Wellbore Strengthening in Narrow Margin Drilling*

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Abstract

Natural gas is one of the cleanest energy sources, its usage ranges from fueling power stations to cooking and heating. Global demand for natural gas is expected to rise in the coming years. Meeting these energy demands means drilling deeper exploration and development wells to access huge volumes of gas present under high pressure and high temperature (HPHT) conditions. Despite the attractiveness of the reward, managing the narrow drilling window between the reservoir pore pressure and the formation fracture gradient has remained a major source of cost escalation and non-productive time on HPHT projects. In order to improve the economics of HPHT projects, technologies like Managed Pressure Drilling and borehole strengthening have been used as a means of mitigating the risks associated with narrow margin drilling, thus enabling a paradigm shift from traditional casing seat selection methodology. In the Niger Delta, it is not uncommon to observe significant jumps in pore pressure values in proximate high pressure formations. The simplification of well designs and successful drilling operations are often challenged by the need to navigate through series of high pressured reservoirs in narrow margin windows. Compliance with process safety requirements requires selection of mud weight that is low enough to prevent mud loss and high enough to overbalance the reservoir pressure. Mud loss induced by formation fracture is often encountered in tight margin drilling, and when this happens, the focus shifts to strengthening the damaged wellbore using various techniques such as pumping chemical resins to seal off the loss zones. Various degrees of results have been achieved when borehole strengthening techniques are deployed with the objective of restoring wellbore integrity in both permeable and non-permeable formations. Successful deployments have

resulted in achieving the well objectives safely and cost effectively. This paper details loss of wellbore integrity experienced on an HPHT well in the Niger Delta and the wellbore strengthening strategy that was used to restore the strength in a non-permeable formation. It sheds light on how understanding the nature of the fracture, rock lithology as well as proper job execution can restore a damaged wellbore to its previous strengths. A cost reduction approach to the execution of the strategy is also discussed.

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INTRODUCTION

- **Challenges of modern wells**

- Deeper depth

- High pressure and narrow drilling window

- Fractures and Losses

- **Case study : well ST**

- 18 Degree deviation

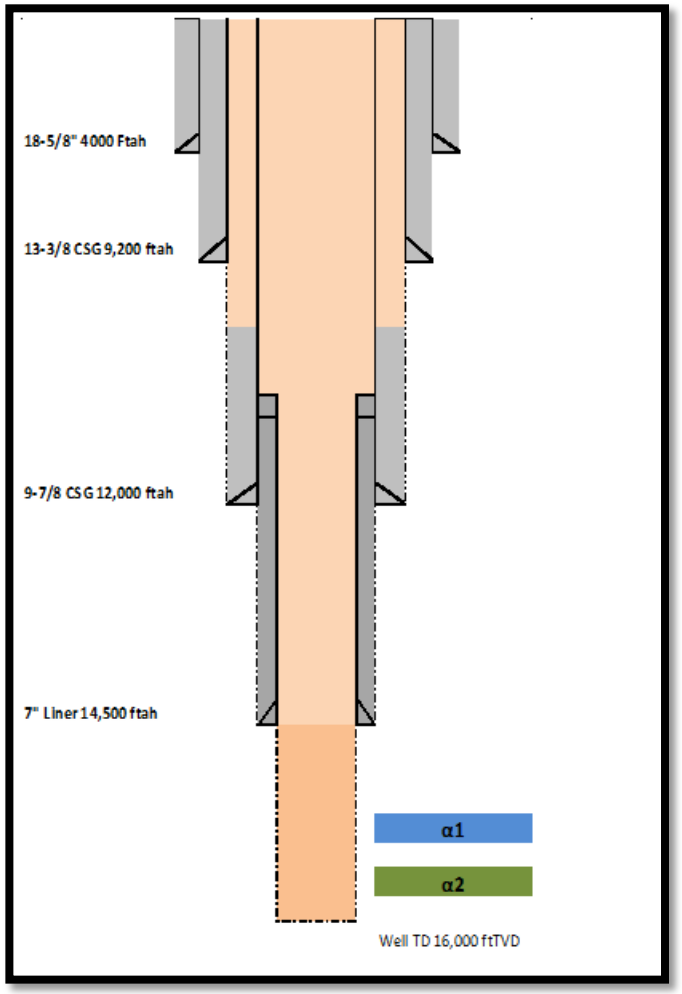
- Depth > 15,500ftss

- Drill with Managed Pressure Drilling, MPD

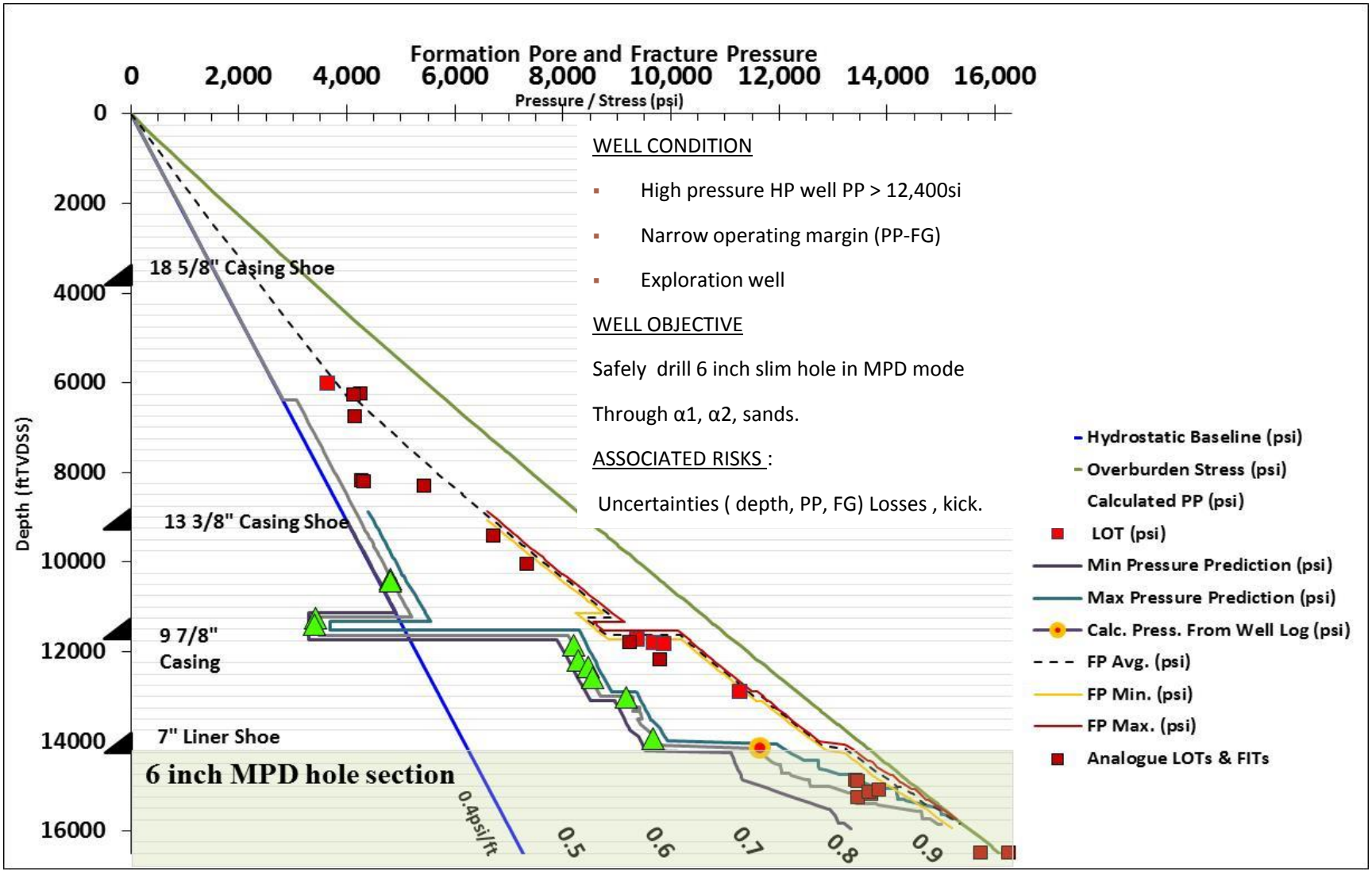
Key Well Objectives

✓ To prove reservoir presence, hydrocarbon fill, fluid characteristics

✓ To evaluate quality of the alpha (αs) sands



WELL ST1 OVERVIEW



LOSSES – NEED FOR WELLBORE STRENTHENING

Potential causes of Losses

- Drilling operation through narrow window margin (WELL ST1)
- L.O.T, F.I.T
- Depleted weakened formation

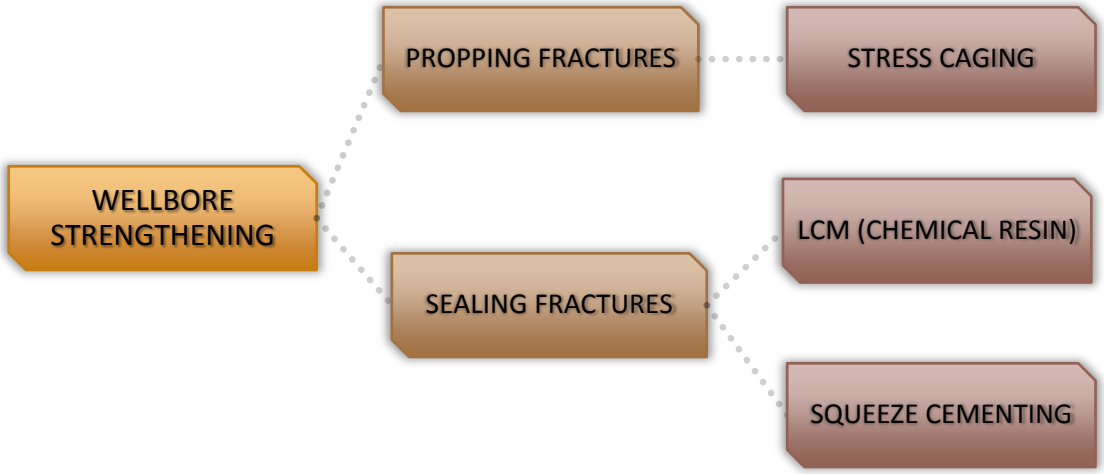
Consequences of losses

- US$800mln/year (Murchison 2006) well cost, Stuck pipe, influx, NPT
- Impossible to achieve well objective due to loss of formation integrity

Mitigations and Control

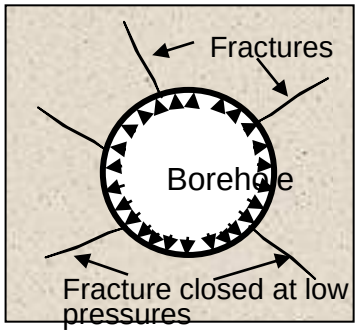
- MPD drilling
- Pre-treating mud with G-seals
- LCM (e.g. Cement squeeze, mud conditioning, Cement plugs)

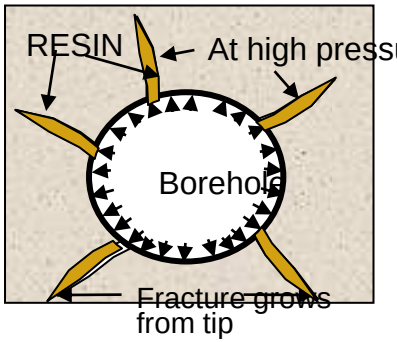
How to Strengthen the wellbore



ROLE OF LITHOLOGY

- The chosen method has to be effective for the lithology of the formation that is intended to be strengthened.
- Wang et al in 2007 discovered that by properly sealing a crack, a wellbore can contain the same pressure as it did before the breakdown.
- Successes have come in permeable formations such as naturally fractured sands.
- In Niger Delta, not much successes have not been replicated in impermeable formations such as shale.





SQUEEZING INTO IMPERMEABLE FORMATIONS HYPOTHESES

SEEPAGE

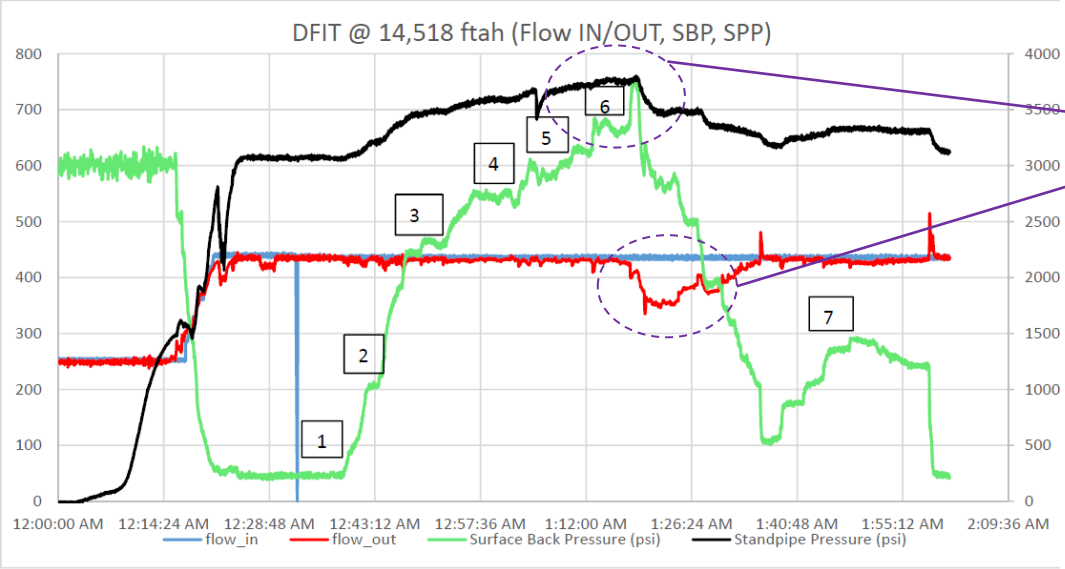
At Fracture Propagation Pressure → Fracture expands due to Seepage through seal → Gets rid of seal on the RESIN.

TRAPPED FLUID

At Fracture Propagation Pressure → Trapped fluid flows into wellbore → Gets rid of seal on the RESIN.

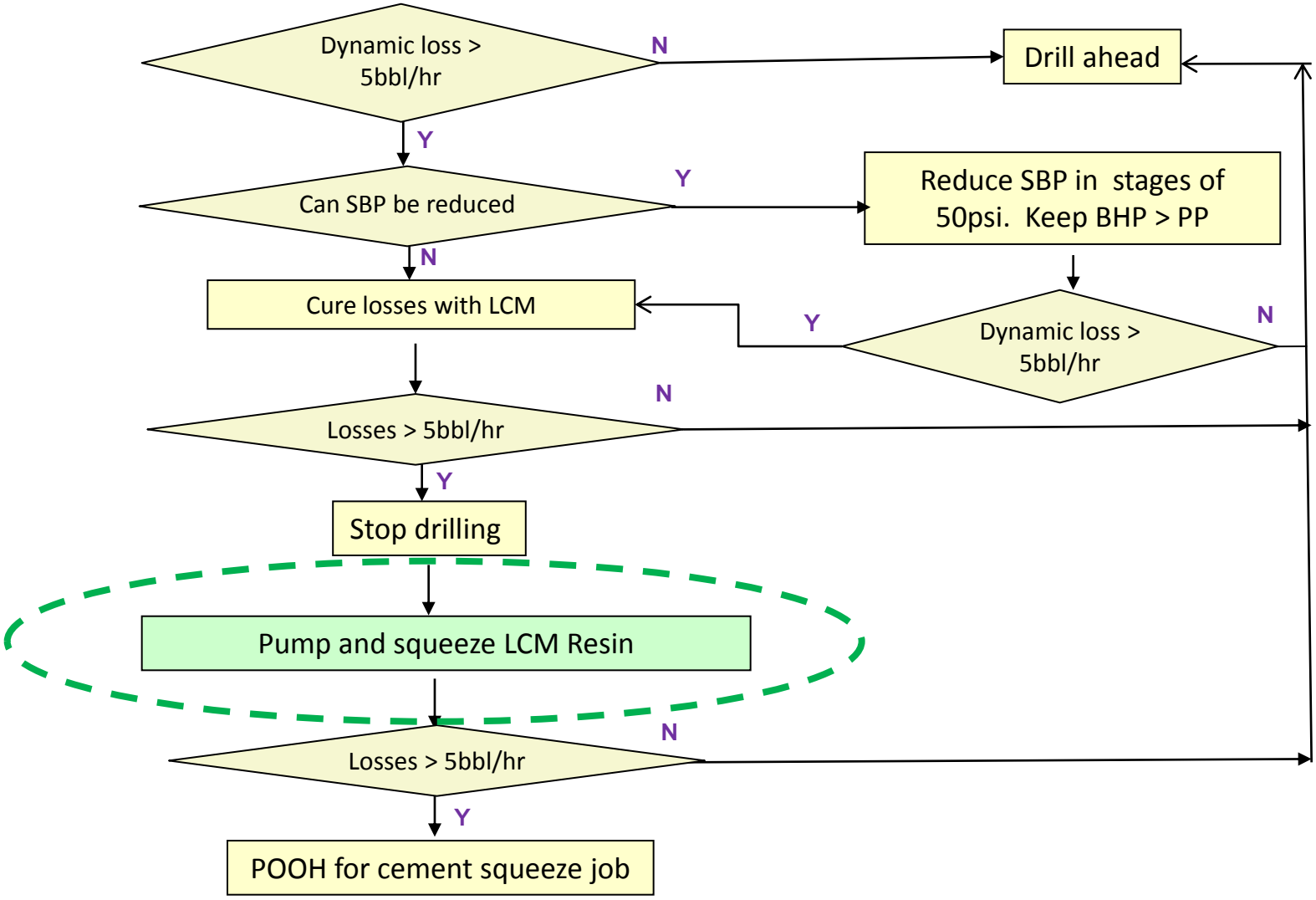
WELL ST1 FORMATION INTEGRITY TEST (FIT)

- Formation strength test was carried out to determine maximum strength available for drilling the remaining 6” hole to planned depth.
- Planned dynamic formation limit test (DFIT) with MPD mode 1.0 psi/ft.
- Breakdown occurred @ 0.94 psi/ft. 40bbl/hr losses



Indication of losses at 0.94psi/ft

LOSS DECISION TREE FOR MPD DRILLING

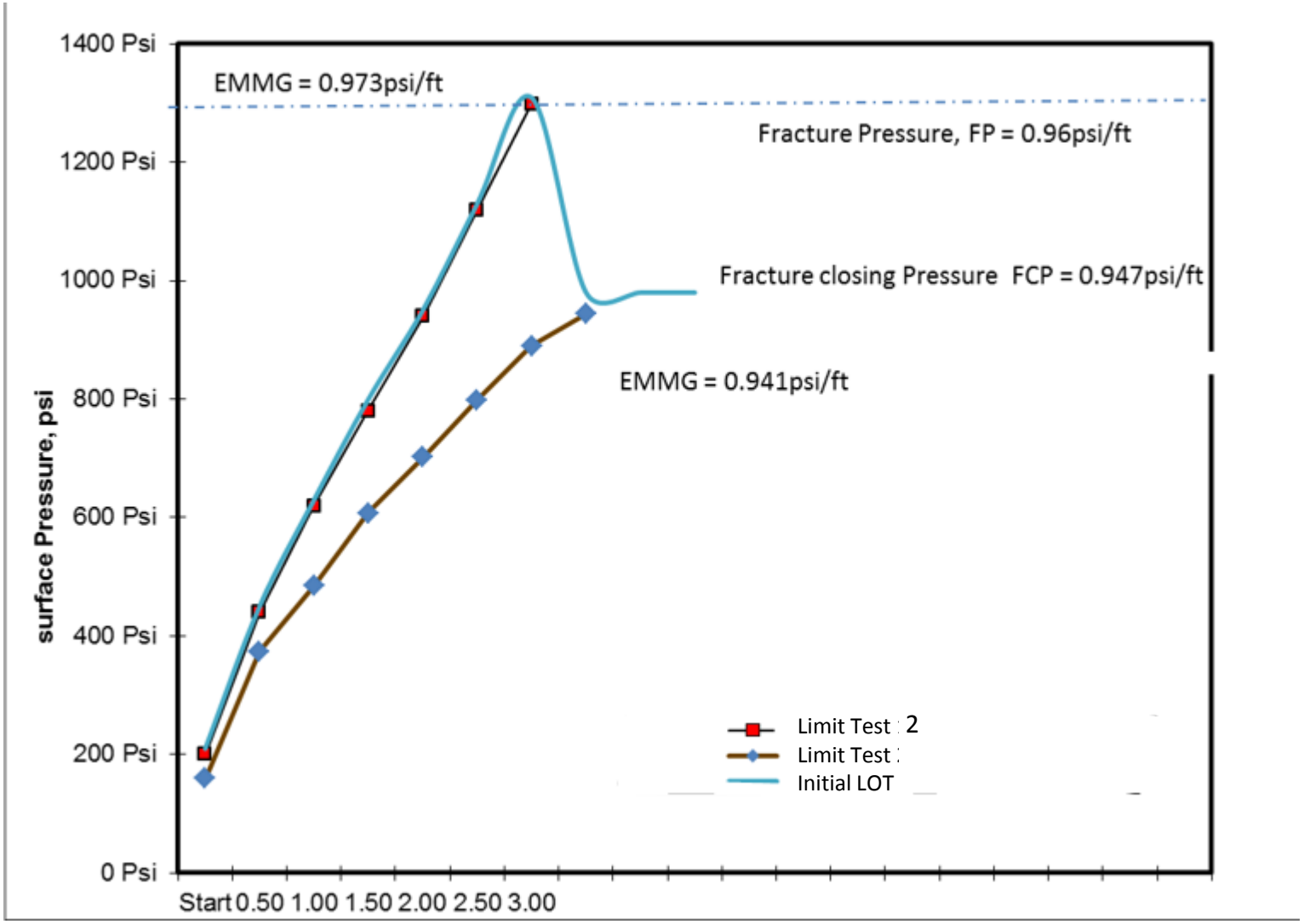


Source : drilling program

CHOICE OF STRENGHTENING METHOD

Sand / pressure regime	Operation	Loss rate	Effect
Dynamic FIT using MPD at shoe (14,192ftTVD) FG = 0.98psi/ft FCG= 0.947psi/ft			
α1Pore pressure = 12,500psi	Drilling	12bbl/hr	Drilled with losses Choke was fully opened
α1 Pore pressure = 12,500psi	Pumped LCM and applied 275 SBP	<5bbl/hr	Reduced loss rate
α1 Pore pressure = 12,500psi	Drilling	40 bbl/hr	Loss rate increased.
α1 Pore pressure = 12,500psi	Cut down MW 0.87psi/ft to 0.86psi/ft Treated POBM with LCM (CaCO3 + G seal)	< 5bbl/hr	Drilled with minor losses. Conducted dynamic L.O.T = leak off at 0.94psi/ft
Drilling Expectation : Cure losses and regain formation integrity to 0.96psi/ft. Changed MW to 0.873psi/ft			
α2 Pore pressure = 13,073psi	Deployed LCM RESIN	cured losses	Formation strength increase from 0.94psi/ft to 0.97psi/ft.

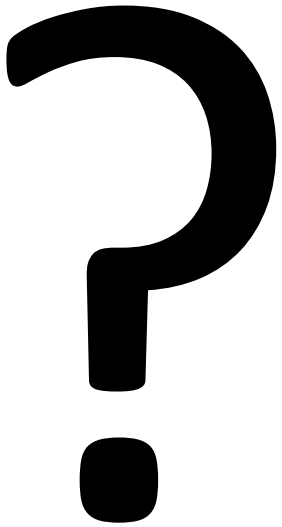
WELL ST1 POST DEPLOYMENT EVALUATION



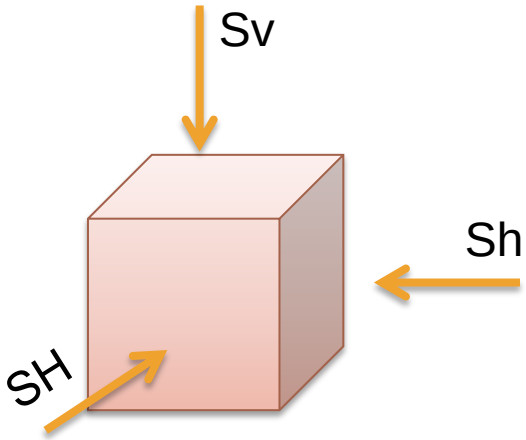
CONCLUSION

1. Managing a narrow margin drilling window entails ensuring that formation strength is not exceeded. When this occurs it is necessary to restore the wellbore strength.
2. It is possible to strengthen shale using a chemical resin containing RESINS.
3. Proper planning and execution is a key factor to the success of the operation.
4. Making adequate allowance for the resin to set has direct impact on the quality of outcome.

QUESTIONS



THANK YOU



- Sv = Vertical Stress
- SH = Maximum Horizontal Stress
- Sh = Minimum Horizontal stress

Fig 1.0 In-Situ Stresses

- Two barriers in terms of controlling well bore pressures.
  - Near Wellbore Stresses
  - Far field Stresses
- The greater of both stresses usually determines wellbore containment pressure.
- Usually Sv > SH > Sh
- Fracture occurs when pressures are more than the minimum horizontal stress Sh.
- Determines upper limit of mud weight window.

Can Sealing a crack restore the pressure containment or even strengthen the wellbore?