



Management of an Underground Well Flow



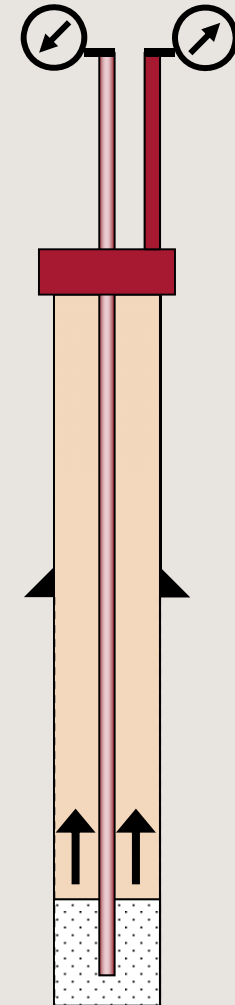
Management of an Underground Well Flow

- Case Study – Well A
 - What Happened?
 - Why Did this Happen?
 - How Did We Solve the Problem?
- Underground Flow Toolkit
 - Barite Plug – Design, Placement, Behaviour
- Lessons Learned

Case Study

Case-1: Observations while drilling ahead

- Drilling ahead at 2912m with 1.3sg mw.
- Detect influx, shut in.
 - Post analysis 91bbl taken over 3hrs.
 - Heavy weather, Low flow rate, Nothing seen on conn.
- SIDPP=750psi, SICP=760psi. MAASP=750psi w/1.25sg.
- Commenced W&W Circulation – Total Losses
- SIDPP=40psi, SICP=710psi – Uncontrolled flow.
- High CO₂ observed, MW_{out} < MW_{in}, Low Chlorides
 - Diagnosed as HP, LV water flow, with associated gas
 - High pressure mantle source likely via fault.
- Estimated KI later estimated at 3.5ppg (0.4sg).
 - Cannot determine at first influx.



Case-1: Offset Analysis

WELL SCHEMATIC

All Depths in mTVDRT unless noted

762mm (30")
Cement Job:
Class 'G'
cement
1.90 S.G
200% excess
TOC
(seabed)



476mm (18
3/4") DrillQuip
SS10C
Wellhead

813m TOC 1.9sg Class
G Cement (50% XS)

914mm (36") Hole

555 m

Seawater & sweeps

762mm (30")
HAC/38-25mm

1.5"-1") X-52 4jt
Conductor

20" Davis Lynch float
shoe

1263 m 340mm (13-3/8")
(72#) NT80HE BTC

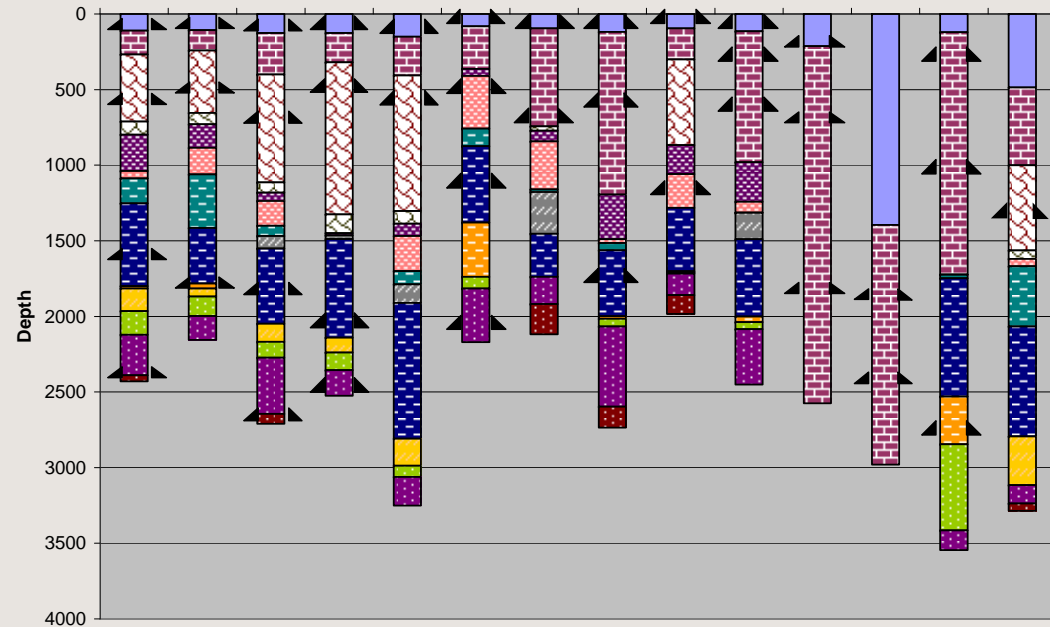
1268m 445mm (17-1/2")
TD - Seawater & sweeps

1.25-1.30sg Ultradrill
WBM

3308m+/-240m

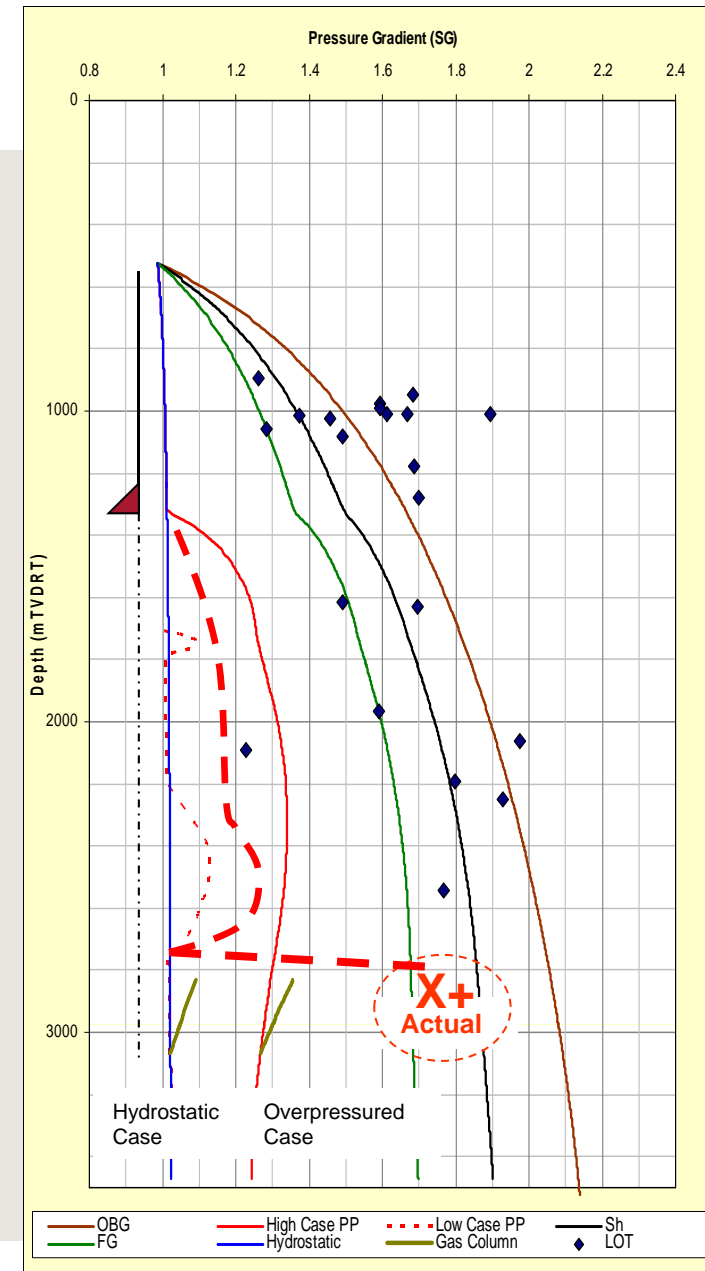
311mm (12-1/4") Hole

X X X X

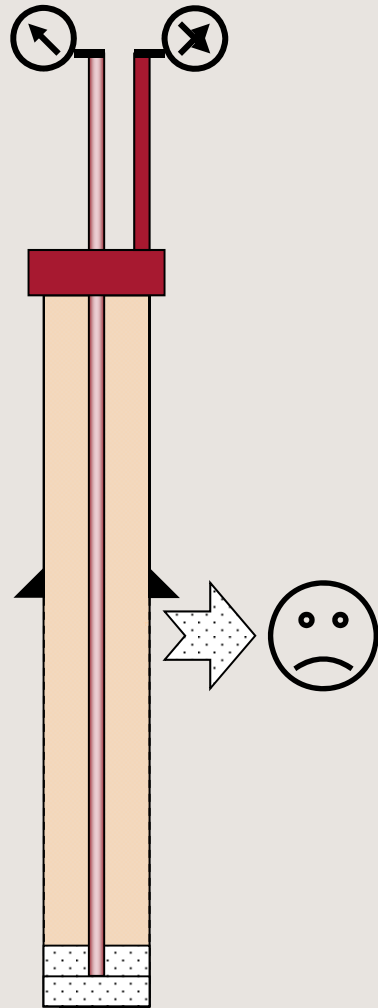


Case-1: Well Design Summary

- Prognosed Max PP = 1.37sg, Mid PP = 1.25sg
 - Pre-Drill PP consistent with offsets.
 - Prognosis consistent with RT PP Modelling.
 - No seismic bright indicative of high PP.
 - Horst block play a risk.
- 50bbl Kick Tol. for 1.37sg max PP at TD -
 - 1.70sg LOT Expected -> Achieved
 - Development <18km away; good PP control
 - Horiz Stress Field; LOT > Overburden
 - No losses encountered while drilling open hole.
- Typical overpressure mechanism in basin driven by shale under-compaction. Long sections of shale/marl.
- Conductive faults not previously encountered.
- 9 5/8" casing string held as contingency for low LOT or wellbore instability.
- **LESSON: Drilling is an uncertain business. Despite robust planning, the unexpected can occur.**



Well Design – Kick Tolerance

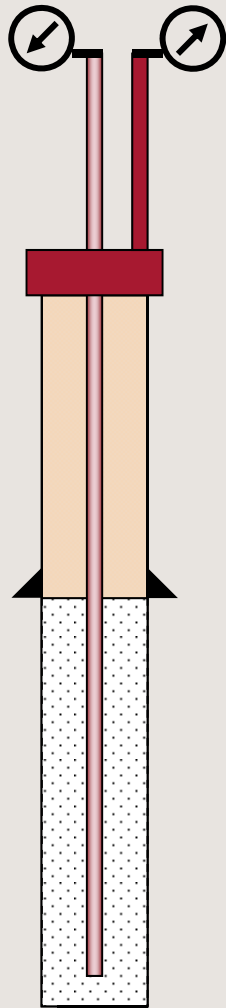


Maximum influx volume from a given depth and pressure that can be circulated out of the well.

What happens when kick tolerance is exceeded?

- Attempt to circulate kick out of well
- Casing pressure increases
- Form. fracture, limits back pressure.
- Losses
- For Gas, BHP reduces as kick expands up hole, allowing more fluid into hole.

Signs of an Uncontrolled Flow



What happens?

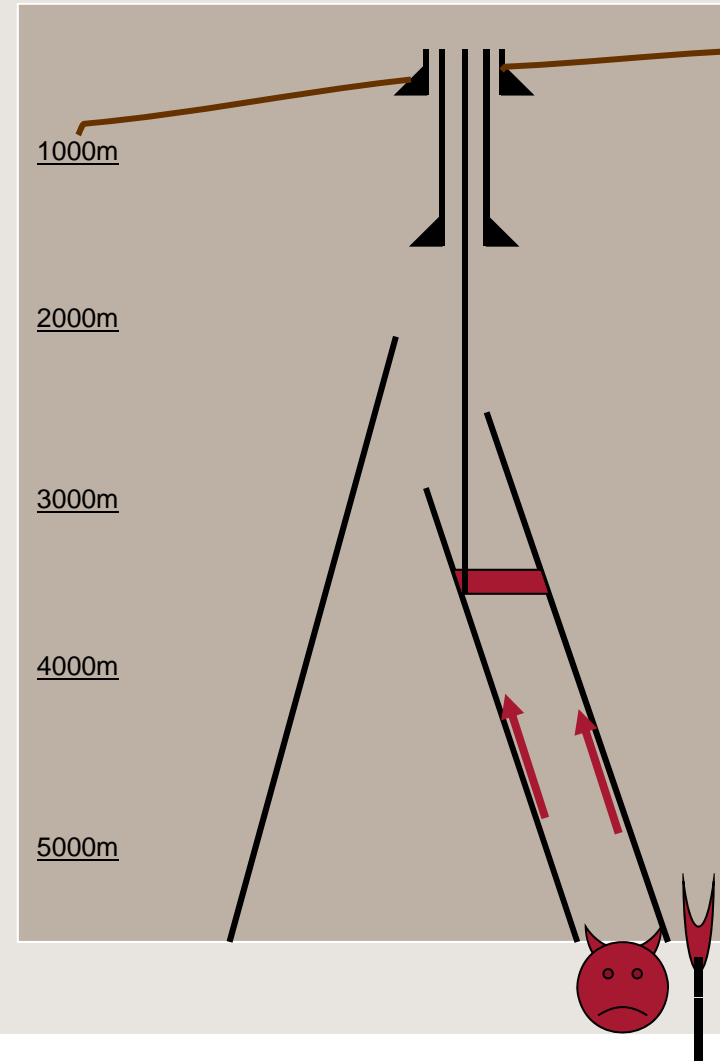
- SIDPP = SICP. May drop quickly as annulus unloads (gas kick).
- SICP equal, or close to MAASP.
- Losses while attempting to circulate.

Why might this happen?

- Unidentified weak zone below shoe.
- ✓ Maximum kick volume exceeded.
- ✓ Larger than expected pore pressure.

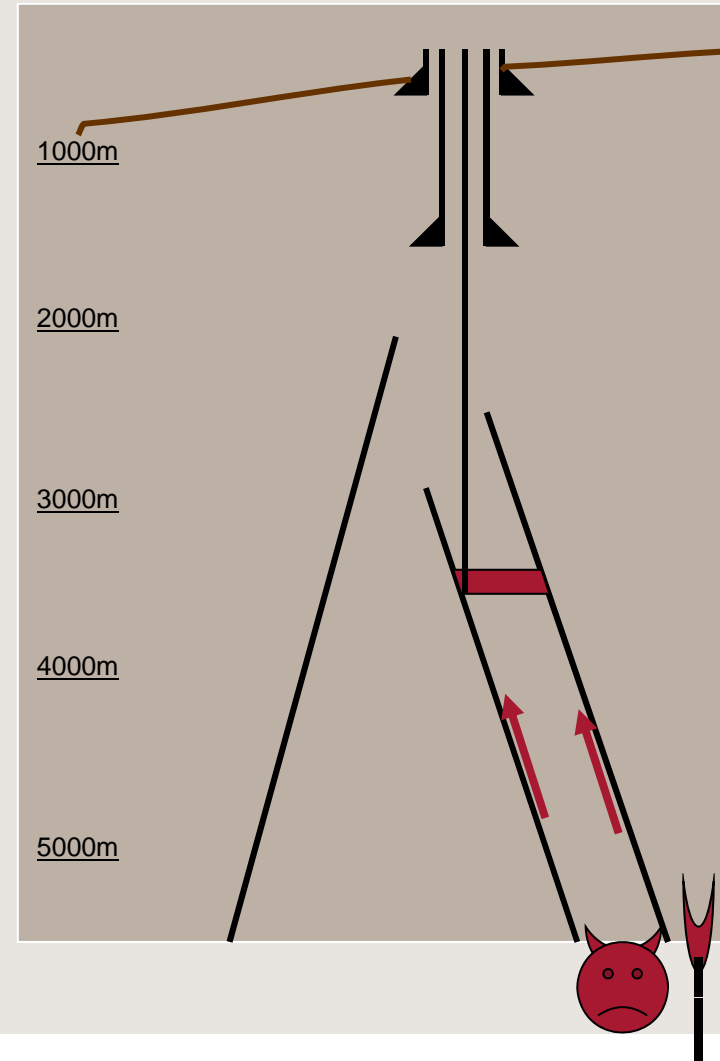
Case-1: Response

- Kick taken whilst drilling ahead at 2912m (1.03sg water with CO₂ content, suspect mantle source.)
- Shut In well – immediately exceeded MAASP – BHP unknown.
 - Suspect fracture initiated at or near casing shoe.
- **Recognised Conventional Well Control not possible.**
 - Stepped up mud weight in two steps. 1.50sg and 1.58sg – each time SIDPP returned.
 - Conventional circulation to minimise loss, and dynamic kill.
- **Conducted controlled bleed backs.**
 - Observing fracture closure at shoe or trapped pressure?
 - Calculated mud dilution, mass balances and commencement of dilution to analyse. Water cross flow evident at maximum achievable mud weight.



Case-1: Response

- Deliberately increased mud weight to induce losses to fracture and employ “**floating mud cap**”. Top filled with seawater to balance.
 - Estimate 1.7sg+ BHP – 3.5ppg Kick Intensity!
- Opened well on losses and retrieved drilling assembly containing nuclear sources. Uncertainty on whether barite could safely be pumped through BHA.
- Ran in on drill pipe to casing shoe and waited on mud materials. Well shut in after continued crossflow unloaded well below mud cap.
- Logistics extremely challenging with losses (>1100 tonnes of Baryte consumed during well control operations)
- Stripped in and held up 300m from TD with drill pipe.
- Conducted P&A operations with well shut in by stripping and bullheading barite and cement into place.





Strategy Summary:

- Step 1: Diagnose Underground Flow
- Step 2: Isolate Overpressure from Loss Zone
 - Barite plug for dynamic flow.
- Step 3: Permanent Plug between Overpressure and Loss Zone
- Step 4: Address loss zones and/or charged zones above.
 - How many barrels did you pump away – plus the well?
 - Bleed back, Induce Losses, Squeeze Cement, etc..



Case-1: Response

Shorebase Response

- Mobilised D&C Tech Support Room and conducted 24hrs operations for first 6 days, then day shift only for another week.
- Well control operations were complex and non conventional - peer review conducted with independent Well Control contractors.
- Successfully conducted P&A operations with well shut in by stripping and bullheading barite plugs and cement into place.

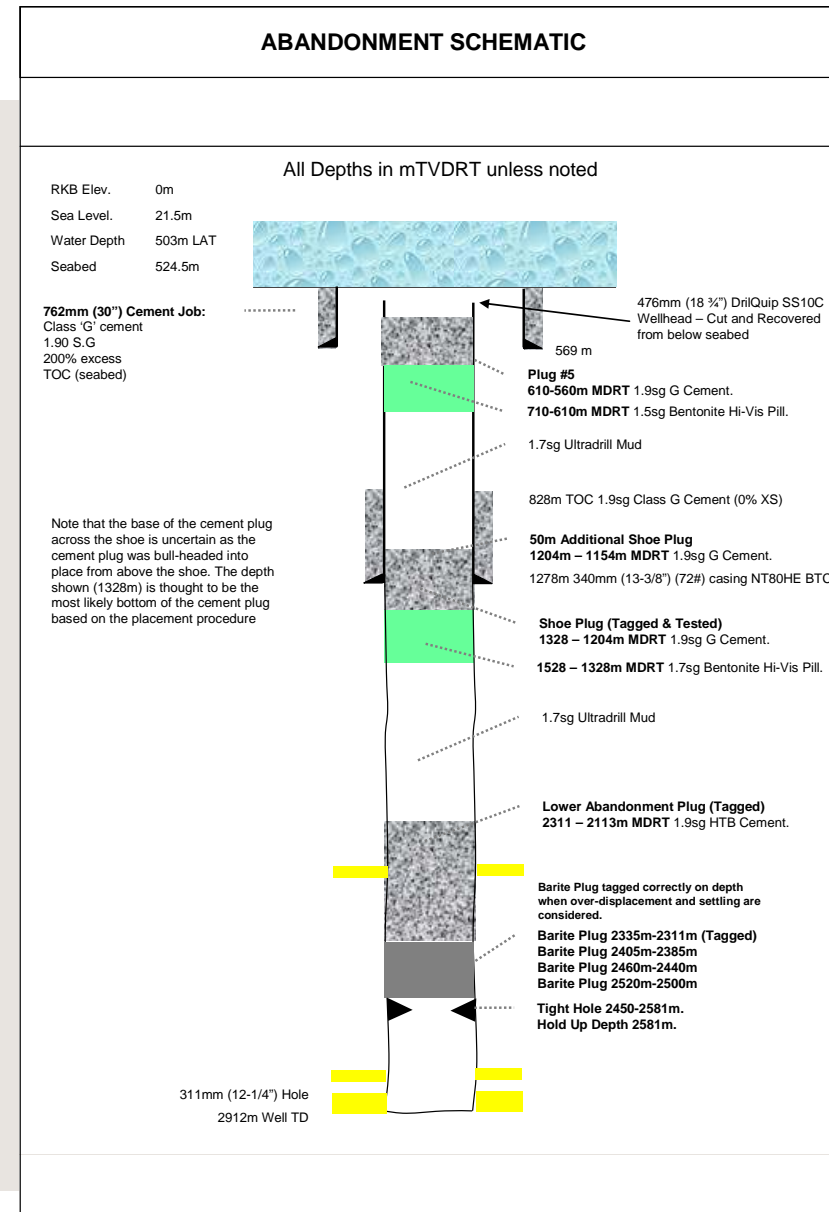
Offshore Response

- Additional resources mobilised to rig (Engineering, Well Site Management)
- Significant logistics and planning challenges; strong weather, limited bulk vol.

Interpretation of well control data very challenging. Needed to overcome constant bottom hole pressure paradigm and thoroughly assess every step.

Case 1: Outcome

- Well Abandonment Compliant with Regulations and Woodside Policy.
- Four barite plugs from TD. Tagged.
- Bullhead 200m cement. Tagged.
- Strip out of hole.
- Bullhead Hi-vis, then cement at shoe.
- Pressure tested and tagged.
- Backup shoe plug.
- Open well, set surface plug.





Underground flow Toolkit



Why choose a barite plug?

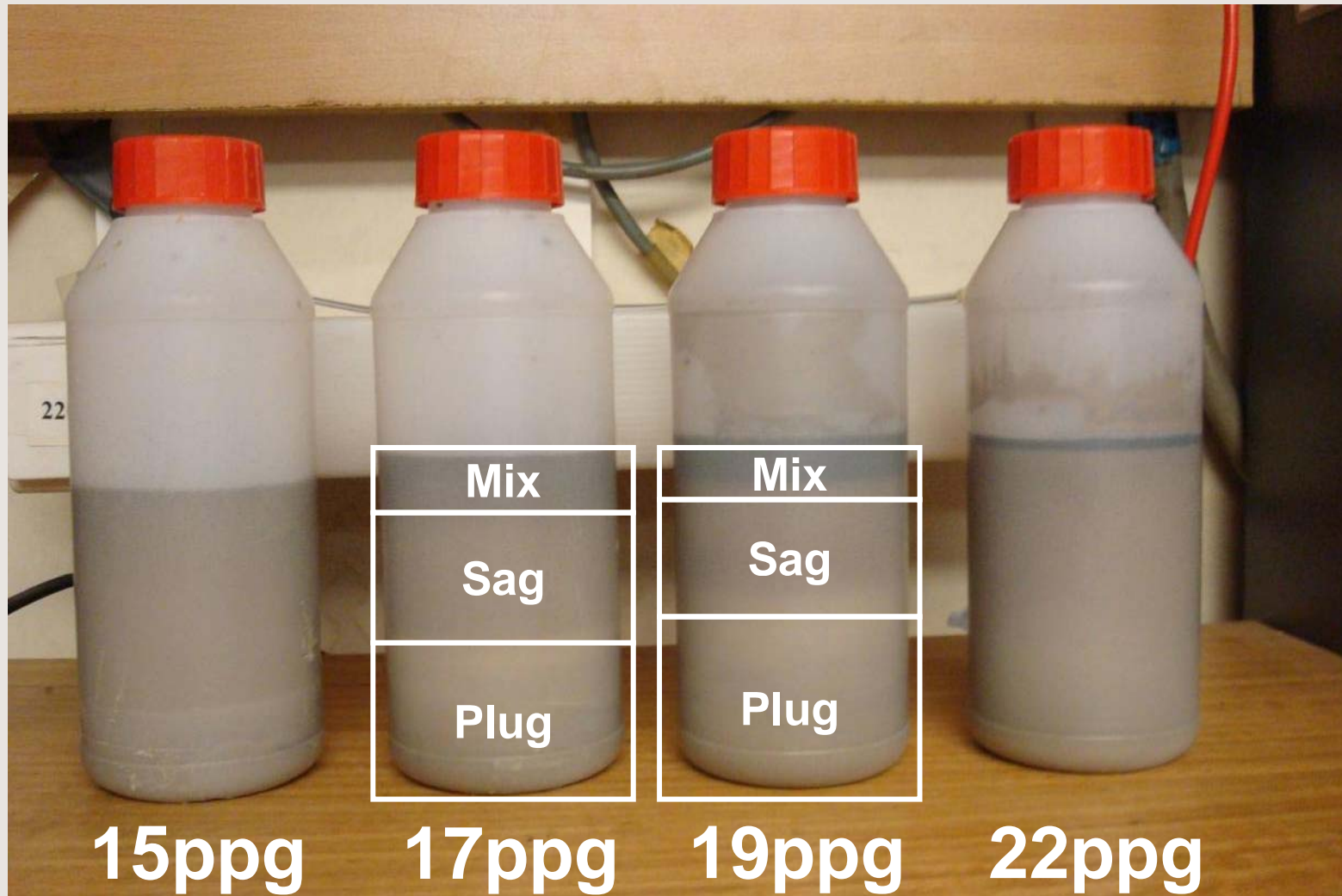
- Cement requires a static well; otherwise risk of channelling, and subsequent loss of access.
- Barite plug settles (eventually) and forms a mechanical, impermeable plug that is robust against continued agitation.
 - Simple – mix Water, SAPP, Caustic (as reqd) and Barite **(in that order!)**.
 - Failed plugs can be bullheaded/circulated away.
 - Can use barite, hematite and other heavy weighting agents.
 - Rapid results (relatively!).
 - Considered robust over geological time, considered a permanent barrier.
- Viscous Reactive Pills
 - Sodium Silicate, BDO Barite/Diesel, BCDO all very effective reactive pills but not commonly used. Limited in-house experience.
 - Key is to control the point of reaction – not in drill string or surface lines.
 - Potential to be used in conjunction with Barite to provide settling time.

Barite Plugs

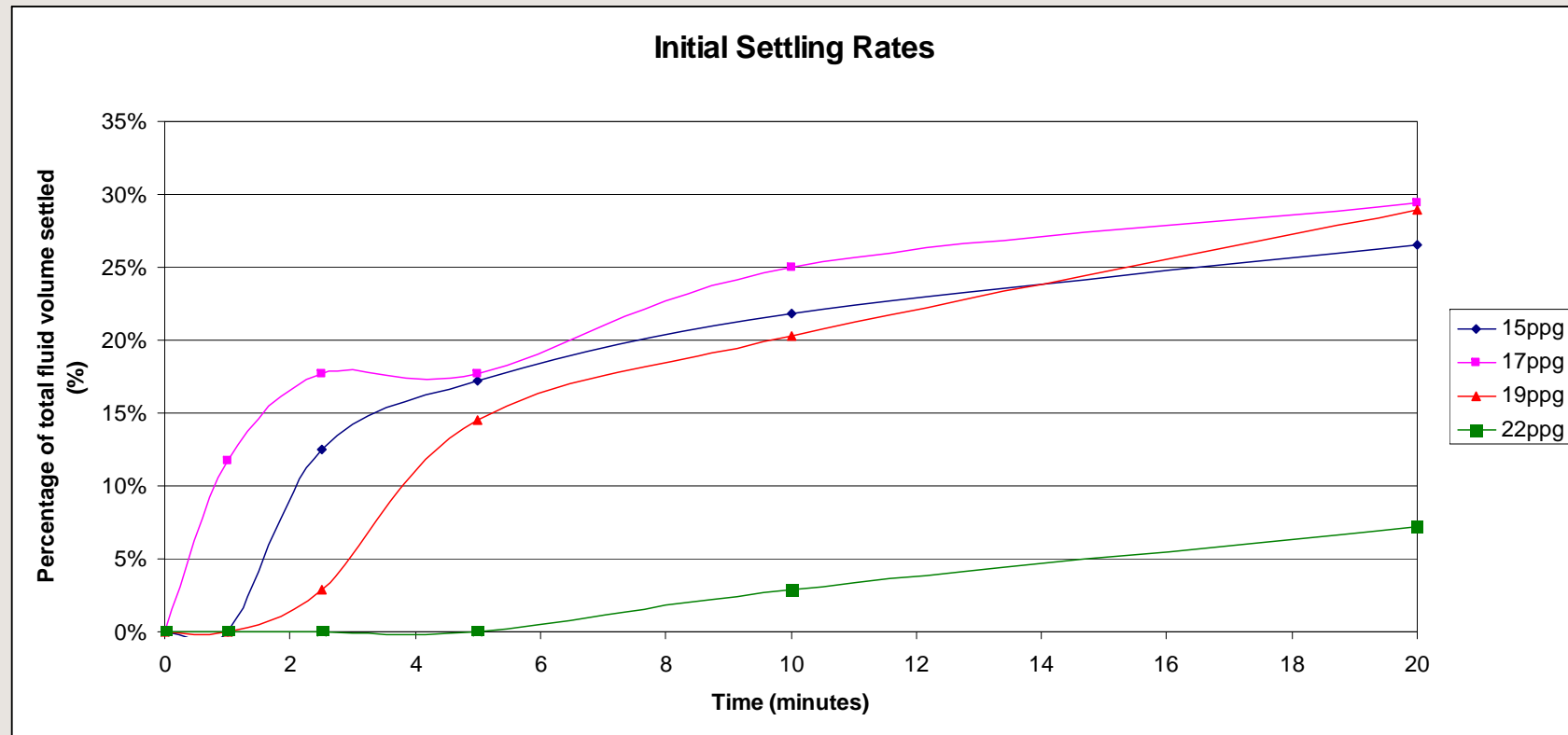
- Designed to slump and solidify.
- Mixture of water, deflocculant, barite
- SAPP, Lignosulfonate deflocculants
- Hindered Settling. Low density = Fast
- Choose 1-2ppb over mud density.
- High Agitation for Barite Suspension.
- API Barite Essential – Large PSD
- Check for Gel/Cement Contamination
- Pilot Testing Essential
- API RP59 is a good guide.



Barite Settling – High Density = Slow Settling



Barite Plug – Settling Time – Choose a compromise





Observations when pump barite plugs...

- Recent experience pumping plug through 8 ½” BHA w/6 x 1 1/32”
 - No difficulty pumping past quad combo MWD and pulser.
 - No difficulty pumping through small nozzles on bit.
 - Fluid Quality Assurance problems – more on that later.
 - Successfully mixed and pumped in agitated Pill Tank.
- Case Well pumped through an open string.
 - IBOP valve positioned mid string – no difficulty pumping past.
 - Mixed and pumped on the fly via cement unit. Mixwater pre-prepared.
- Attempts to mix and pump 22ppg plug for Case Well identified that this mixture is too viscous to pump.
- 12ppg plug fell out of solution very rapidly. High risk of train wreck.



Barite Contamination! Watch out.

- Another case study observed continued cement contamination while attempting to deliver barite to the cement unit.
 - Lab tests prepared with rig barite didn't match pumped slurry.
 - Eventually chose to mix in mud system and pill tank.
 - Very high and very low pH hinders plug settling. 9-11 pH is ideal.
- Mix SAPP into Water **before adding barite.**
 - Prevents clay impurities from yielding prior to deflocculation by SAPP.
 - “We tried both formulations but decided to mix the SAPP after barite – SAPP in mixwater made the barite fall out too early” !?! Paradigm shift!!
- Good quality Barite with few LGS is essential:
 - “UFG Barite and the API Barite both had around the same settling rate – approx 60% after 5 hrs. However a “pencil test” of the two samples had quite different results – the API Barite sample was reported to be quite firm and only allowed about ½” of penetration. With the UFG Barite sample however the pencil was able to be pushed to the bottom of the container without any resistance.



Barite Plug Placement

- Attempt dynamic well kill to eliminate kick fluids in annulus.
 - Minimising flow within annulus
- Pump barite plug
- Strip out of barite plug, plus 1-2 stands (no more than necessary)
- Wait 8-10 hours
- Run in hole to tag for verification – if you can.



Barite Plug Lessons

- Choose the lowest density (1-2ppg above MW) you are comfortable with.
- Ensure barite (and delivery system) is not contaminated.
 - Verify by pilot testing. Watch for Cement/Gel in bulk.
 - Ensure standard API barite is used.
- Prepare the deflocculant in the mix water prior to adding barite.
 - Ensure sufficient agitation via batch mixer or mix on the fly.
- Can pump barite plug through BHA, Bit, IBOP v/v, Float etc...
- Deliver plug into place under pressure – either via high flowrate and dynamic kill and/or via hydrostatic of fluids in annulus.
- Work the problem as a team;
 - Has your cementer pumped this before? Mud engineer? Super?
 - If not, enlist help; expect extended well control anyway.



Questions?

