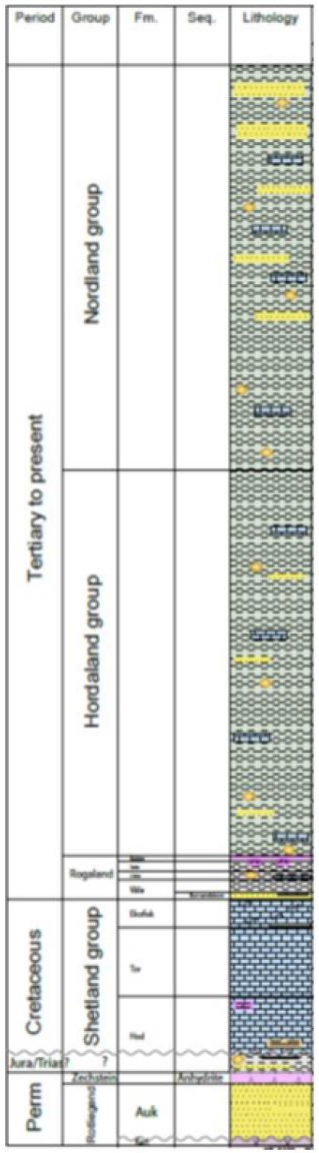
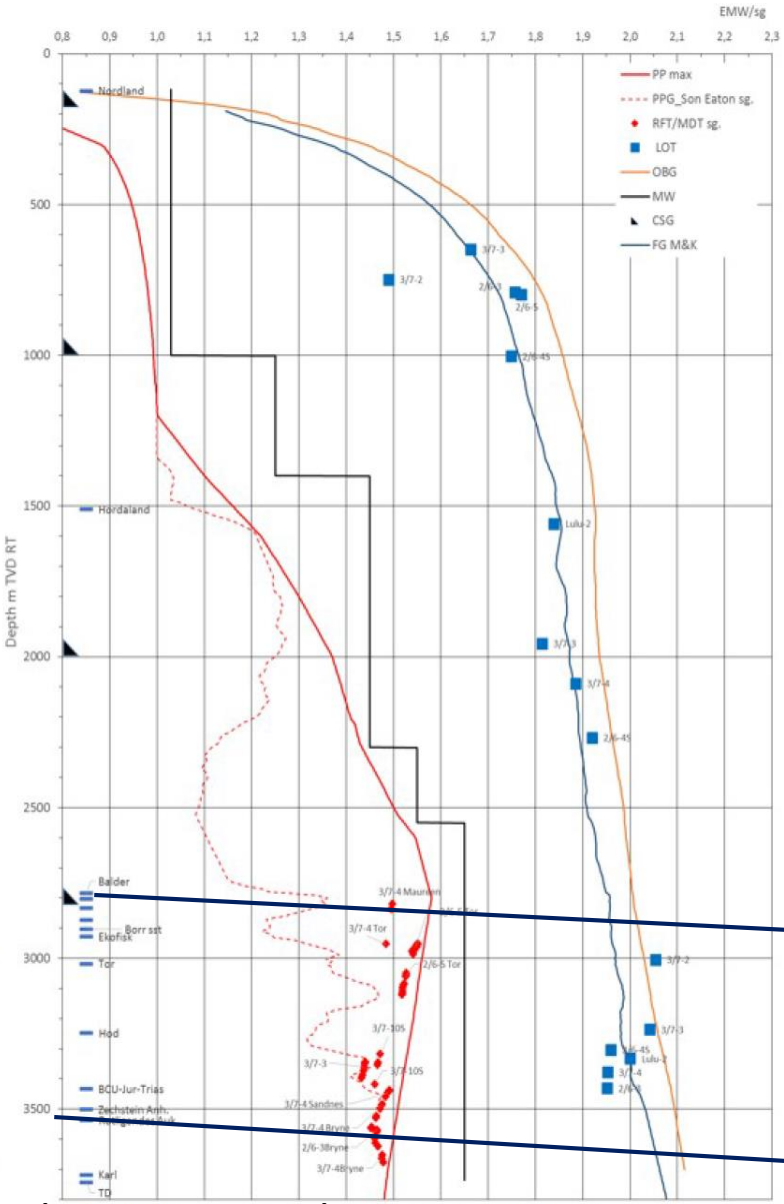
"Sharing to be better # 20"

Well control incident – drilling 8-1/2” hole section

Lithology & formation pressure prognosis





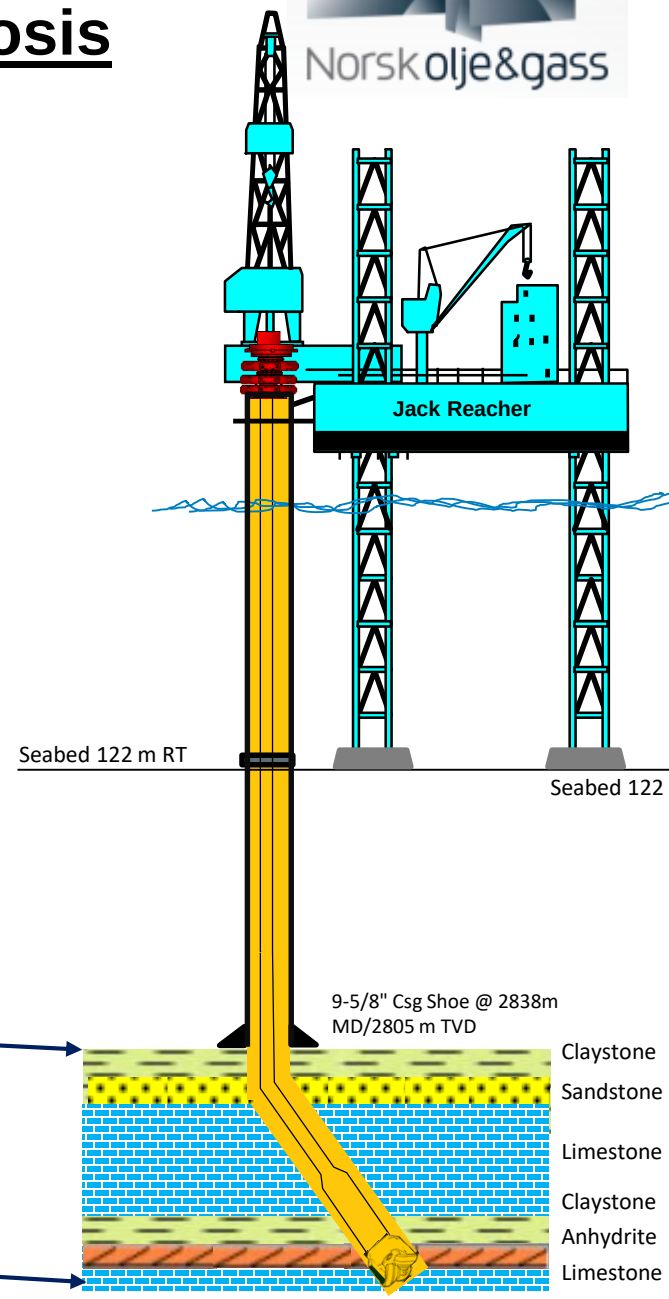


Figure 1. Lithology & Formation pressure prognosis

Situation description

- 9-5/8” casing set @ 2838m MD
- FIT @ 9-5/8” Shoe established at 1,90 SG
- Drilled 8-1/2” Hole section from 2838m MD to 2910m MD with **1,65 SG** mud weight(OBM) . POOH
- Cut a core from in good permeable sandstone 2910m to 2940m MD (sand waterfilled)
- Took 3ea pore pressure measurements @2910m, 2925m & 2945m MD, **max pore pressure 1,53 SG**
- Cont. to drill 8-1/2” hole from @ 2940 m to 3664m through hard limestone(with chert), claystone and anhydrite. ROP slowing down from 3524 to 3664 (2-8 m/hr) At 3664 when experiencing a drilling break. (ROP increased to 10-20 m/hrs)
- **DISCUSSION:**
- WHAT POSSIBLE RISK DO YOU SEE?
- WHAT ARE STATUS OF BARRIERS?
- WHAT ACTION TO BE TAKEN?

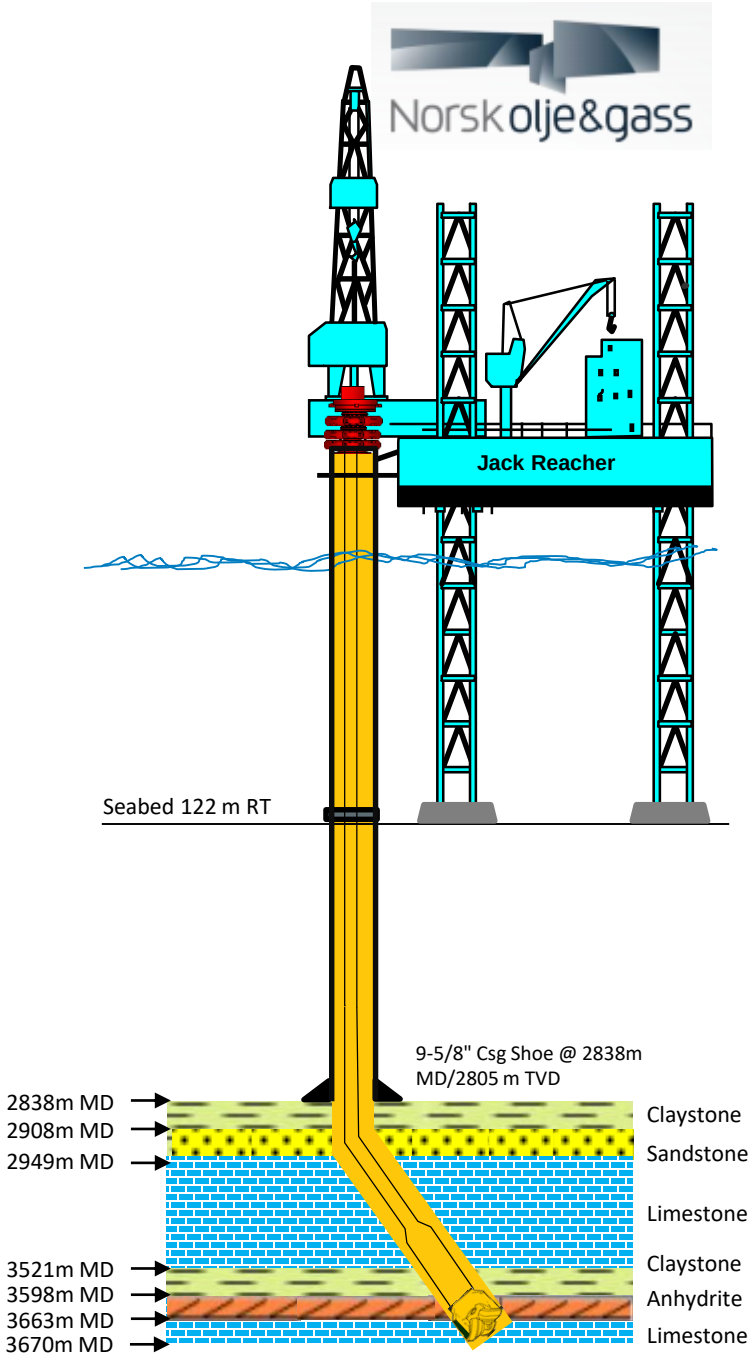


Figure 2. Well schematics

Situation description

- Flow checked drilling break – neg (Well static)
- Cont. to drill from 3667m to 3670m
- Observed sudden 10 bar reduction in pump pressure followed by severe losses, 35 m^3/hrs dynamic, 20 m^3 /hrs static – decreasing and stabilizing at 15 m^3 /hrs static.

- **DISCUSSION:**
- HOW DO YOU EXPLAIN THE PRESSURE DROP?
- WHERE DO YOU THINK THE LOSSES ARE?
- WHAT ARE STATUS OF BARRIERS?
- WHAT POSSIBLE ACTION CAN BE TAKEN?
- WHAT POSSIBLE RISK DO YOU SEE?

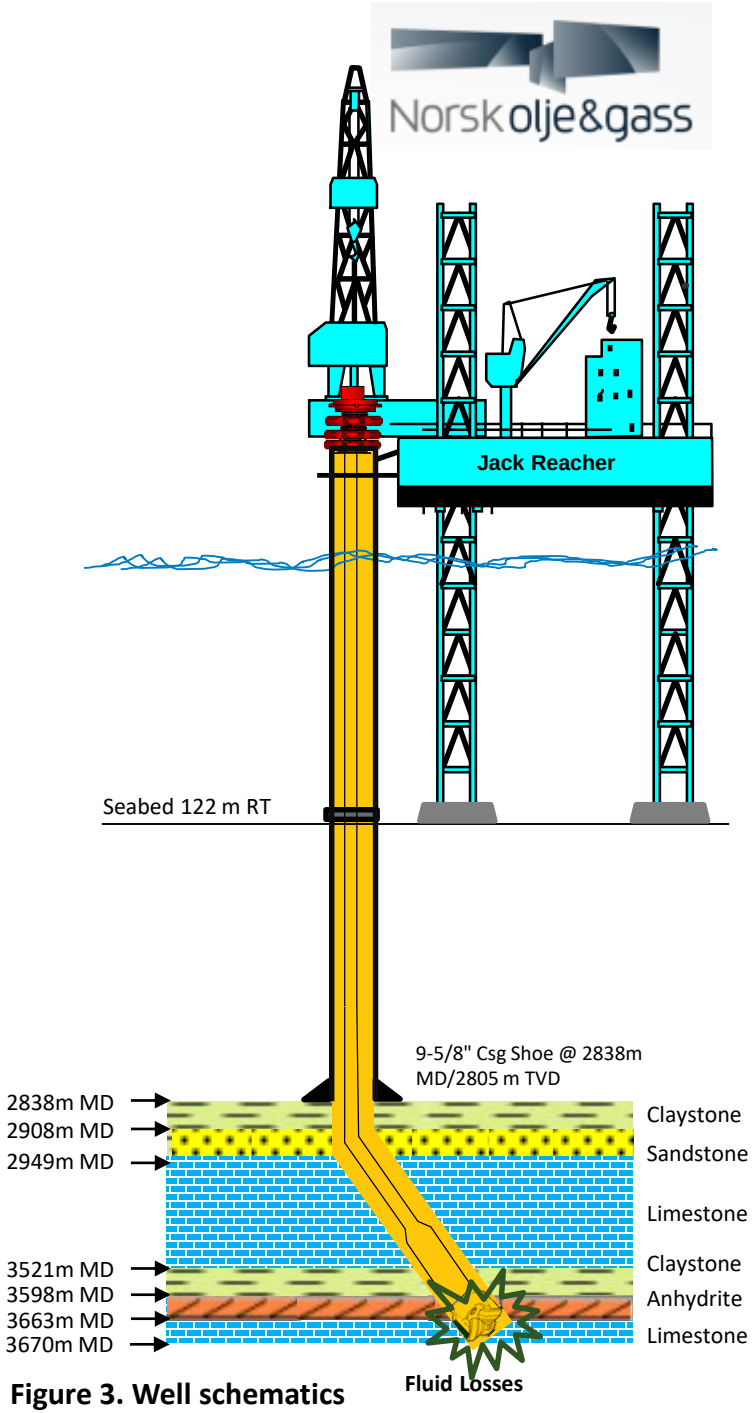


Figure 3. Well schematics

Situation description

- Displaced a 12 m3 LCM pill down the DP to cure losses
- No effect
- Topped up well with 0.81 sg base oil. After filled 12.5 m3 base oil in annulus – losses decreased to zero.

- **DISCUSSION:**
- WHAT POSSIBLE RISK DO YOU SEE?
- WHAT ARE STATUS OF BARRIERS?
- WHAT POSSIBLE ACTIONS CAN BE TAKEN?

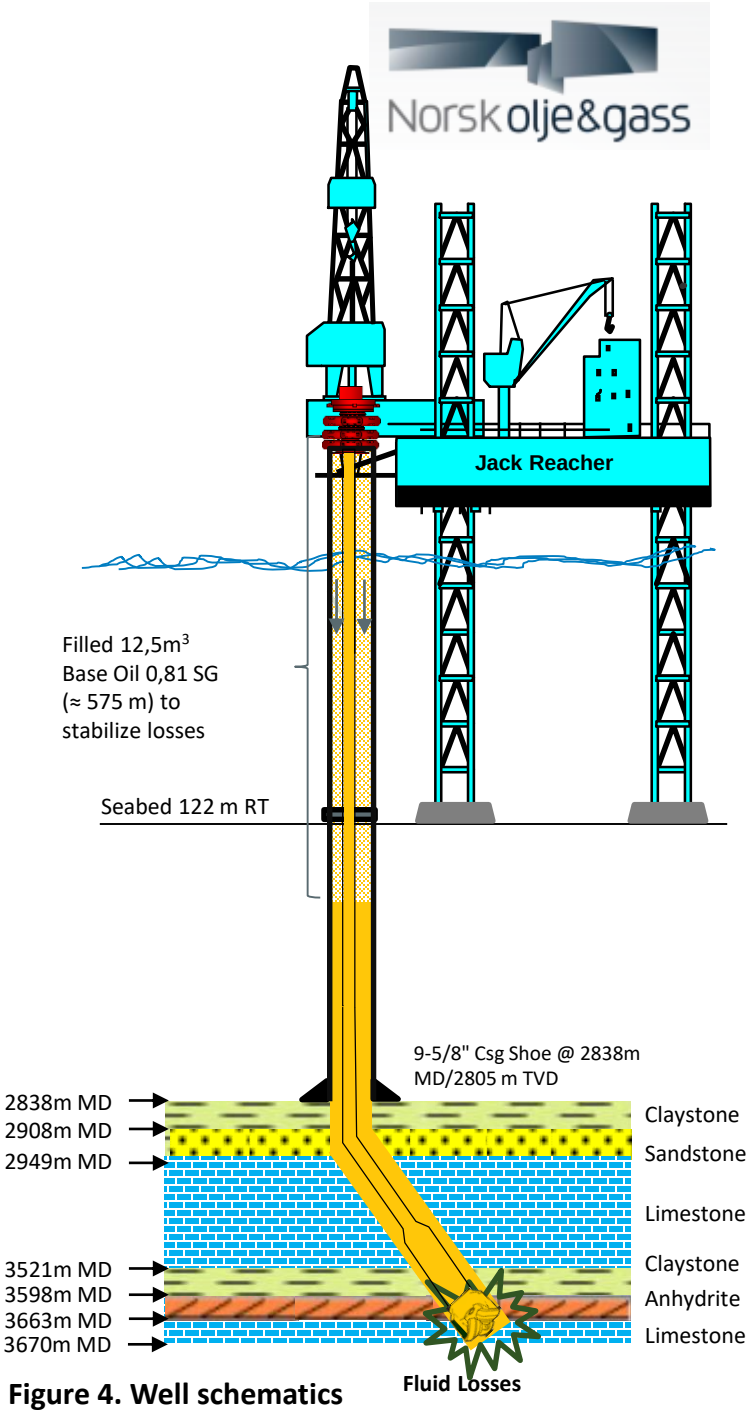


Figure 4. Well schematics

Handling “Pressure in Well”

- Flow checked the well, indication of slight gain.
- Shut the BOP and observed;
  - ① $SICP_{Initial}$ ≈ 10 bar,
    - $SIDPP_{Initial}$ ≈ 0 bar (Float in DP)

- **ANALYSE SITUATION AND DISCUSS:**
- WHAT MIGHT HAVE HAPPENED?
- WHAT ARE STATUS OF BARRIERS?
- WHAT POSSIBLE RISK DO YOU SEE?
- WHAT POSSIBLE ACTION CAN BE TAKEN?

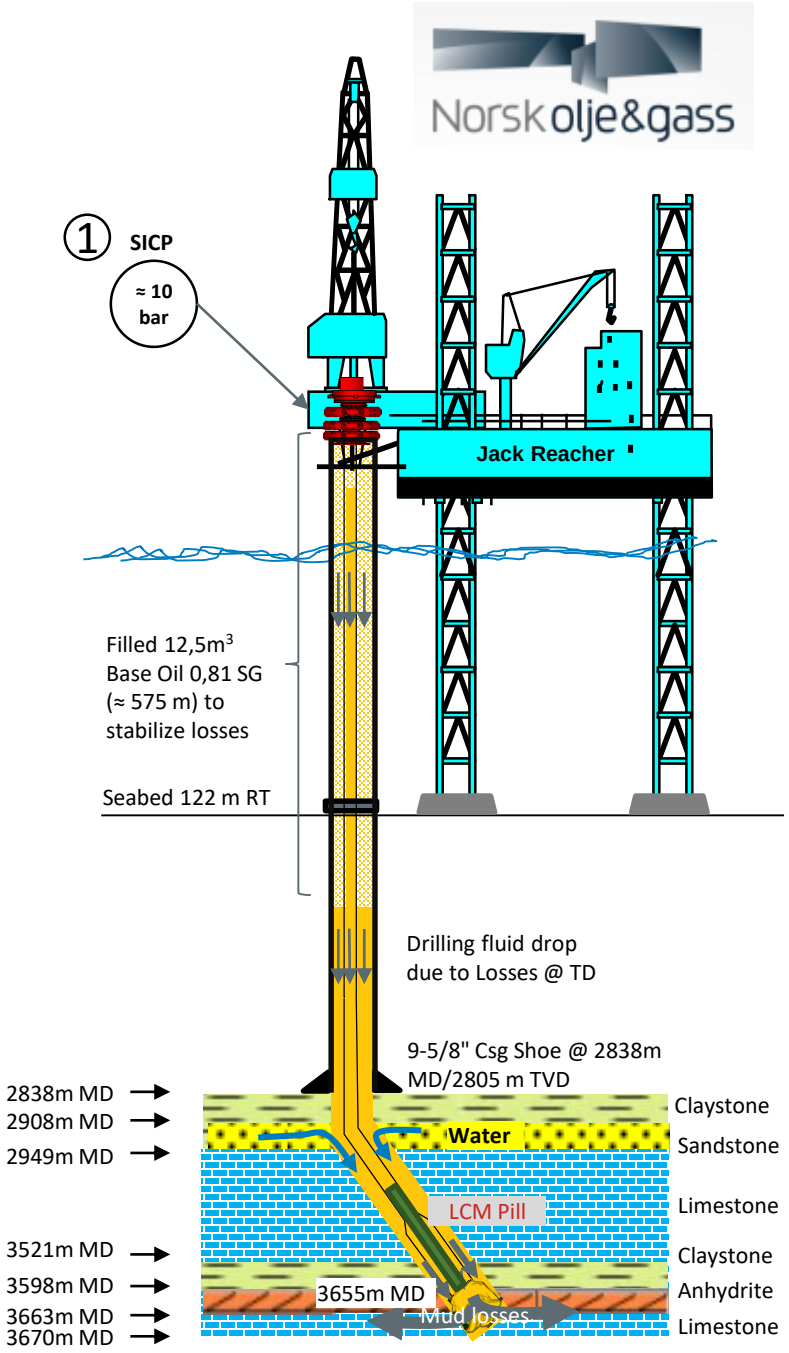
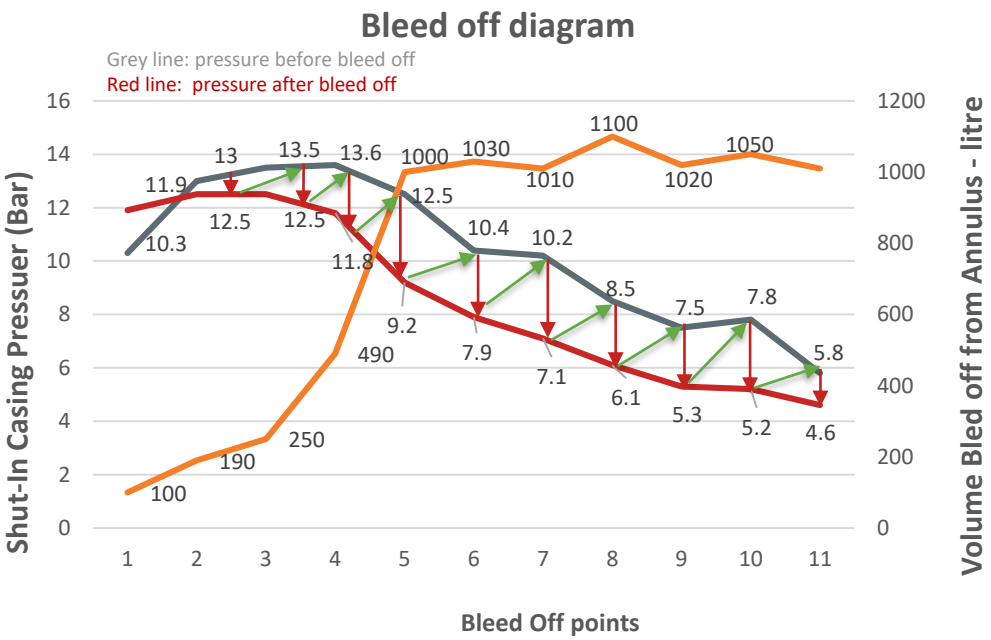


Figure 5. Well schematics

Handling “Pressure in Well”

EVENTS	COMMENTS
Bled of fluid from annulus in steps to check for ballooning	Bled off a total of 8,7 m^3 of Base Oil, SICP dropped from 10 bar and stabilized at ≈ 5 bar.



- **ANALYSE SITUATION AND DISCUSS:**
  - WHAT HAS HAPPENED?
  - WHAT ARE STATUS OF BARRIERS?
  - WHAT POSSIBLE RISK DO YOU SEE?
  - WHAT POSSIBLE ACTION CAN BE TAKEN?

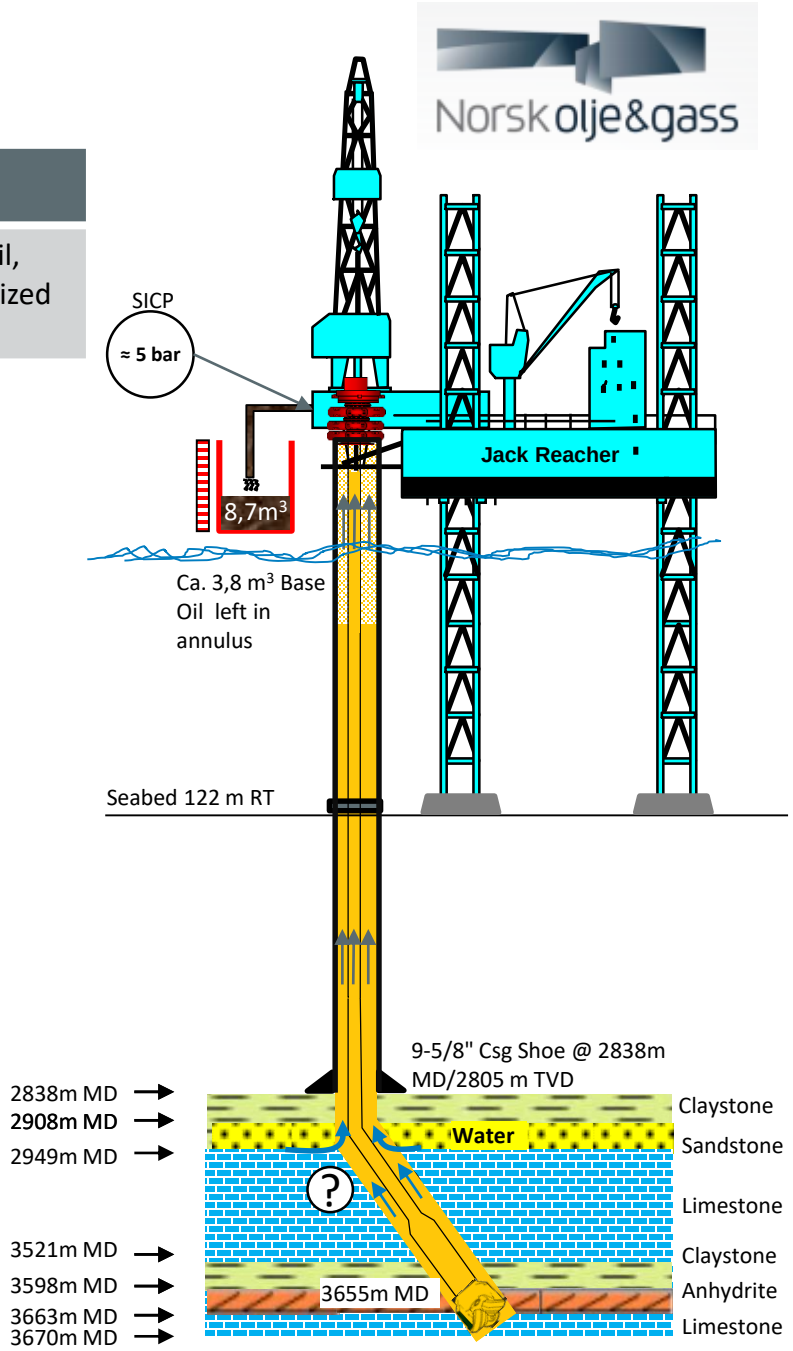


Figure 6 Well schematics

Handling “Well Influx”

EVENTS	COMMENTS
Opened BOP, established rotation and confirmed that DP was free.	① Monitored well on trip tank, gained 1700 ltr in 1 hr 20 min
Shut-In BOP (UPR)	SICP ≈ 5,7 bar
Bled of 1014 ltr fluid from annulus to Trip tank	② ③ Choke pressure before/after bleed off: 5.7/3.7bar - increasing to 6.9 bar in 25 min

- **ANALYSE SITUATION AND DISCUSS:**
  - WHAT HAS HAPPENED?
  - WHAT ARE STATUS OF BARRIERS?
  - WHAT POSSIBLE RISK DO YOU SEE?
  - WHAT POSSIBLE ACTION CAN BE TAKEN?

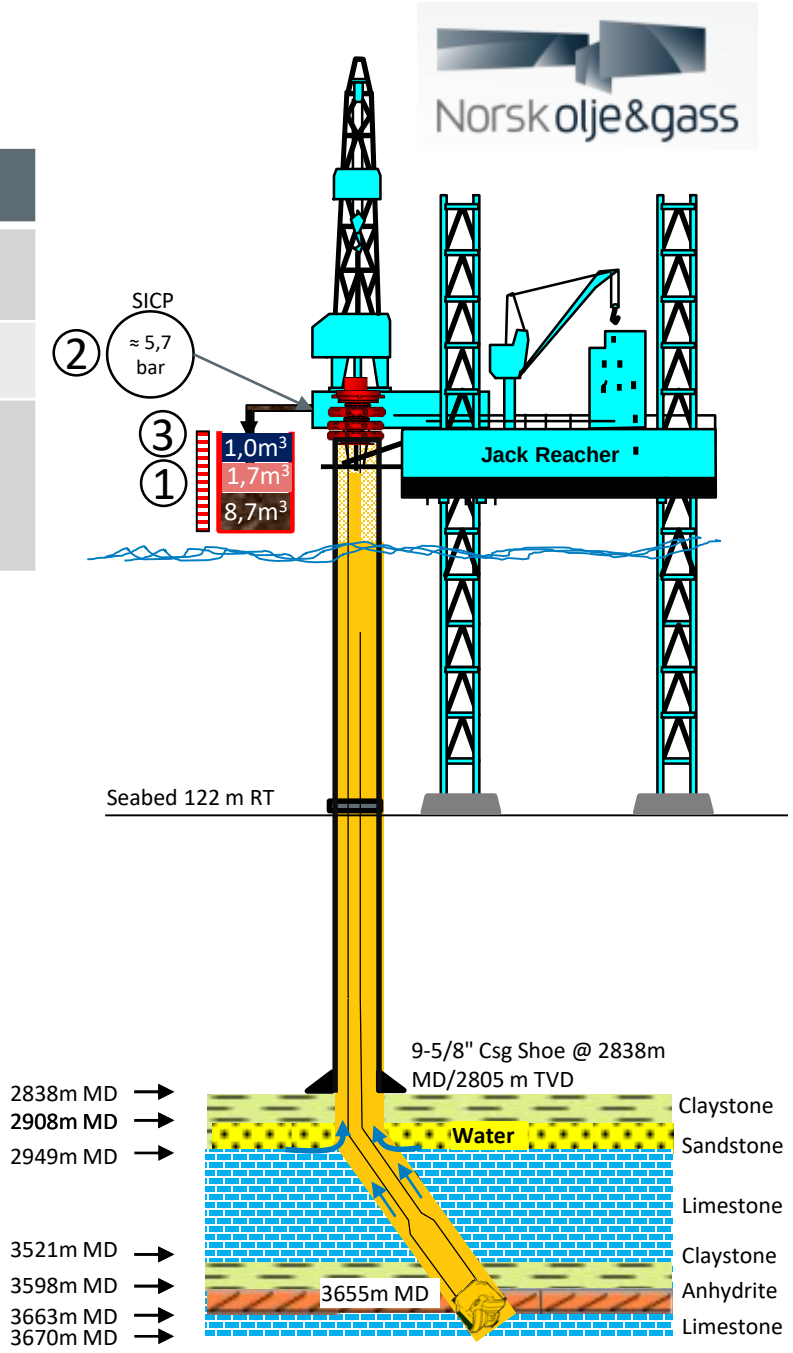


Figure 7 Well schematics

Handling “Well Influx”

EVENTS	COMMENTS
Started pumping down string, with open choke, in an attempt to establish loss free circulation ①	Gradually increased back-pressure on choke up to 10-12 bar. Initial/final loss rate: 600 ltr/hr / 3 600 ltr/hr
Closed in well after 677 stks pumped (12.8 m^3), due to choke pressure behaviour.	Monitored Choke pressure, max. 38 bar, gradually decreasing and stabilizing @ 31 bar. ②
Cont. to monitor well	Closed Annular, and opened UPR, confirmed string free by moving (reciprocating) same periodically. ② Choke pressure increased from 31 bar to 33 bar.

- **ANALYSE SITUATION AND DISCUSS:**
  - WHAT HAS HAPPENED?
  - WHAT ARE STATUS OF BARRIERS?
  - WHAT POSSIBLE RISK DO YOU SEE?
  - WHAT POSSIBLE ACTION CAN BE TAKEN?

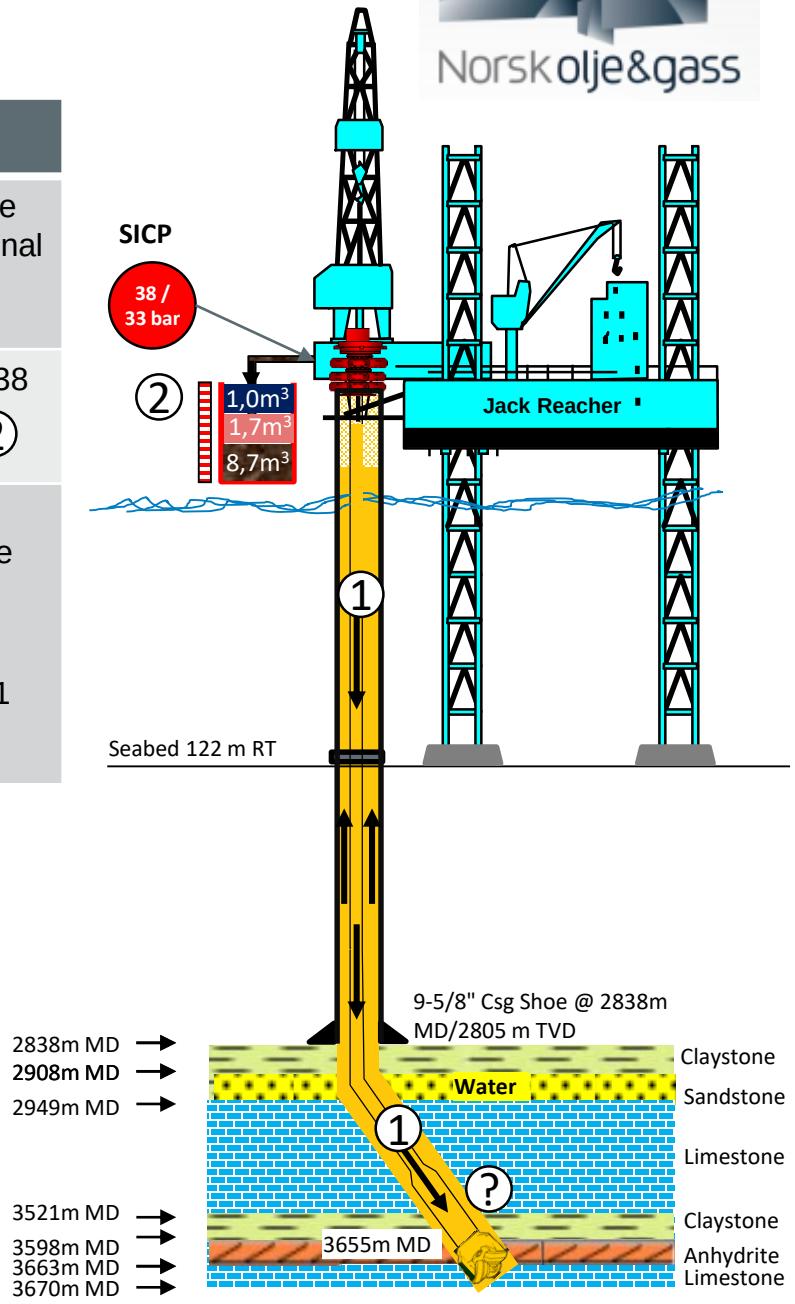


Figure 8. Well Influx / Kick

Handling “Well Influx”

EVENTS	COMMENTS
Commenced displacing 1.56 SG OBM down drillstring, with intention to bullhead string content (1.65 sg) OBM into formation. Negative! ①	DP pressure started to increase after pumping 125 stks (2.8 m^3) and continued to increase to 63 bar after pumping another 55 stks (1.2m^3) Choke pressure increased from 32.9 bar to 113bar. ②
Stopped pumps and observed DP/choke pressures: 43 bar/110 bar	

- **ANALYSE SITUATION AND DISCUSS:**
  - WHAT HAS HAPPENED?
  - WHAT ARE STATUS OF BARRIERS?
  - WHAT POSSIBLE RISK DO YOU SEE?
  - WHAT POSSIBLE ACTION CAN BE TAKEN?

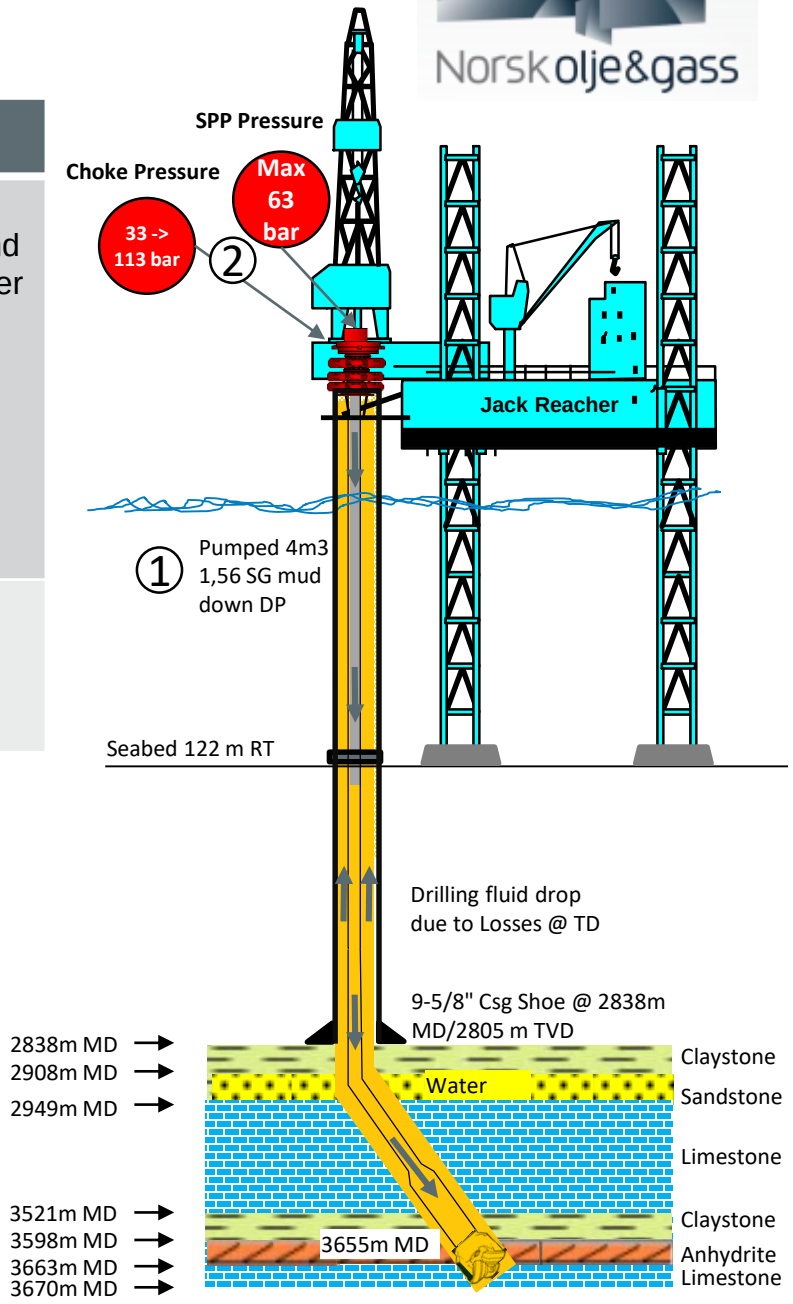


Figure 9. Well Influx / Kick

Handling “Well Influx”

DAY	EVENTS	COMMENTS
(3)	Bled off trapped pressure. ① Opened choke, and bled off DP pressure to below 5 bar	Bled off 220 ltr ②
(3)	Closed Well (Annular) and monitored same	DP/Choke pressures: 4.7 / 70 bar @ shut-in. DP/Choke pressures after 3 hours: 3,2/65 bar. Moved string (Up/Down) every hour to confirm free.
(3)	Prepared for Kill Operations with 1.65 sg MW	Filled trip tank with 1.65 SG OBM. Monitored shut in pressures: SIDPP 4bar, SICP 65bar.

- **ANALYSE SITUATION AND DISCUSS:**
  - WHAT HAS HAPPENED?
  - WHAT ARE STATUS OF BARRIERS?
  - WHAT POSSIBLE RISK DO YOU SEE?
  - WHAT POSSIBLE ACTION CAN BE TAKEN?

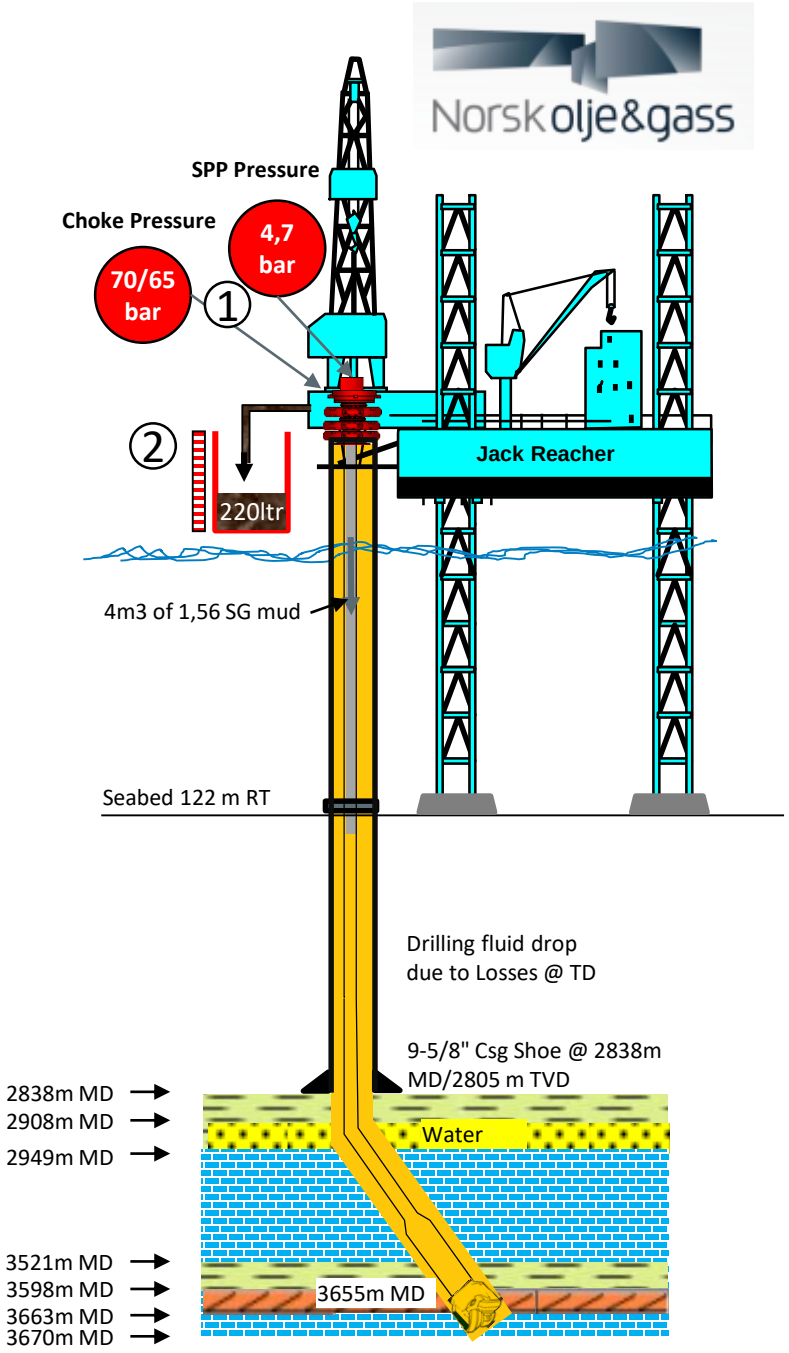


Figure 10. Well Influx / Kick

Handling “Well Influx”

EVENTS	COMMENTS
Started well killing operation using Driller's method. ①	Bit at 3655m ②
Staged up MP #3 to kill rate of 20 SPM while attempting to maintain SICP at 65 bar.	DP pressure increased to 99 bar, simultaneously opening choke. Choke pressure dropped to 63bar
Shut down pump and closed in well on choke.	SICP stable at 63bar.
Discussed situation with town	
Bled off annulus pressure in increments of 10bar until SICP 10bar and constant.	Observed for pressure build up and verified no trapped pressure in annulus during bleed off sequence

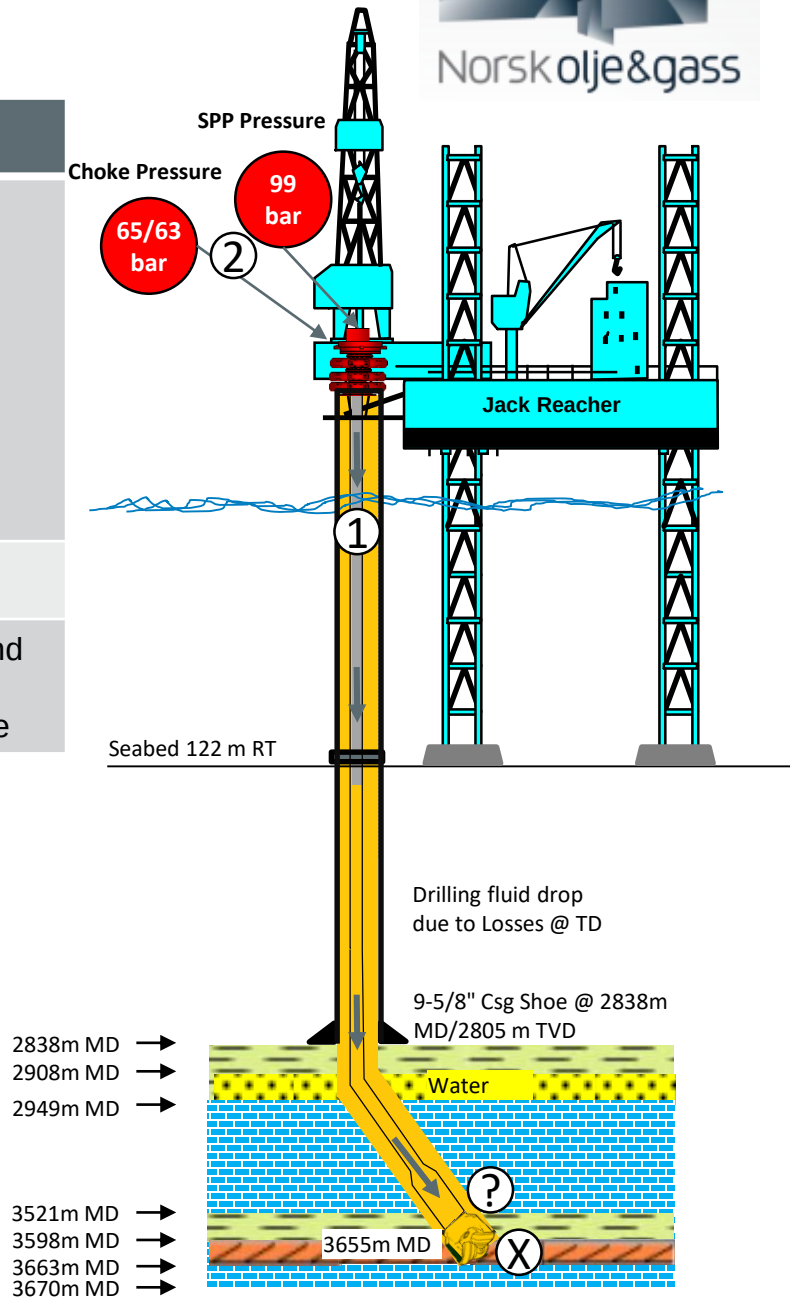


Figure 11. Kill operations

- **ANALYSE SITUATION AND DISCUSS:**
  - WHAT HAS HAPPENED?
  - WHAT ARE STATUS OF BARRIERS?
  - WHAT POSSIBLE RISK DO YOU SEE?
  - WHAT POSSIBLE ACTION CAN BE TAKEN?

Handling “Well Influx”

EVENTS	COMMENTS
Attempted to pump down Drill pipe. Negative! ①	DP Pressure increased up to 100 bar ② No pressure increase observed on choke manifold.
Closed Annular Preventer and opened UPR to be able to move DP	
Moved string to ensure free.	Observed overpull 30MT to free string but no change in SIDPP and SICP pressures - 100/10 bar
Bled off pressures on DP and Annulus.	

- **ANALYSE SITUATION AND DISCUSS:**
  - WHAT HAS HAPPENED? *(think out of the box….)*
  - WHAT ARE STATUS OF BARRIERS?
  - WHAT POSSIBLE RISK DO YOU SEE?
  - WHAT POSSIBLE ACTION CAN BE TAKEN?

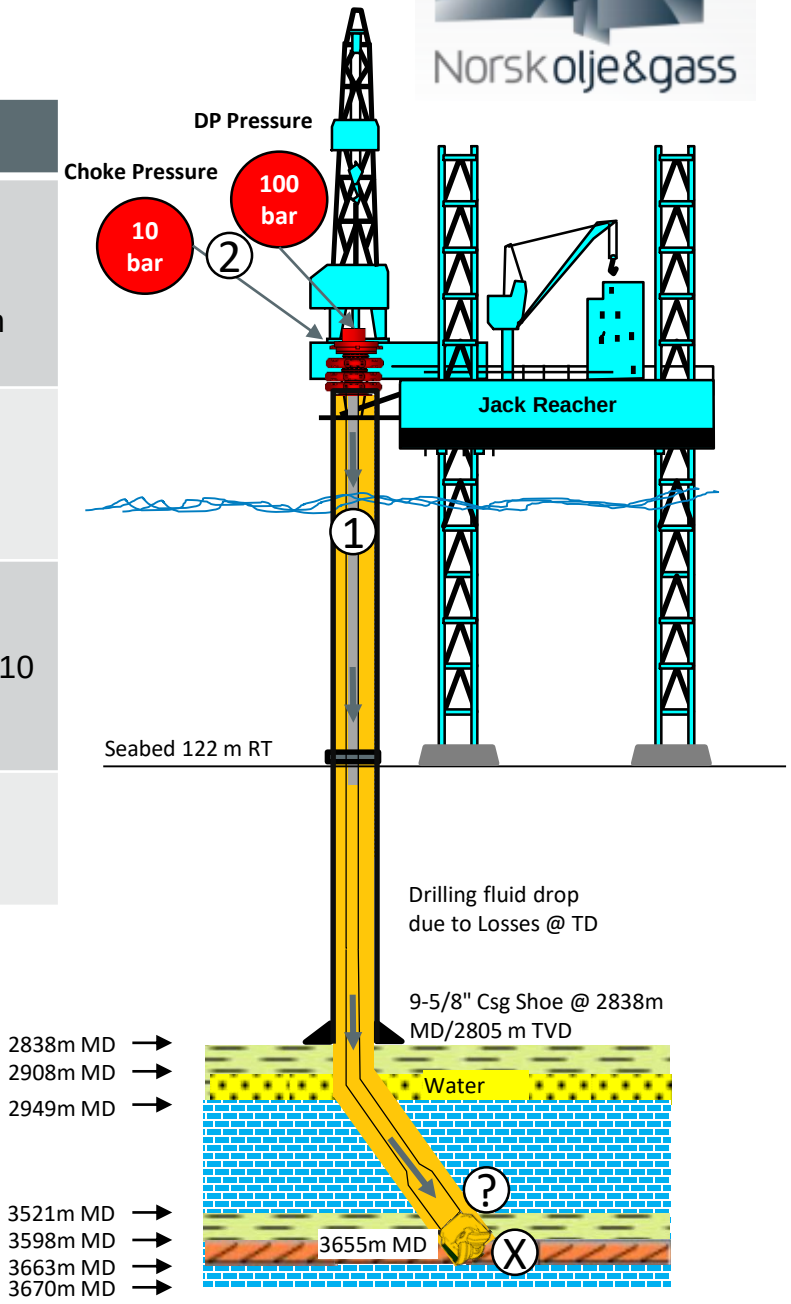


Figure 12. Kill operations

Handling “Well Influx”

EVENTS	COMMENTS
Opened Annular preventer and re-attempted to pump down DP with returns to trip tank. ①	Observed DP pressure increased to 110 bar - No returns.
Bled off standpipe pressure to zero. Pumped into string with 370 lpm and observed drillpipe pressure increased to 113 bar ②	Worked string upwards to 3641m and observed DP pressure decreased slowly while moving string out of hole. ③
Established rotation with 45 rpm and 15.5 kNm torque when pulling string	Hole tight when pulling string to 3641m. Slight overpull 3-4MT
Flow checked well on Trip tank for 10 min at 3641m	Well Static !

- **ANALYSE SITUATION AND DISCUSS:**
  - WHAT HAS HAPPENED?
  - WOULD YOU HAVE OPENED THE BOP?
  - WHY PULLING STRING OUT OF HOLE – WHY DO THE PRESSURE DROP?
  - WHAT ARE STATUS OF BARRIERS?
  - WHAT POSSIBLE RISK DO YOU SEE?
  - WHAT POSSIBLE ACTION CAN BE TAKEN?

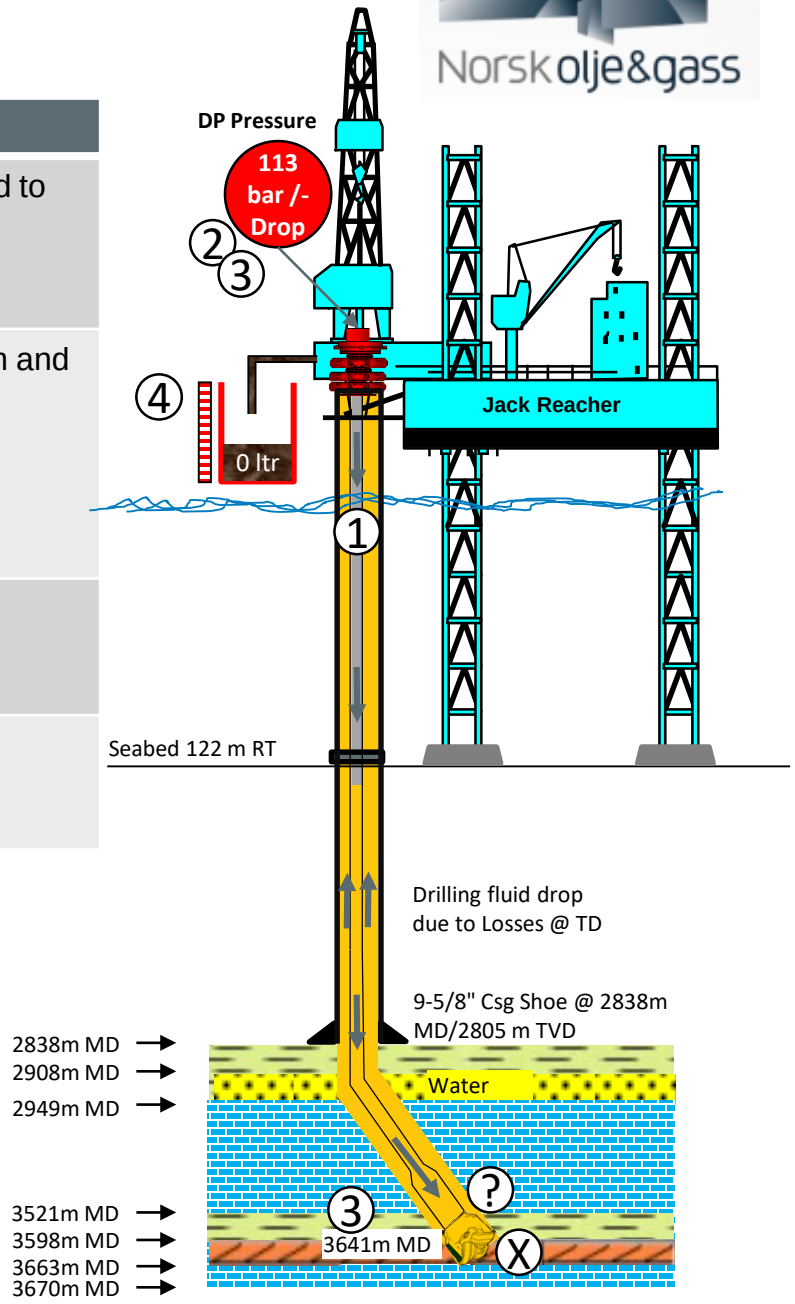


Figure 13. Kill operations

Handling “Well Influx”

EVENTS	COMMENTS
Racked stand & M/U Topdrive to ① string and maintained 30 bar pressure on DP with Slow Pump Rate (1-2 SPM). Rotated with 60 rpm at 15-16 kNm and backreamed slowly from 3641 - 3632 m.	Observed returns from well at 3632 m. Increased flow to 270 lpm and 28 bar. ②
Continued to pull to 3626 m with circulation and rotation 60 rpm.	Observed DP pressure reducing to 5 bar. Stopped pump
Flow checked well on trip tank.	Gained 400 ltr. ③

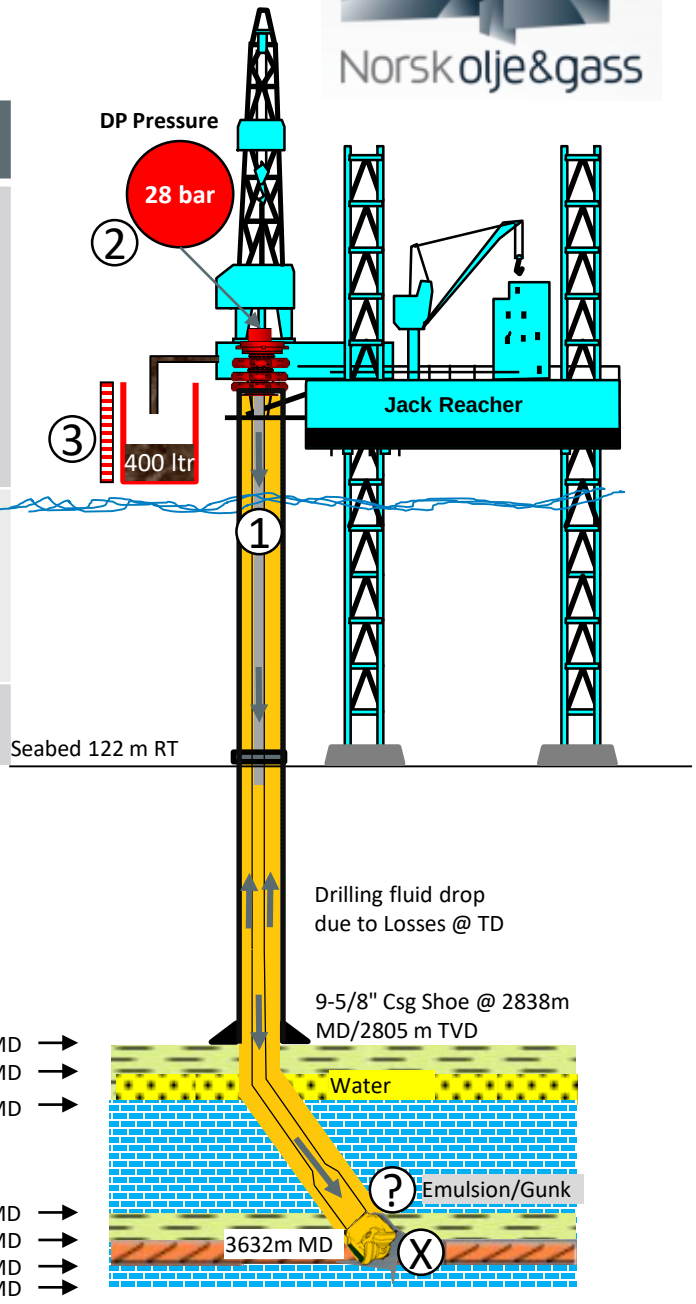


Figure 14. Kill operations

- **ANALYSE SITUATION AND DISCUSS:**
  - WHAT HAS HAPPENED?
  - WHAT ARE STATUS OF BARRIERS?
  - WHAT POSSIBLE RISK DO YOU SEE?
  - WHAT POSSIBLE ACTION CAN BE TAKEN?

Handling “Well Influx”

EVENTS	COMMENTS
Shut in well on Upper Pipe Rams.	Monitored well. Initial SICP 44 bar increasing to 50 bar over 30 minutes, then stable
Pumped down string with low flowrate to open float.	Recorded SIDPP 3.5 bar. ①
Started Well Kill Operation using Drillers method.	SIDPP 3.5bar, SICP 50bar. Staged up pump in 5 spm increments to 20 spm. Pump kill rate at 370lpm. No losses observed during circulation.After pumping 44 m3 of kill mud observed a slug of 10-12 m3 of 1.08 SG pure alkaline water coming in return. After 49 m3 pumped, observed gas returns increasing to 3.35% at shakers.
Stopped pumps when MW in/out at 1.65sg	Closed in well on choke at 3626m. Observed for pressure increase for 15 min – Well STATIC Opened choke, flow checked for 10 min – Well STATIC. Opened Annular Preventer and flow checked well for 30 min - Well STATIC

- **ANALYSE SITUATION AND DISCUSS:**
  - WHAT ARE STATUS OF BARRIERS?
  - WHAT POSSIBLE RISK DO YOU SEE?
  - WHAT POSSIBLE ACTION CAN BE TAKEN?

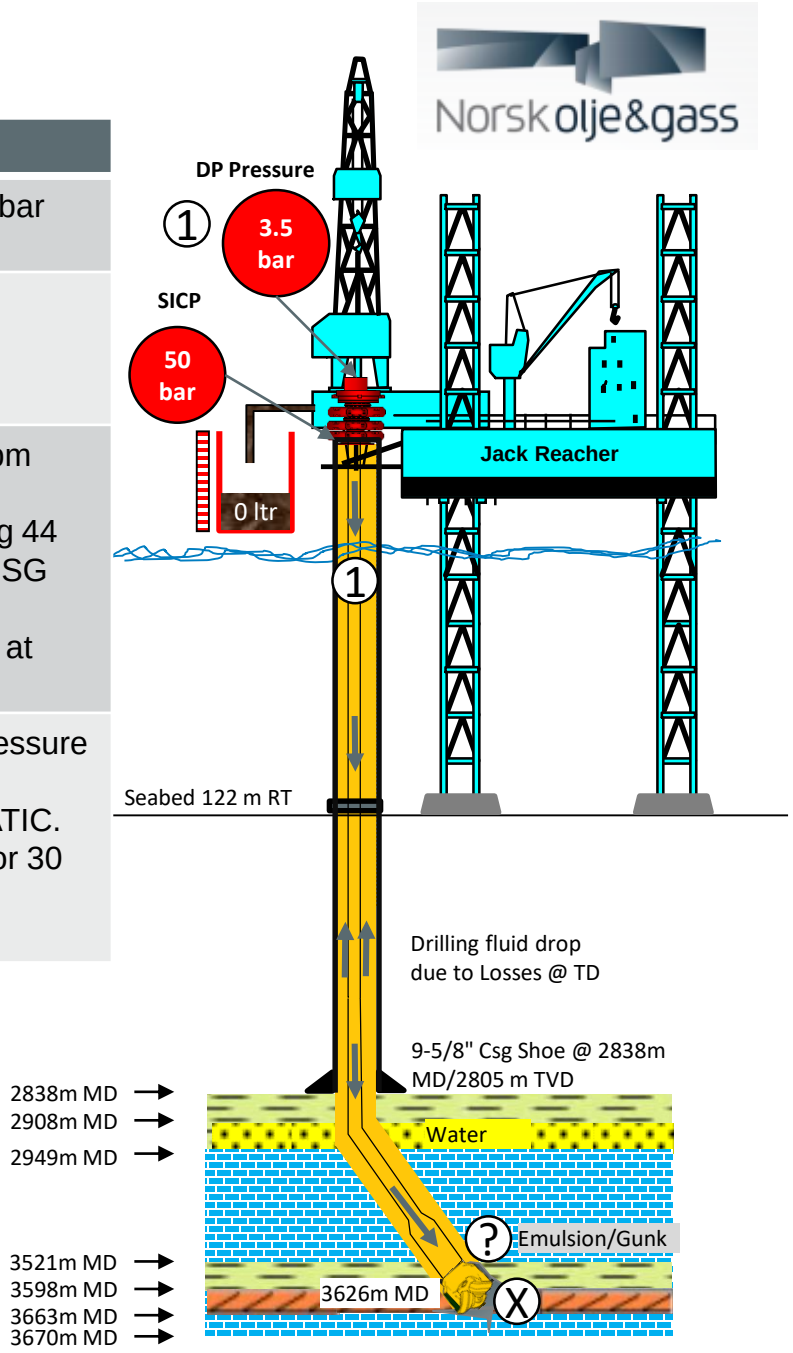


Figure 15. Kill operations

Lessons learned

- Pore pressure predictions was too high in lower part of well
- Water kick came from small sandstone in Anhydrite
- Mud system not optimized with respect to reducing ECD
- Unable to judge the severity of the undergauge/worn bit/BHA from parametres provided (e.g. ECD & Caliper log readings, torque values, etc.)
- Undergauge hole causing high pressure build-up at or close to bit, NOT observed by “ECD” sensor
- Severe losses were experienced in what is assumed to be a fractured limestone
- When pumping OBM into a water kick an emulsion may be created
- Installed a 7” contingency liner @ 3651m MD to isolate fractured Anhydrite/limestone formation made it possible to finish well

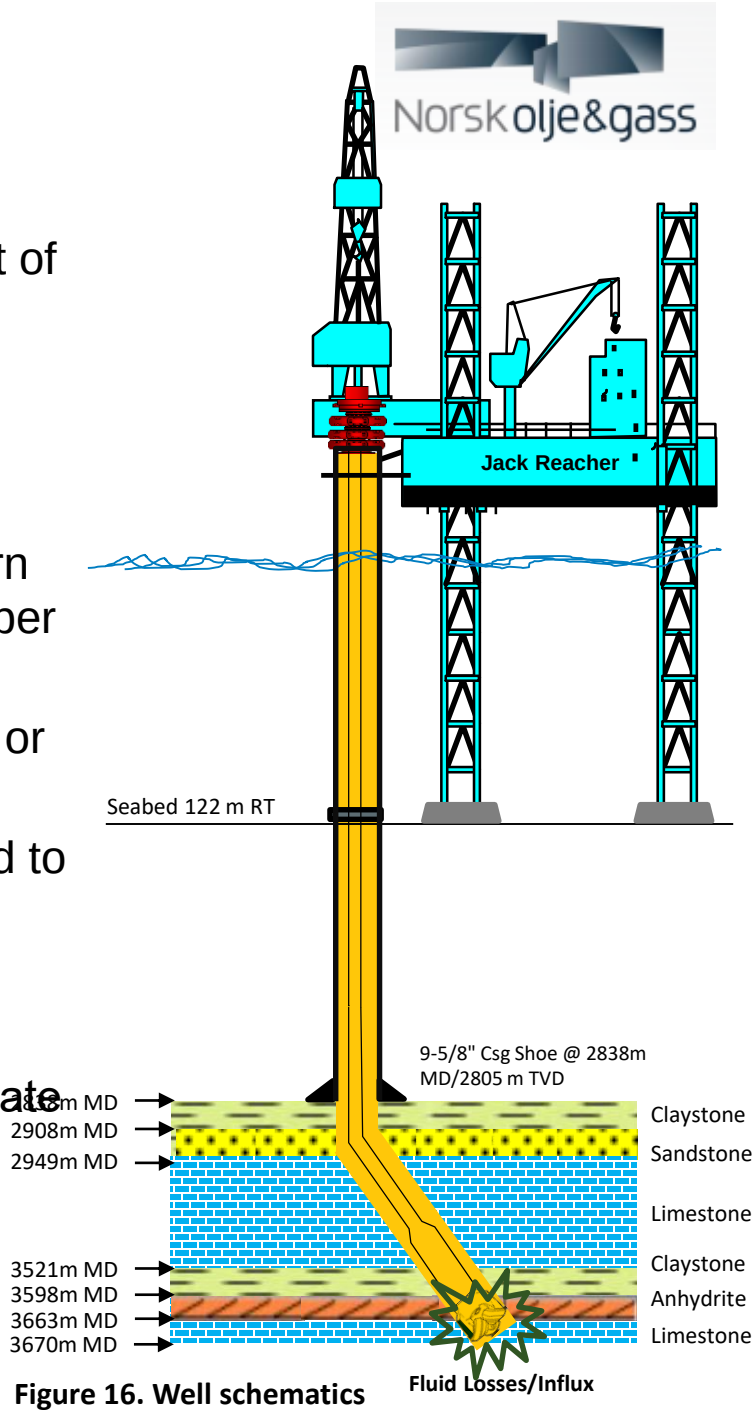


Figure 16. Well schematics

Contributing factors to the incident

- Severly undergauge bit – used steering pads as hole openers.....
- Probable pack-off around/above the undergauged bit caused an increase in ECD at bit, undetected by the ECD sensor
- Naturally fractured limestone – causing severe losses
- Mud system not optimized wrt reducing the ECD