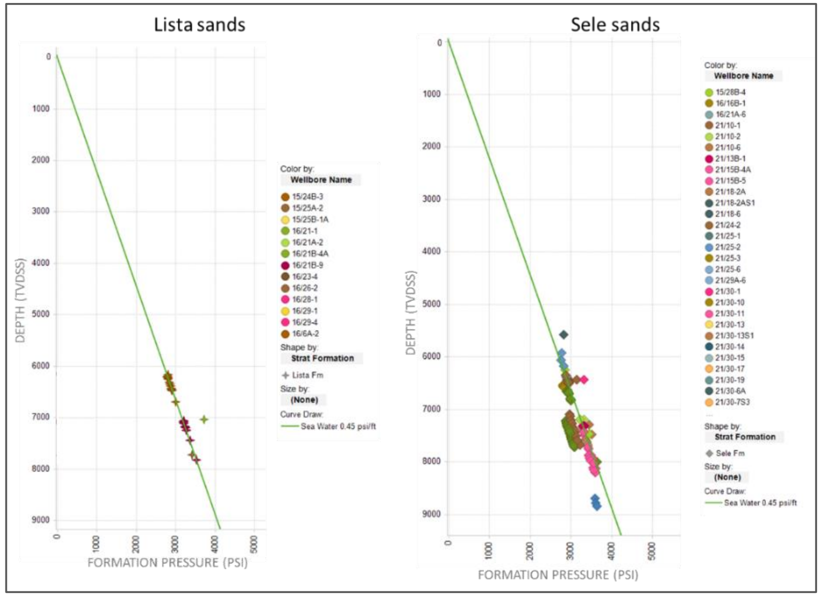


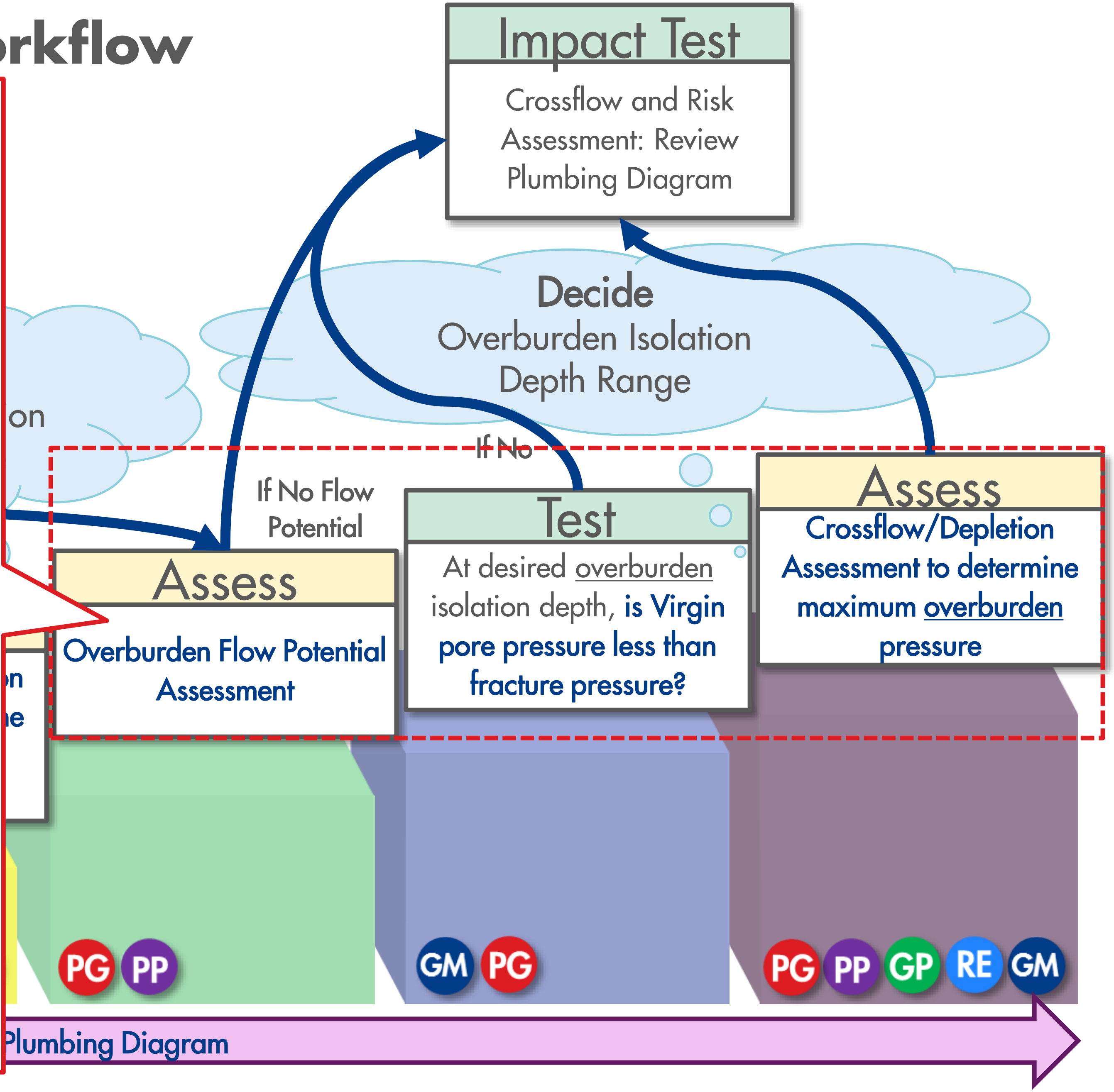


Subsurface Isolation Strategy Workflow

Overburden Flow Potential Assessment:

- If it is assessed that there exists no credible risk of overburden flow potential, no overburden barriers are specified.
- If there exists a risk of overburden flow potential, optimal placement of the overburden plug(s) is decided using the same workflow as that for reservoir barriers.

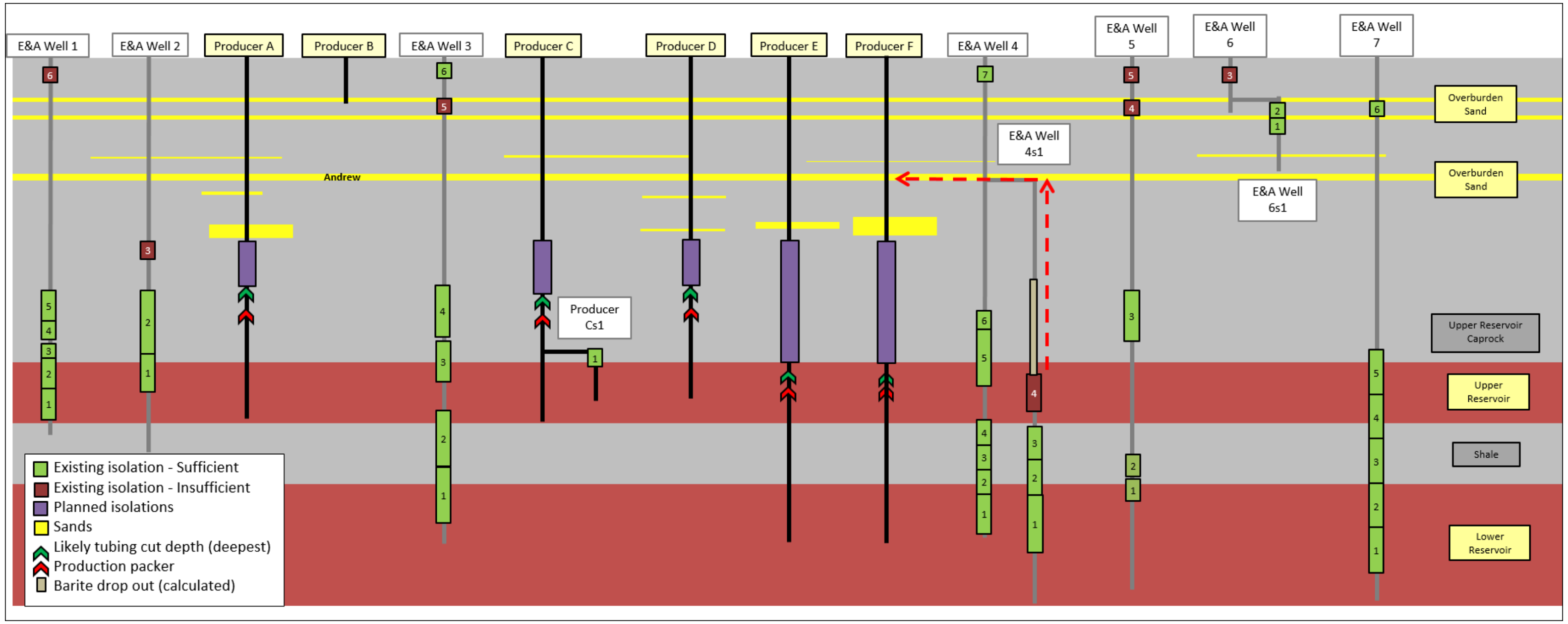


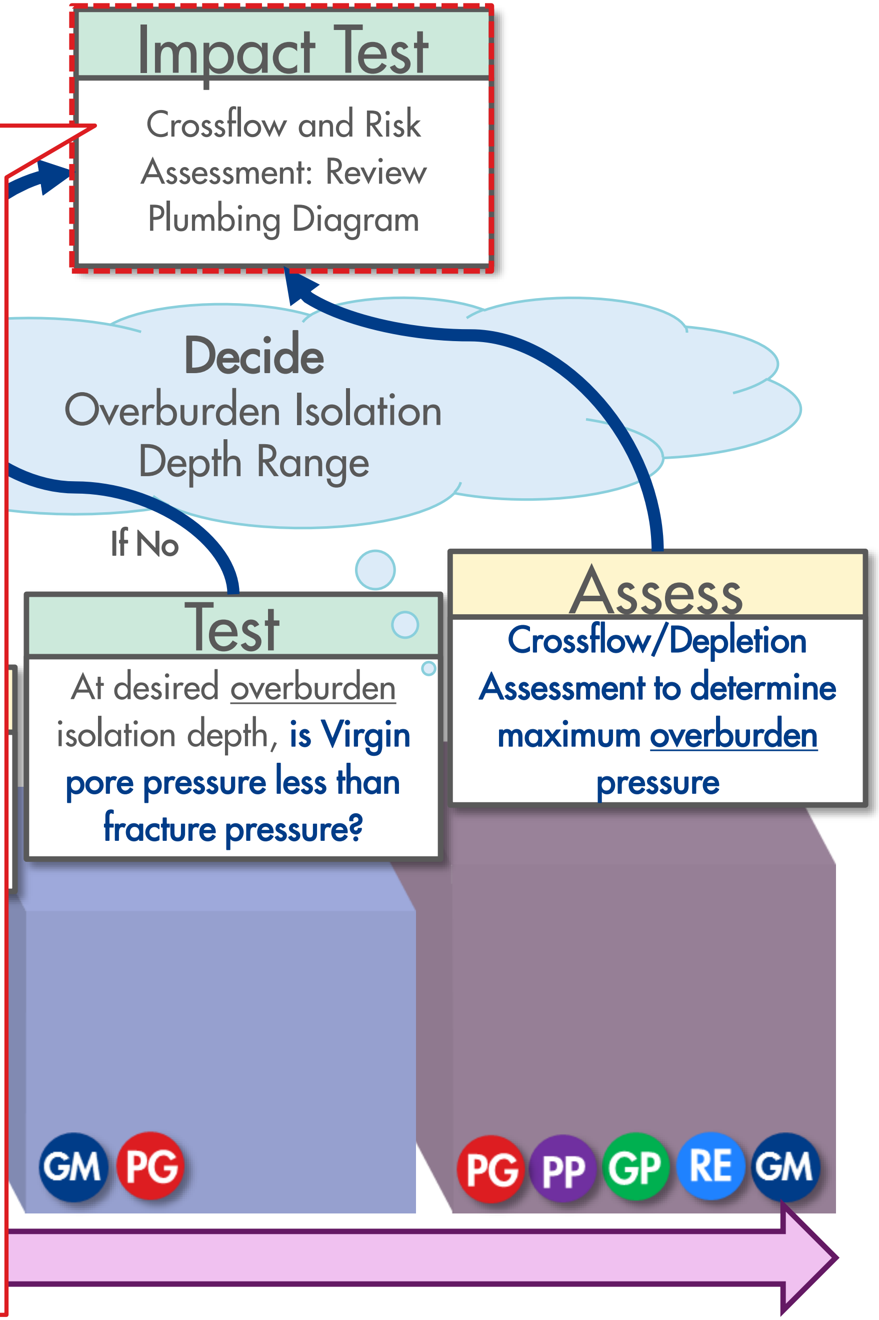


Subsurface Isolation Strategy Workflow

<u>Impact Test (Review of "Plumbing Diagram")</u>

- During preparation of the SIS, a "Plumbing Diagram" is drafted and populated as more data is gathered. This gives an overview of overburden and reservoir formations, existing well penetrations, and previously abandoned (eg, E&A) well trajectories.
- By the end of the process, provisional reservoir and overburden isolation depths have been established. The plumbing diagram is inspected to assess whether any further isolations are required due to cross-flow effects.
- In the example below, further analysis would be conducted to determine likelihood of fluid leakage from the Upper Reservoir and Producer F, and hence whether additional isolation is required.





Summary & Acknowledgements

- A detailed understanding of what cost savings can be achieved (by removal or scope, or by application of technology) – and how this links to isolation depths – drives the subsurface work to be conducted early in the abandonment design phase.

- An integrated and well-defined subsurface isolation strategy is critical to the success of a well abandonment campaign, in that cost savings are maximised and risk of future release of reservoir fluids to surface is reduced to ALARP.

- Across the Shell UK subsea abandonment portfolio, the total reduction in Abandonment Expenditure through integrated Subsurface Isolation Strategies exceeds £80 million, with significant further scope for savings through optimised execution strategy.

- The authors would like to thank all of our colleagues and partners who have worked with us on preparation of Subsurface Isolation Strategies, and in preparation of the integrated workflow.