Case Study

Underbalanced Drilling Procedures to Reduce Drilling Fluid Losses and Rig Time in Fractured Formation

Challenge

- Drilling in Lower Malm formation has historically been challenging due the formation composition of vugular limestone and its fractured nature. This results in a below-normal fracture gradient (±0.75 SG).

- High drilling fluid losses and associated rig time attempting to heal the losses increased total well costs.

Solution

- ECD Management in collaboration with Viking Services provided technical analysis, equipment, and personnel to drill though the Malm formation.

- The UBD program was designed to allow the operator to carefully manage downhole pressures with a simple two-phase system (N_2 & light polymer WBM)

- If the fracture gradient was below 0.35 SG, a contingency plan was established to drill with Foam system

Results

- The operator was able to drill to TD ahead of drilling curve and below AFE cost.

- The downhole pressure was maintained below the fracture gradient minimizing fluid losses.

Successfully Minimized Fluid Losses to the Malm Formation

When drilling into the vugular Lower Malm formation, UBD drastically mitigated loss rates and reduced NPT required to re-establish circulation. The use of UBD lowered the ECD to 0.70 SG, by injecting 45 m^3/min Nitrogen and 1040 L/min light polymer water-based fluid. Fluid losses while drilling the 8½" interval were substantially lower compared to offset wells; 450 m^3 with UBD compared to 5050 m^3 with conventional methods - **a reduction of 91%.**

See Table 1: Comparing Losses of conventionally

Quickly Resolved Fluid Losses Allowing Operator to Drill Ahead with Minimal Delays

The ability to quickly convert from a conventional WBM system to an Underbalanced system drastically reduced the total number of operating days on the well. The UBD well was drilled conventionally until losses were encountered. At this point it was approximately 3 hours to fill the large vugular void and continue drilling with a two-phase system. Time spent to circulating to cure losses was **reduced by 27.7 days** compared to the offset well.

See Figure-2: Days vs Depth Drilling Curve.

Comparing Conventional Well to UBD Well

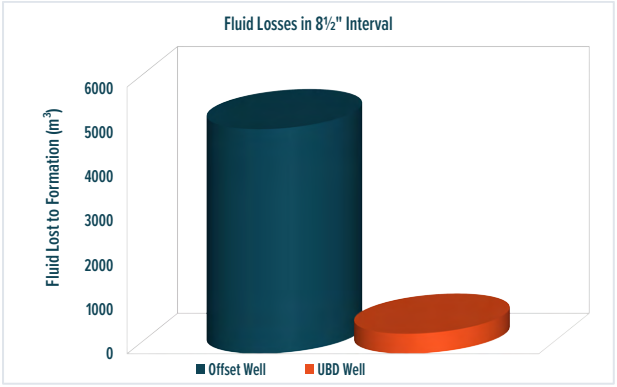

Figure 1: Comparing Fluid Losses in 8 ½" Intervals

Section	Unit	Offset Well		UBD Well
	Inch	8½"	6"	8½"
Interval	m	2285-3014	3014-3698	2100-2978
Length	m	729	684	878
Mud Type		KCl Polymer	KCl Polymer	Two-phase (N2 & Polymer Water)
MW / ECD		1.05 - 1.10 / +	1.05 / +	1.00 / 0.7
Losses in Formation	m^3	5050	2811	450
Loss (per 100 m)	$m^3/100m$	6.9	4.1	0.5
Percent Fluid Loss Increase to UBD		91%		-

Table 1: Comparing Losses of conventionally drilled offset well to UBD well.

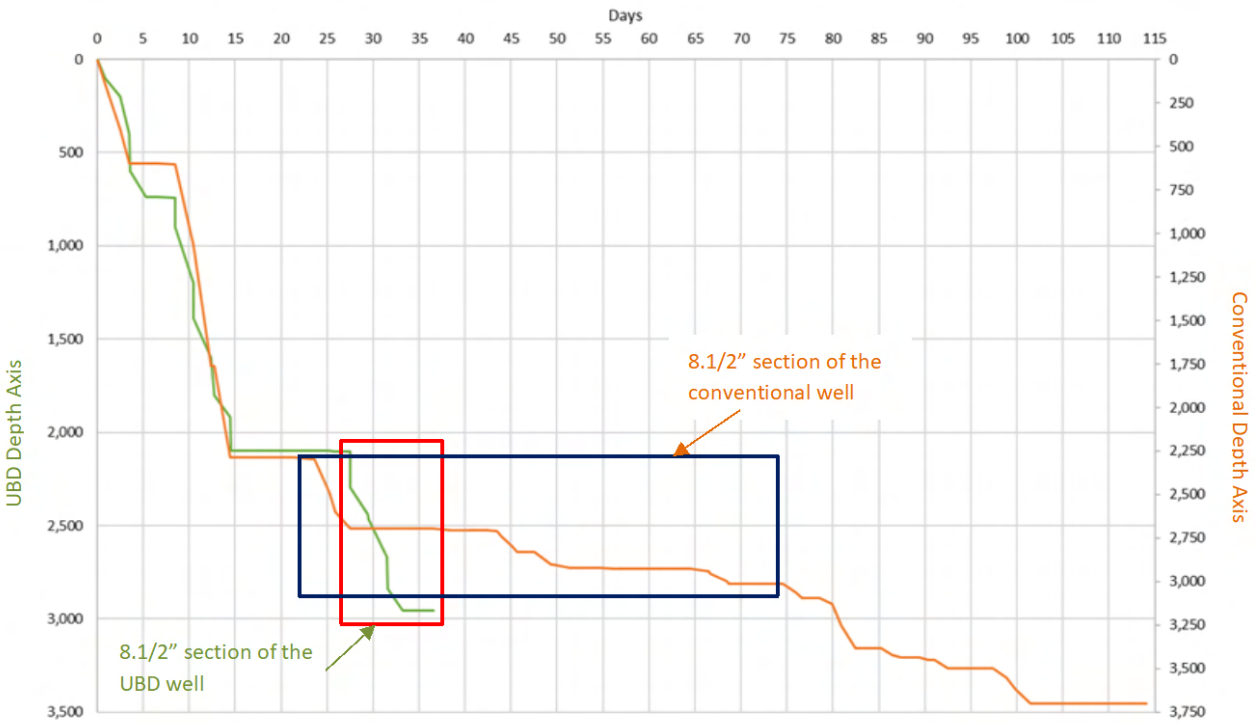

Figure-2: Days vs Depth Drilling Curve

- Green: UBD well (left axis depth)
- Orange: Conventional well (right axis depth)
- Box: 8 ½" Interval's