Gas Field Development - Challenges and Current Best Practices to Maximise Value

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Enhancing Well Completion Productivity in HPHT Tight Gas Reservoirs

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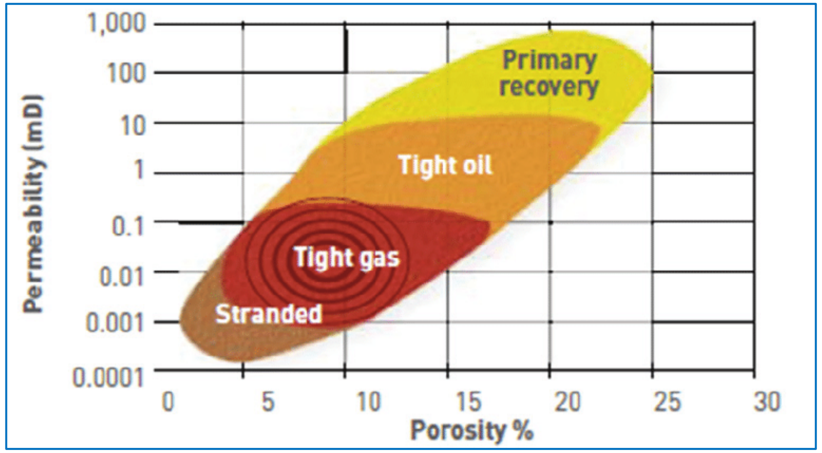
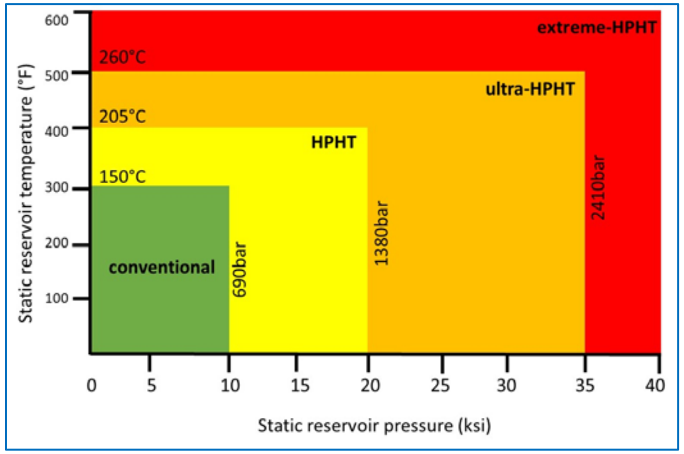
Agenda

1. Problem Statement and Objectives
2. Economic Importance of Well Productivity
3. Key parameters, Data Required
4. Well Completion Productivity Models
5. Completion Techniques - Highlights and Best Practices
6. Summary, Conclusion

Challenges and Objectives



(Ahmed et al., SPE 126181, 2010)



(Debruijn et al., Oilfield Review, 2008)

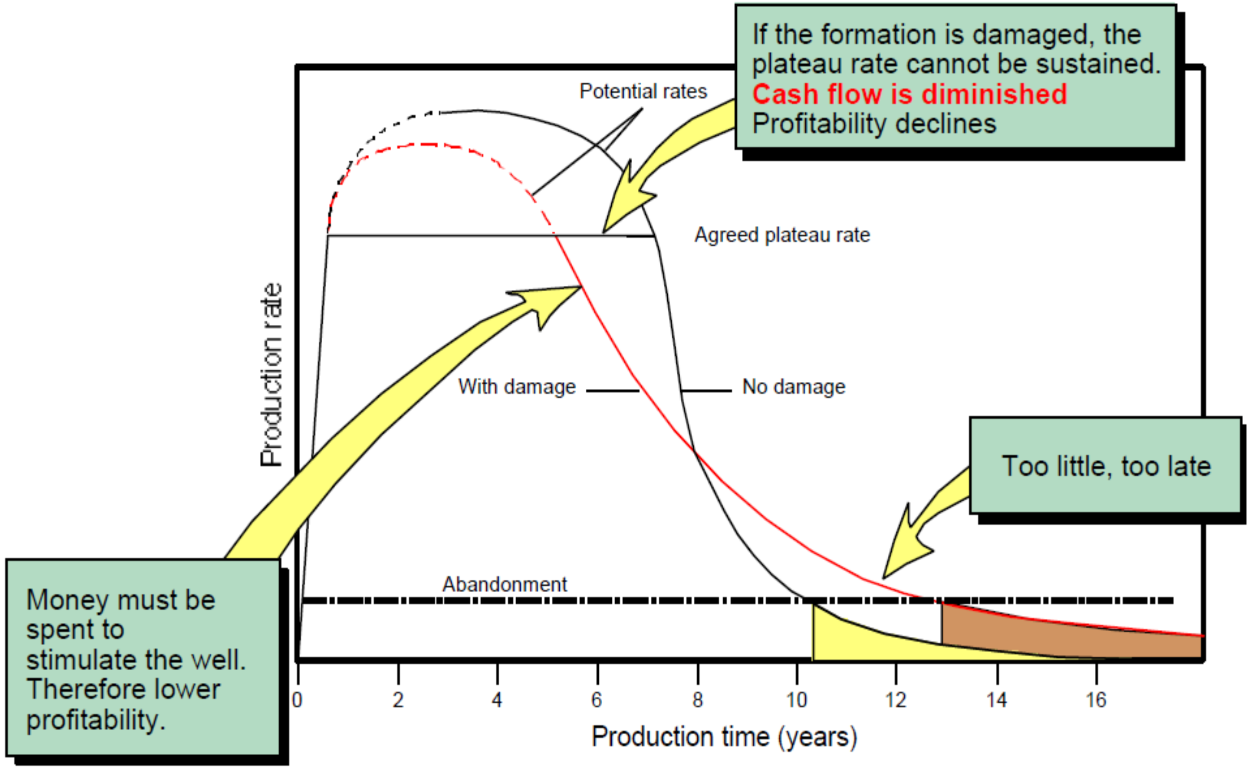
Challenges

- Low permeability
  - Flow capacity
  - Well clean-up, phase trapping concerns
  - Strong impact by high skin
- High temperature
  - Equipment, chemical temperature rating
  - High performance gun and charge system
  - Stimulation fluid

Objectives

- Select appropriate completion method for each specific reservoir, fluid properties
  - Well productivity
  - Cost and reliability
- For selected completion method
  - Verify impact of each parameter
  - Optimize design of each parameter to maximize well productivity

Economic Importance of Well Productivity

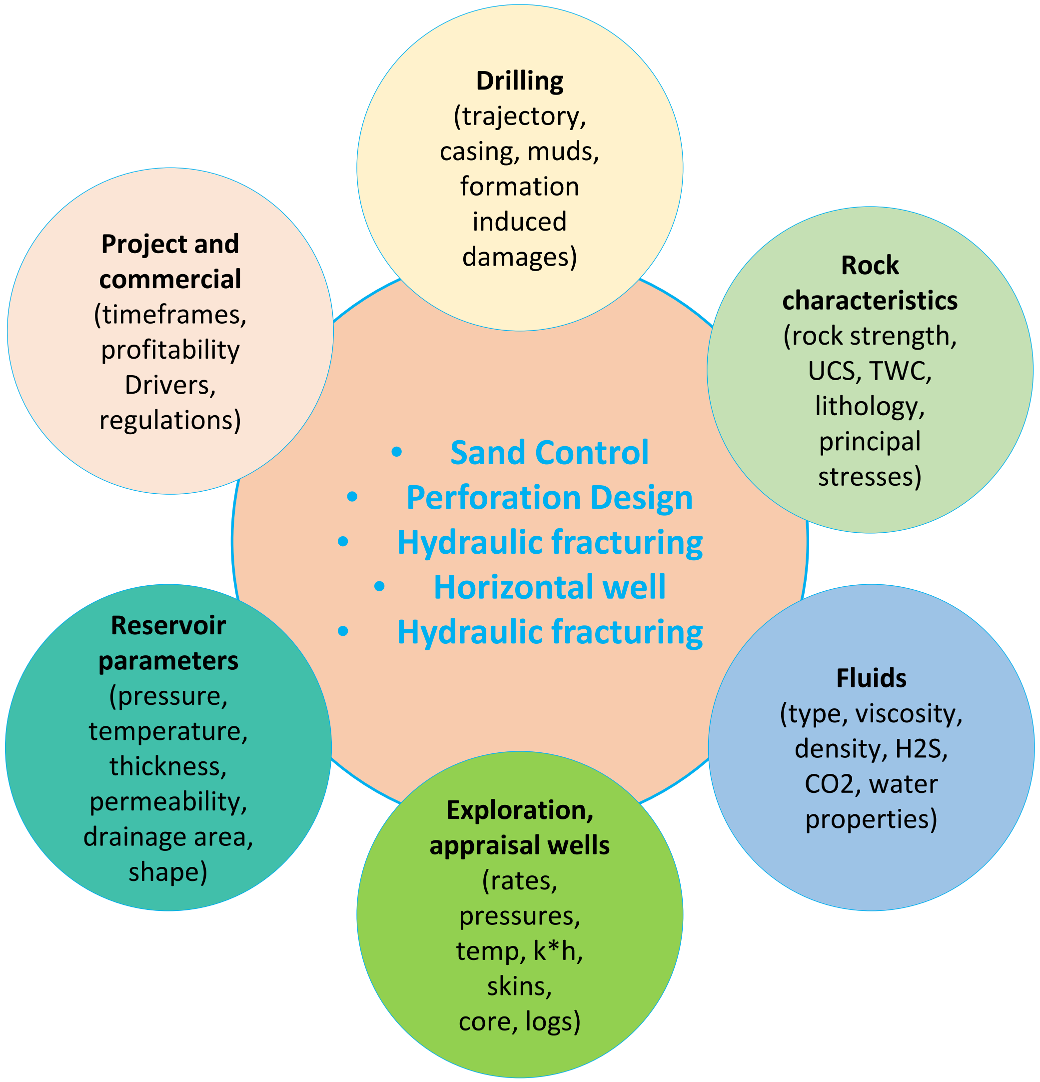


(Well Productivity Awareness, TRACS, BP, 2001)

Maximize NPV with high well productivity

- Meet agreed plateau rate
- Accelerate production
- Minimize well count
- Less workover, well services works
- Enhance recovery factor
- Project economic

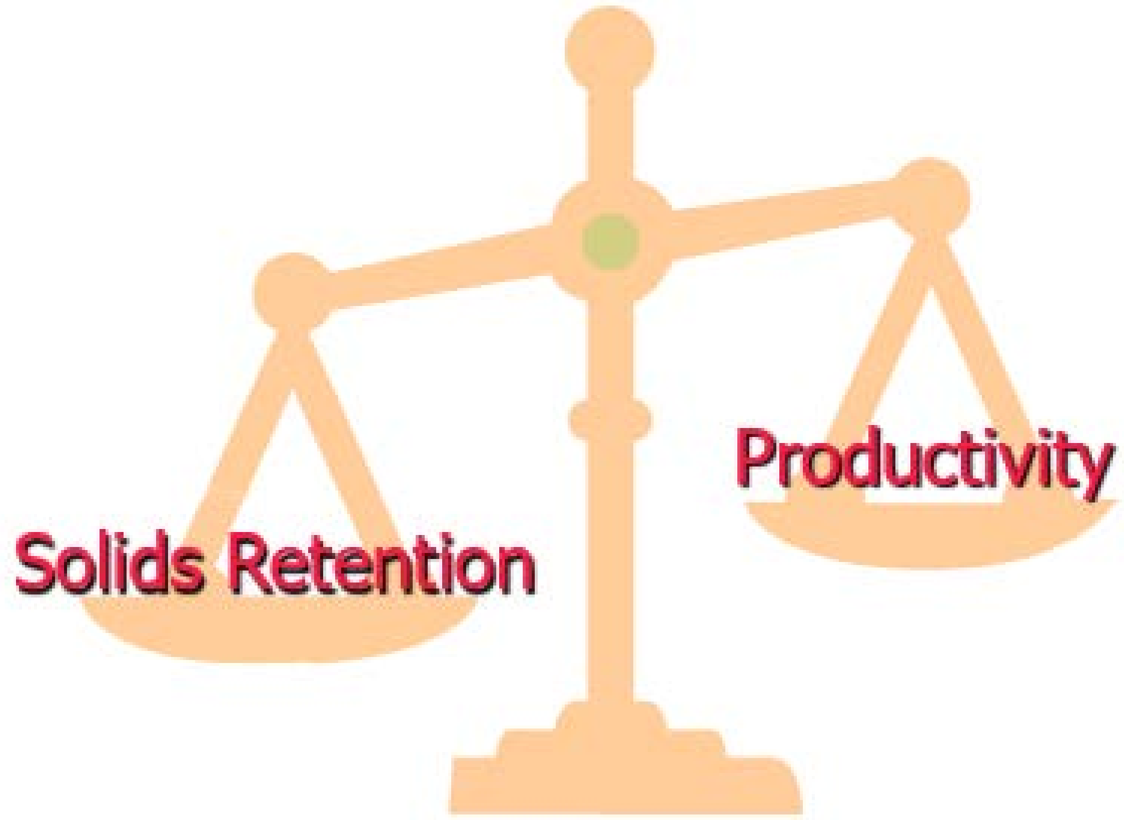
Well Productivity – Key Parameters



Key parameters affecting well productivity

- Value of information
- Data acquisition program
- High-quality input data
- Range and uncertainty

Sand Control



Do we need sand control completion?

- Sufficient data set required for sand control design.
- Sand control or no sand control required
- Well productivity and experience of installation.
- Remedial works do not restore the well productivity
- DO IT RIGHT THE FIRST TIME

Well Productivity Models

Vertical well model
(Steady-state)

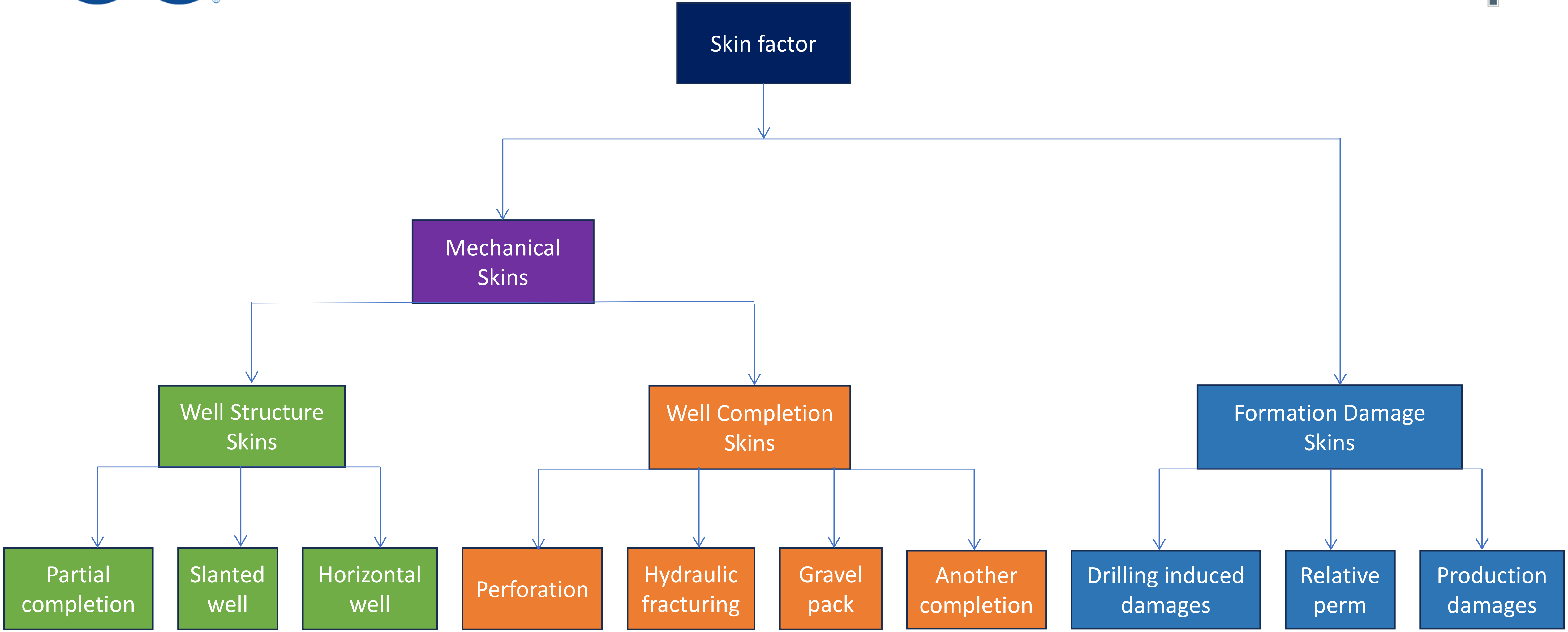
$$q = \frac{k_h\, h(\psi_{pe} - \psi_{wf})}{1422T_R\, [ln\frac{r_e}{r_w} + (s_{p,total} + Dq)]}$$

Horizontal well model
(Steady-state, Joshi and Economides's model)

$$q = \frac{k_h\, h(\psi_{pe} - \psi_{wf})}{1422T_R\left[ln\left(\frac{a + \sqrt{a^2 - (L_w/2)^2}}{L_w/2}\right) + \frac{I_{ani}h}{L_w}\, ln\left(\frac{I_{ani}h}{r_w(I_{ani}+1)}\right) + \frac{\boldsymbol{I_{ani}h}}{\boldsymbol{L_w}}(s_{p,total} + Dq)\right]}$$

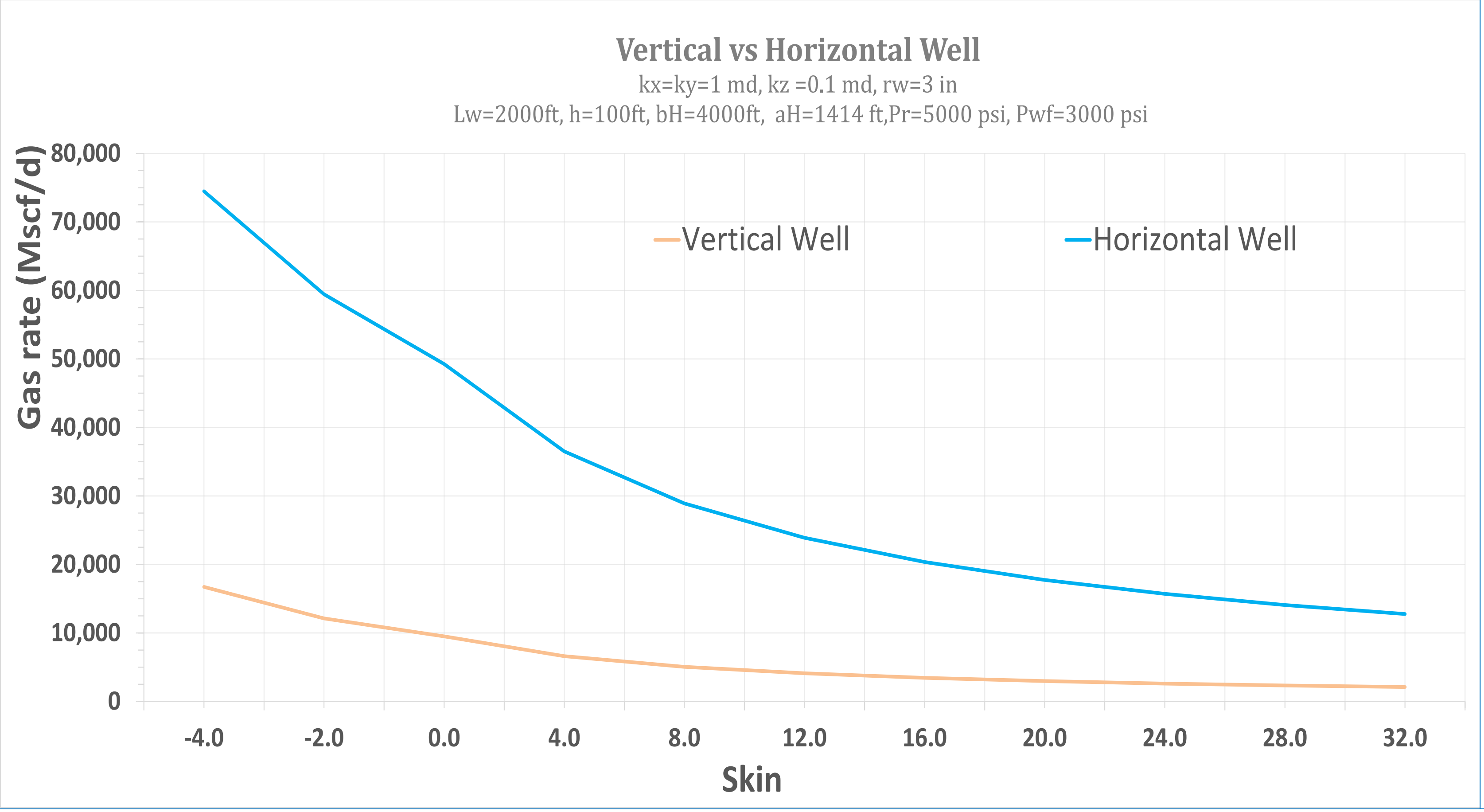
- Well Completion Efficiency representative by Skins
- Models are valid for various completion methods
- No-Darcy skin is significant in gas well
- Horizontal well: Completion skin and non-Darcy skin are multiplied by $\frac{\boldsymbol{I_{ani}h}}{\boldsymbol{L_w}}$.
- With a thin reservoir and long horizontal length: $I_{ani}h \ll L_w$; $\frac{\boldsymbol{I_{ani}h}}{\boldsymbol{L_w}} \ll 1$.
- Impact of skins on horizontal well reduced when compared to vertical well.

Minimizing Skins



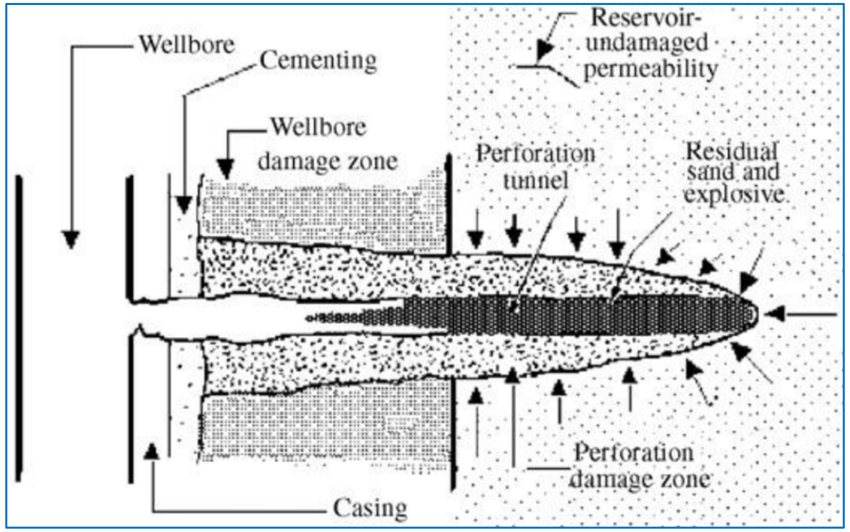
- Design well, completion to minimize skins
- Minimize skins throughout the well's life
- Not all skins are removable
- Best practices are available

Vertical vs Horizontal Well

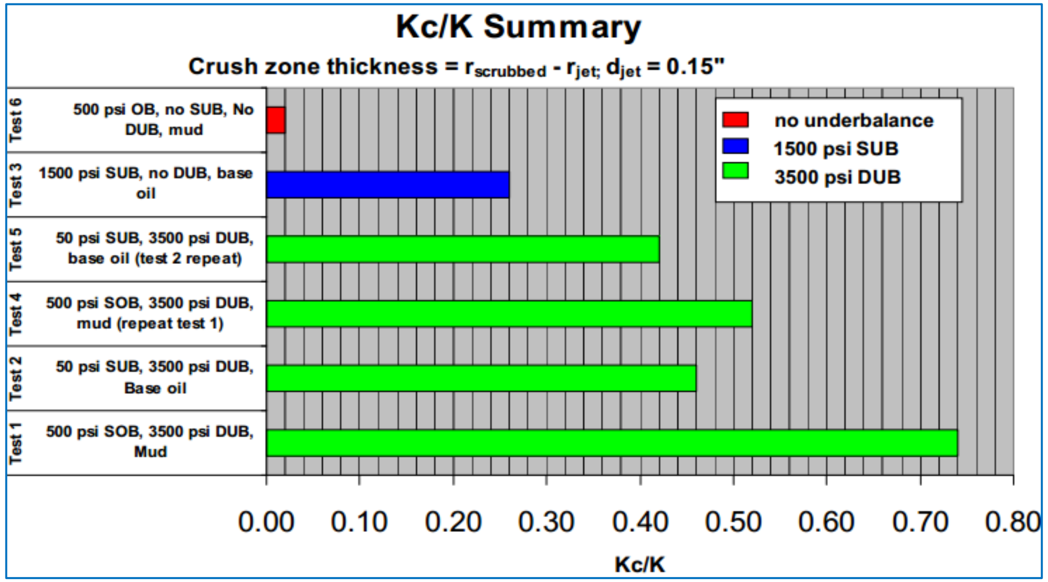


- Negative skins can be achieved by HF (Skin approx. -4) or advanced perforation (Skin approx. zero)
- Feasible to achieve low positive skin for horizontal well
- Tight, low perm and thin reservoir, horizontal well significantly outperform vertical well

Cased Hole Perforation



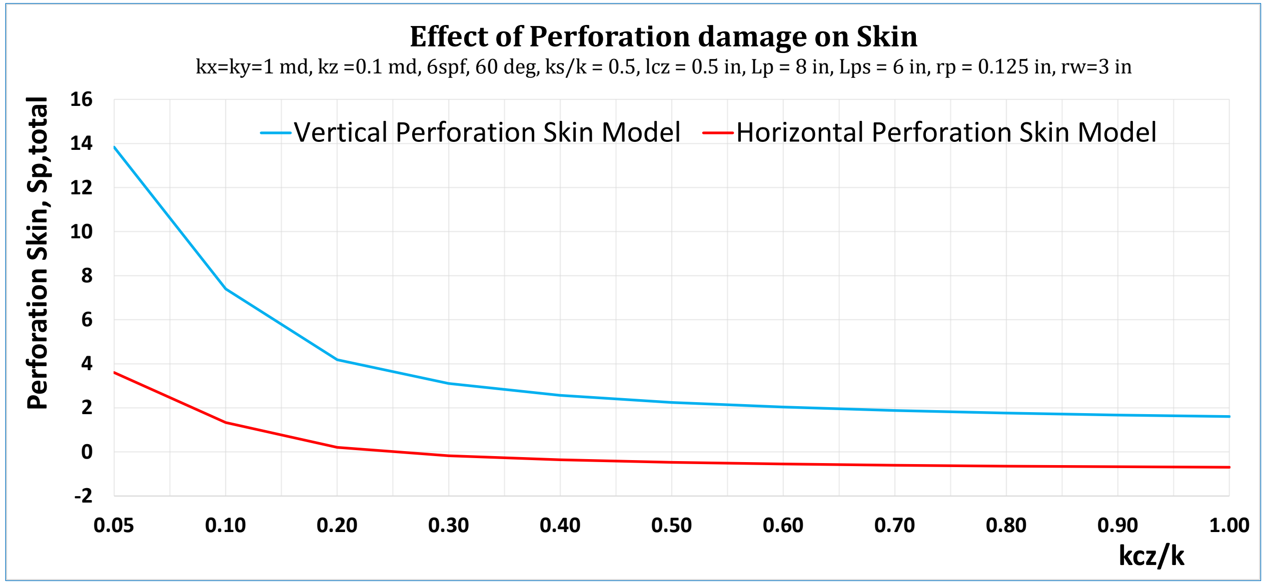
(Rahman et al., Journal of the Franklin Institute, 2007)

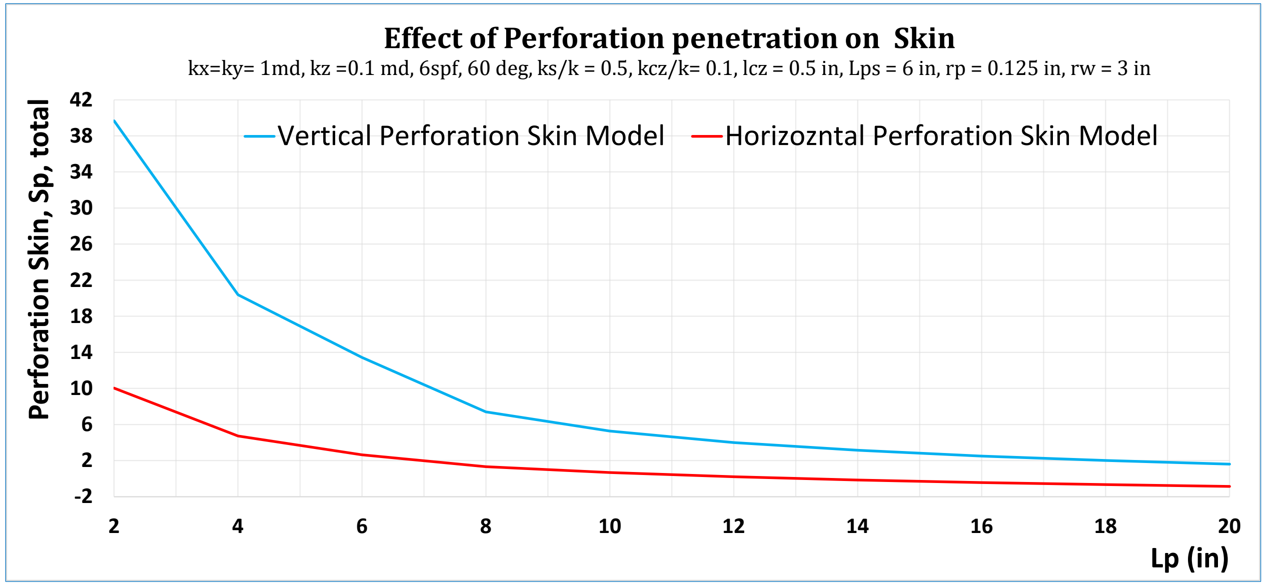


(Procyk et al., SPE 159920, 2012)

- The clear tunnel is relatively narrow, surrounded by crush zone (0.25” – 0.5” thick)
- The clean tunnel only extend to 3/4th of the total penetration
- The remainder (tip) of the tunnel is plugged with compacted fill (no flow contribution)
- The clear tunnel (6-10 in) or entire penetration is within the invaded zone (mud filtrate – drilling induced damage)
- Best practice to use high-performance gun, charge system in combination with Static with Dynamic UB perforation in clean perforation fluid

Cased Hole Perforation

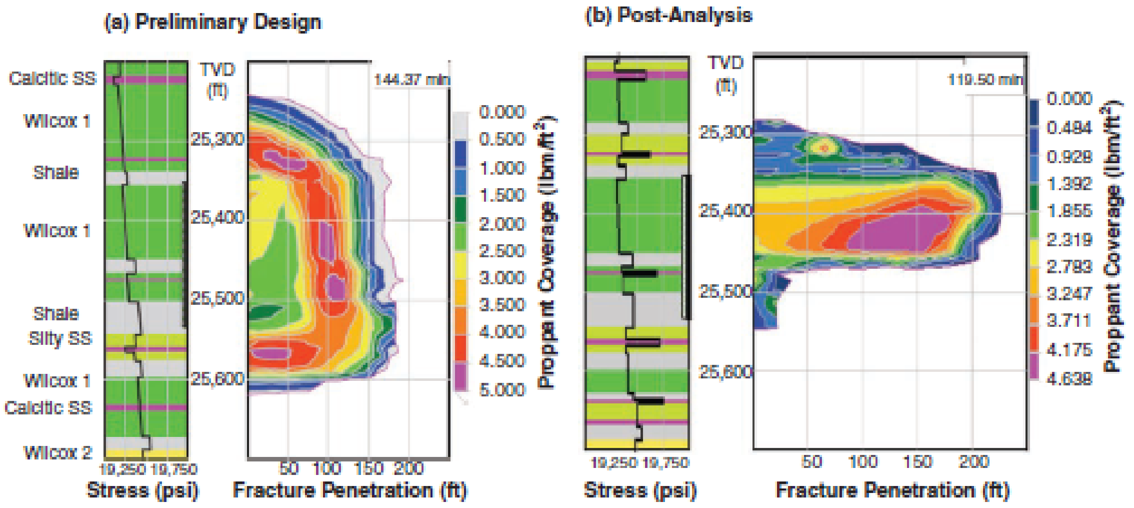




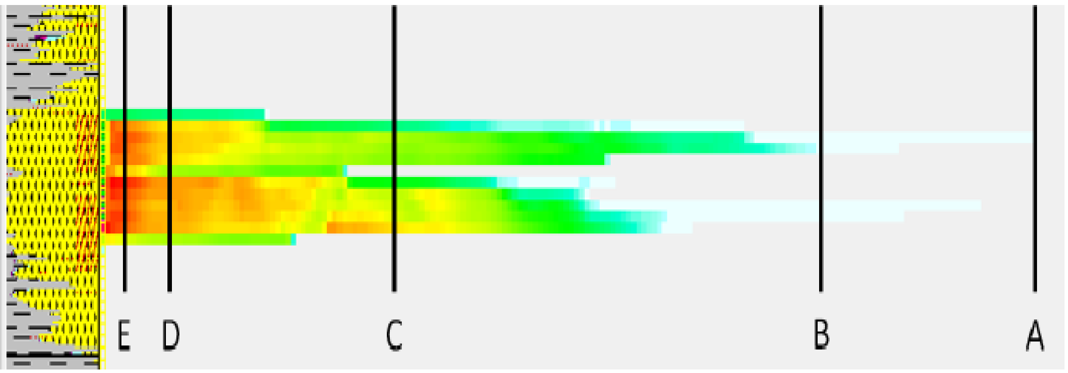
- Use proper perforation skin models for vertical and horizontal well
- Perforation skin of horizontal well is overestimated with commonly used skin models
- Impact of perforation damage, penetration are on horizontal well are less than on vertical well
- Extension of the perforation length beyond the damage caused by drilling will yield a significant skin reduction
- Optimal perforation parameters are different between horizontal and vertical well

Hydraulic Fracturing

$$q = \frac{k_h\, h(\psi_{pe} - \psi_{wf})}{1422 T_R\, [ln\frac{r_e}{r_w} + (s_{p,total} + Dq)]}$$



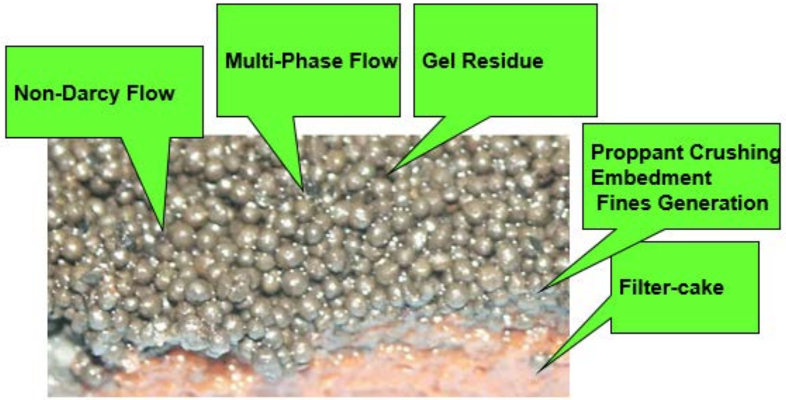
(Haddad et al., SPE 140498, 2012)

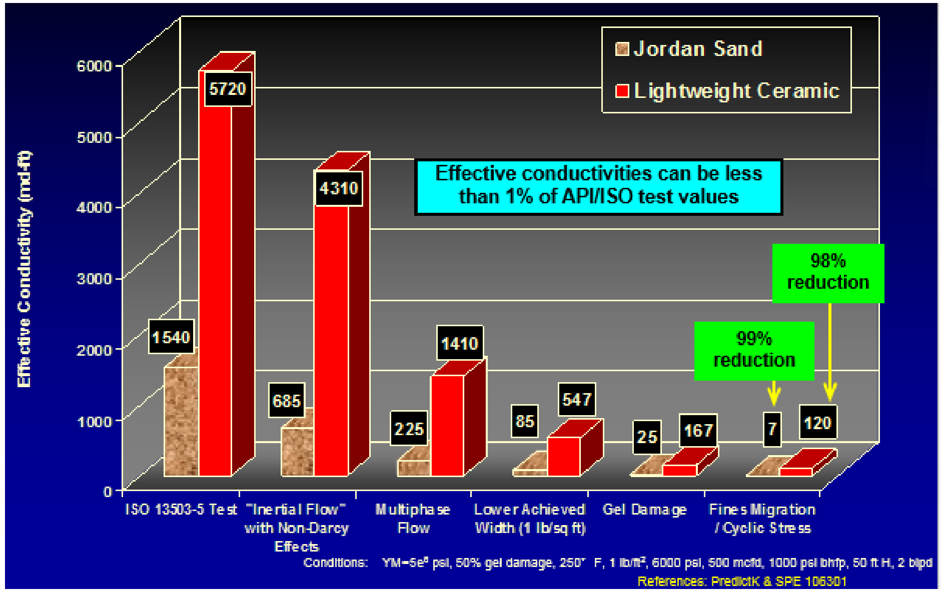


(Barree & Associates, GOHFER Manual, 2014)

- k*h and skin (s+Dq) are the most dominant important to well productivity.
- HF to increase (s+Dq) but not kh unless for multistage HF
- Effective fracture half-length could be significantly lower than expectation
- Modelling of effective fracture half-length and height contributing to production
- Maximize reservoir coverage and effective fracture half-length

Hydraulic Fracturing





(Palisch et al., SPE 106301, 2007; Barree et. al., SPE 84306, 2003)

- How much fracture conductivity achieved by HF
- With all potential damages involved, fracture conductivity is much lower than theoretical one
- HF design and optimization to account for realistic output parameters:
  - pay zone coverage
  - effective Xf
  - frac conductivity
  - non-darcy impacts
  - long-term conductivity

Summary, Conclusion

- Data acquisition of reservoir, rock, fluid characterizations
- More challenges with HPHT tight gas reservoirs in maximizing well productivity
- Every reservoir is unique, no single design fits all
- Performing sensitivity analysis of well productivity for various completion methods
- Applying recommended practices for specific completion method to maximize well productivity
- Selecting the best completion method based on well productivity, long-term reliability and economic

Acknowledgements

- Harbour Energy

- Author(s) from the cited references