
Deepwater Horizon
Mississippi Canyon Block 252
Macondo Well

Gulf of Mexico response | BP internal investigation | BP - Mozilla Firefox

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# BP internal investigation

## BP has published its internal investigation team's report into the accident on the Deepwater Horizon rig in the Gulf of Mexico on 20 April 2010.

The investigation found that no single factor caused the Macondo well tragedy. Rather, a sequence of failures involving a number of different parties led to the explosion and fire which killed 11 people and caused widespread pollution in the Gulf of Mexico earlier this year.

- Read the press release

- Watch the video (29 mins)

- Download the executive summary (pdf, 3735KB)
- Download the full investigation report (pdf, 13959KB)

- Appendices A, B, F, G, H (pdf, 3634KB)
- Appendices C, D, E (pdf, 2556KB)
- Appendices I to AA (ZIP, 49290KB)

- See presentation slides (pdf, 1347KB)

### Related links

- Read the full press release

### Useful tools

- Printer friendly version
- Recommend this page

http://bp.concerts.com/gom/deepwater_horizon_report_long.htm

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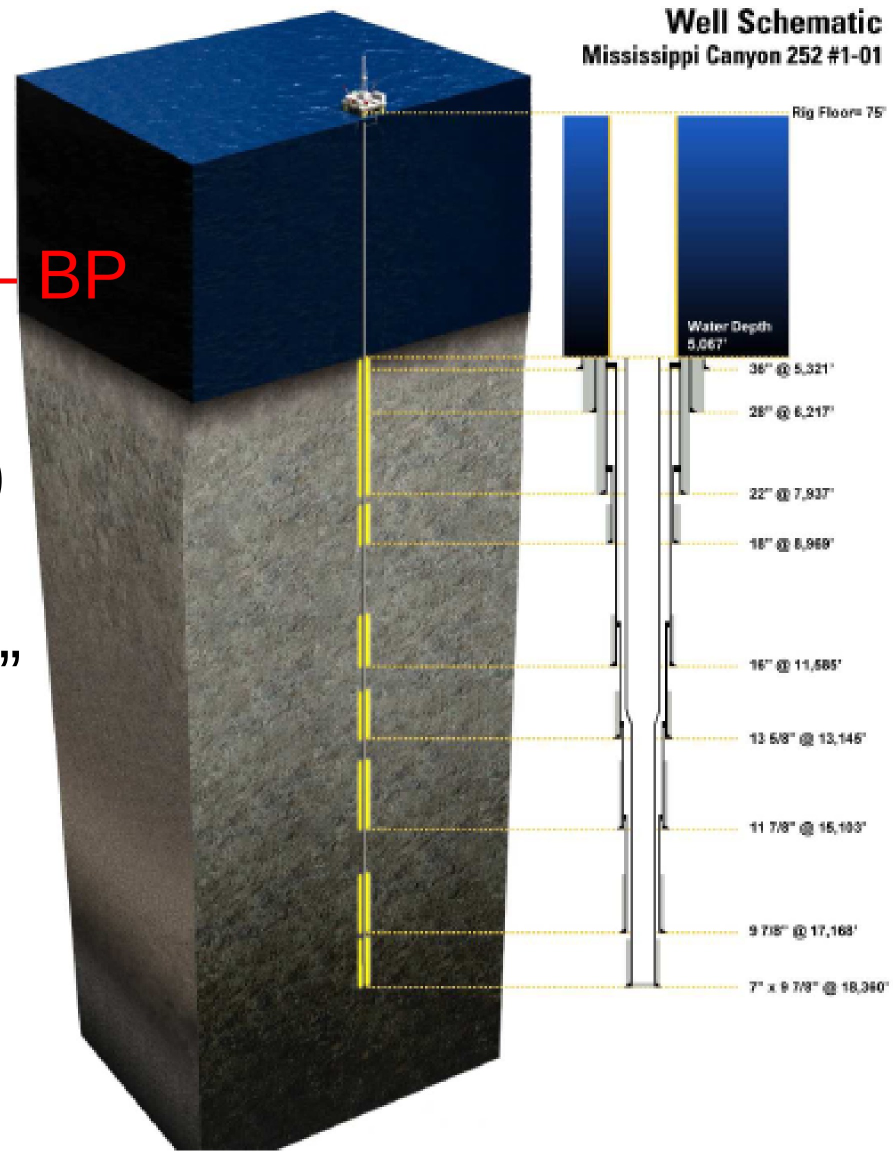
# The Well

- Name: Mississippi Canyon 252#1 (Macondo Well)
- Operator: British Petroleum – BP
- Water depth: 5067’ (1544 m)
- Final depth: 18360’ (5596 m)
- Number of phases: 9
- Production casing: 7” x 9.5/8”
- Planned final operation: Temporary abandonment



# The Rig

- Name: Deepwater Horizon
- Owner: Transocean
- Water depth: 8,000’ (2438 m)
- Well final depth: 30,000’ (9146 m)
- Year built: 2001
- Day-rate: USD 500,000.00
- Cost of construction: USD 350 MM
- Accommodations: 130 people
- Kind of rig: Semi-submersible
- Station keeping: Dynamically positioned

# NASA satellite imagery shows area in the Gulf of Mexico impacted by Deepwater Horizon incident

ROBERT, La. – NASA satellite imagery shows an oil sheen leaking from the site of the Deepwater Horizon incident in the Gulf of Mexico, April 26, 2010. The sheen is approximately 600 miles in circumference and recovery and clean-up efforts have resulted in the collection of 1,152 barrels/ 48,384 gallons of oily-water mixture.

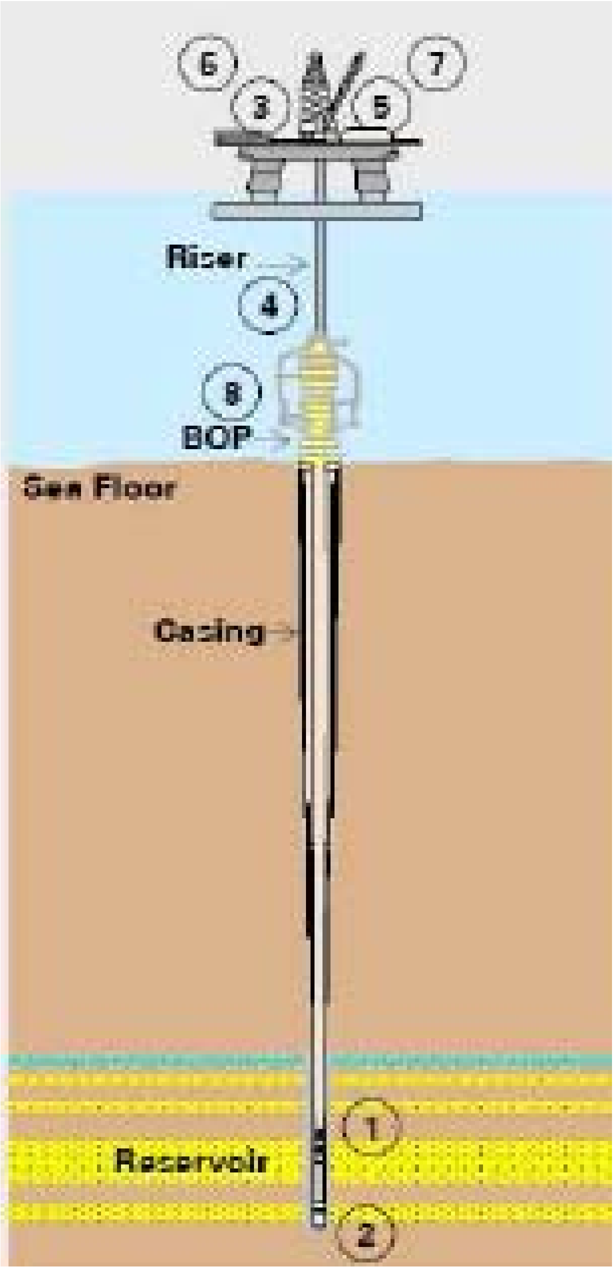
Imagery courtesy of NASA Earth Observatory

**April 26, 2010**

# Chronology of the accident

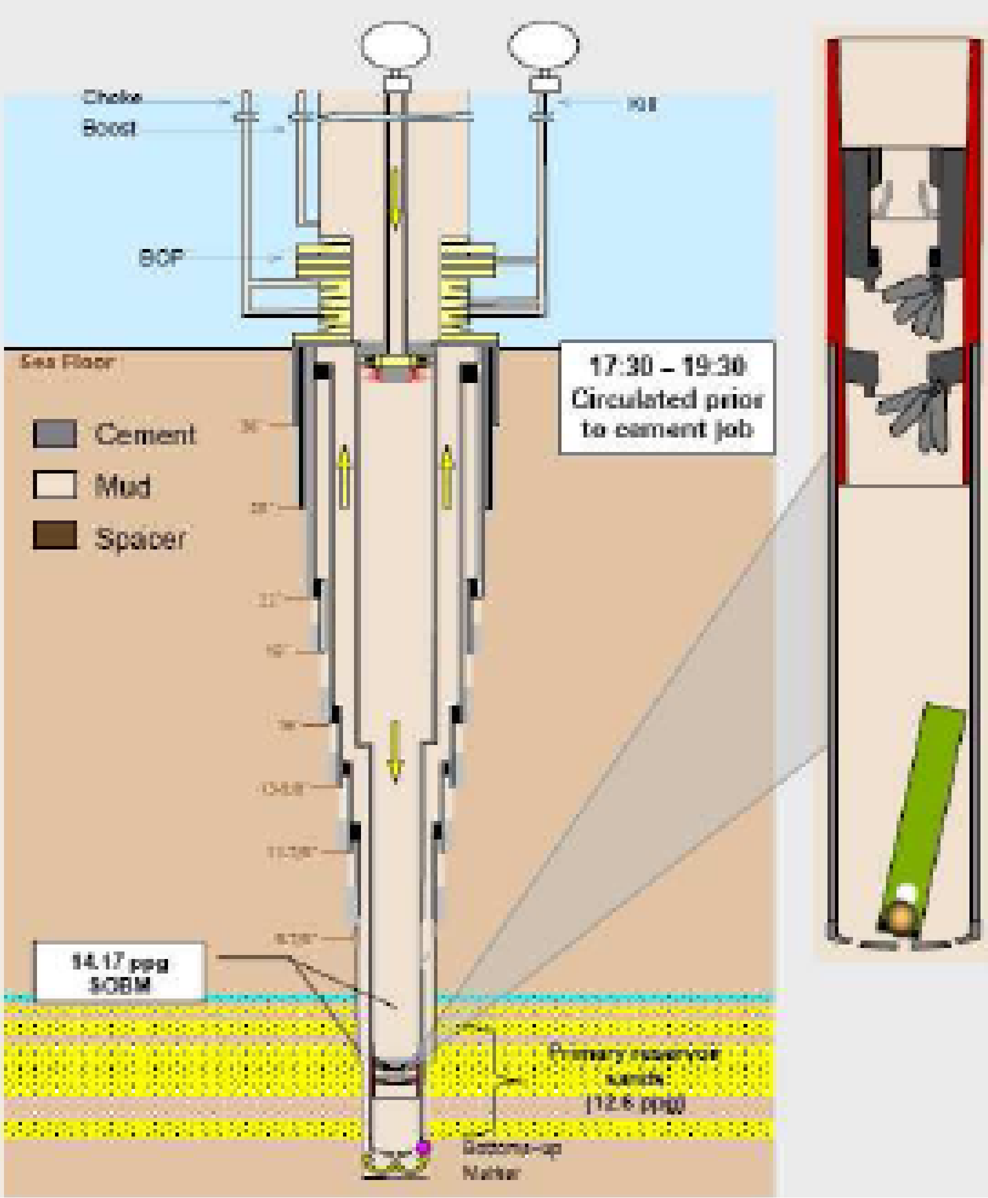
- Finish drilling (at 18360’) and complete logging – April 15, 2010
- Wiper trip – April 17, 2010
- Run casing – April 19, 17:30
- Cement job – April 20, 00:30
- Set seal assembly – April 20, 07:00
- Trip in hole and test casing – April 20, 15:00
- Mud transfer to the boat – April 20, starts 13:20
- Stop pump 21:31
- Explosion – April 20, 21:49
- Rig sinks – April 22, 2010

# Eight barriers were breached




- Well integrity was not established or failed
  1. Annulus cemment barrier did not isolate hydrocarbons
  2. Show track barriers did not isolate hydrocarbons
- Hydrocarbons entered the well undetected and well control was lost
  3. Negative pressure test was accepted although well integrity had not been established
  4. Influx was not recognized until hydrocarbons were in riser
  5. Well control response actions failed to reagain control of well
- Hydrocarbons ignited on the Deepwater horizon
  6. Diversion to mud gas separator resulted in gas ventingonto rig
  7. Fire and gas system did not prevent hydrocarbon ignition
- Blowout preventer did not seal the well
  8. Blowout preventer (BOP) emergency mode did not seal well

# Production Casing Installation



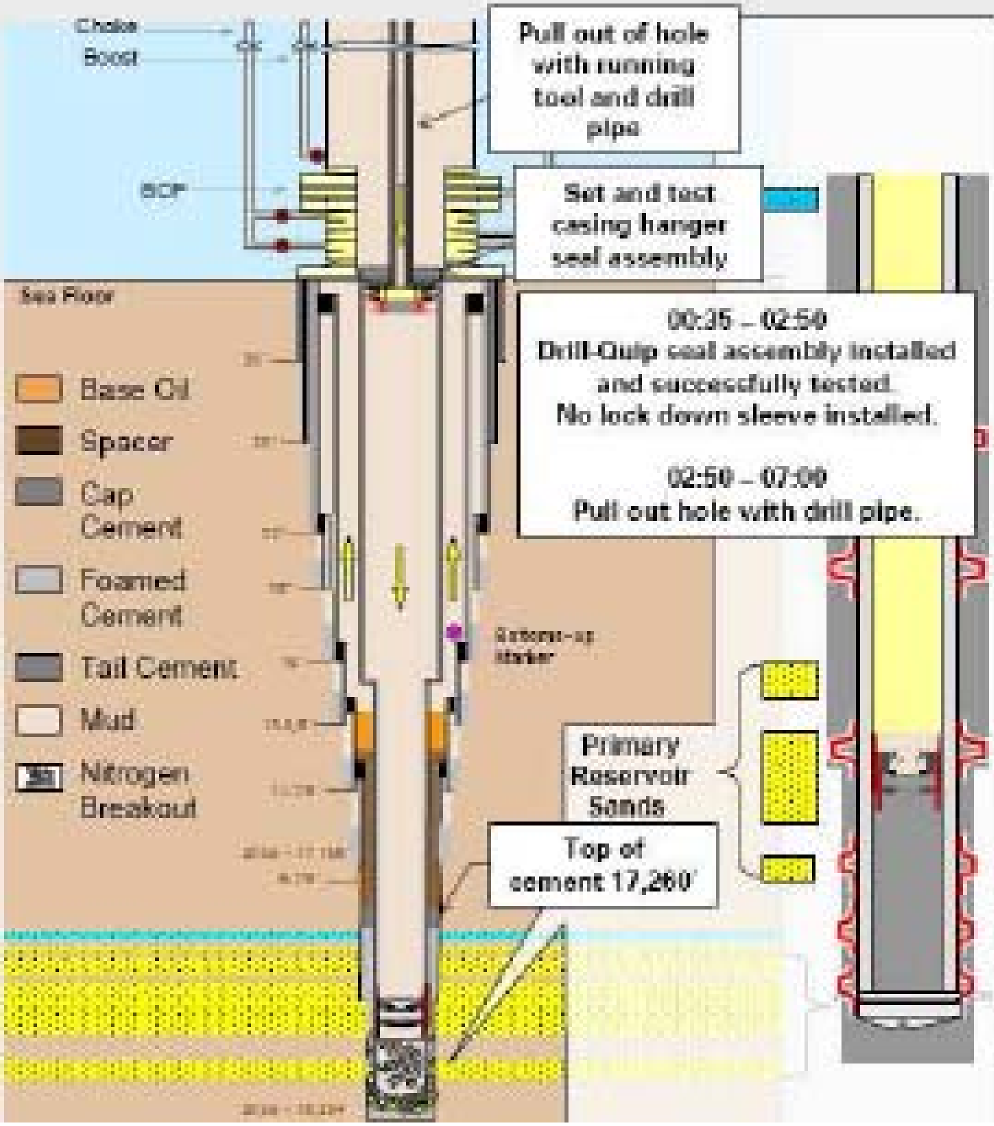

***After drilling to total depth, casing is run to bottom in preparation for the cement job. A double valve float collar is used to prevent backflow or ingress of fluids through the shoe track until the cement hardens and creates a permanent barrier.***

**April 18th 00:30 – April 19th 19:30**

- Long string design robust, consistent with similar wells in the area
- 9 attempts made to establish circulation to convert float valves
- Circulate ~6 times open hole volume, limited circulation due to concerns over creating losses and hole washout
- No evidence that hydrocarbons entered the wellbore prior to the cementing operation

# Cement Job

***Cement is pumped down casing through the float collar and up the annulus to isolate the primary reservoir sands.***

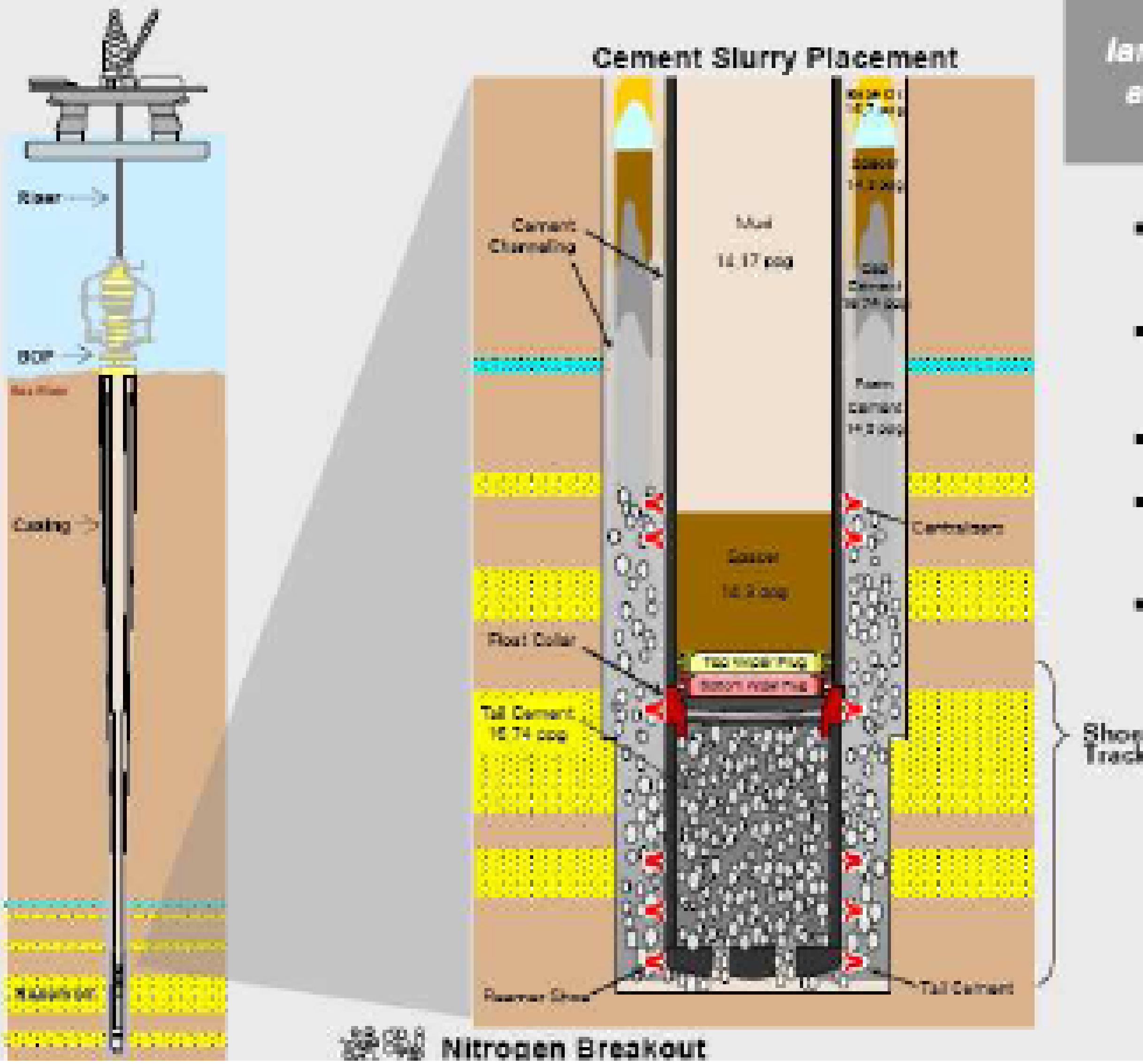



**April 19[th] 19:30 – April 20[th] 07:00**

- Nitrogen cement slurry chosen
  - To achieve light weight slurry due to limited pore pressure / fracture gradient window
- Possible risk
  - Stability of foam
  - Relatively small volume
  - Susceptible to contamination
- Mitigation of risk by
  - Thorough testing of slurry design
  - Precise placement
- Centralization
  - 6 inline centralizers spaced across the reservoir sands
  - Additional centralizers not run because incorrectly thought to be wrong type
  - Risk of channeling above reservoir sands known and accepted

# Key Finding #1

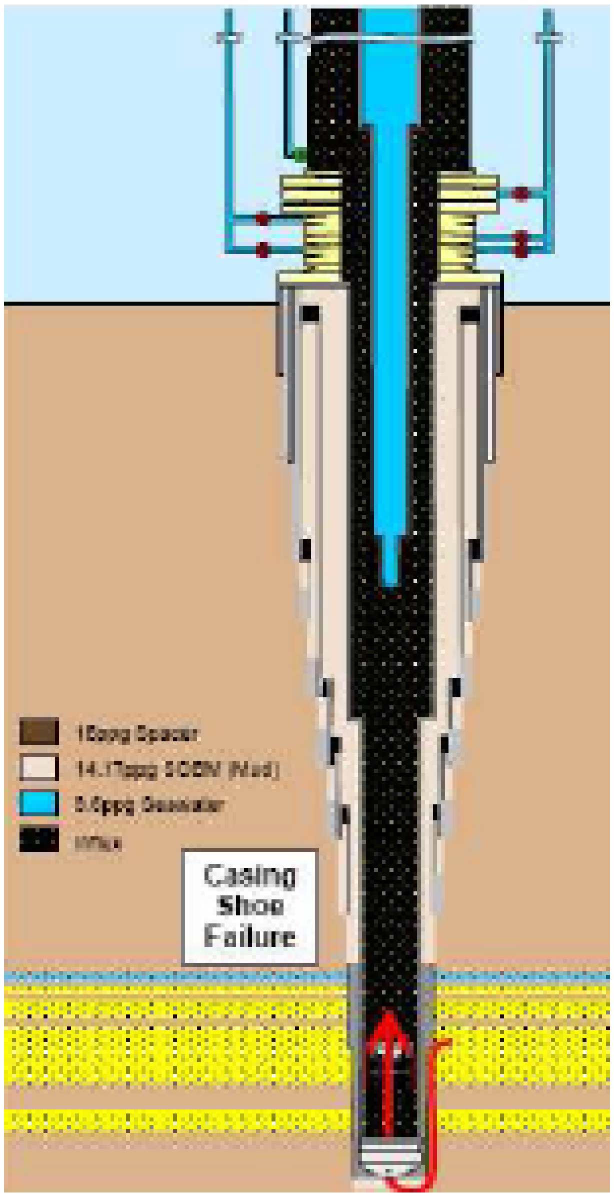
## The annulus cement barrier did not isolate the reservoir hydrocarbons



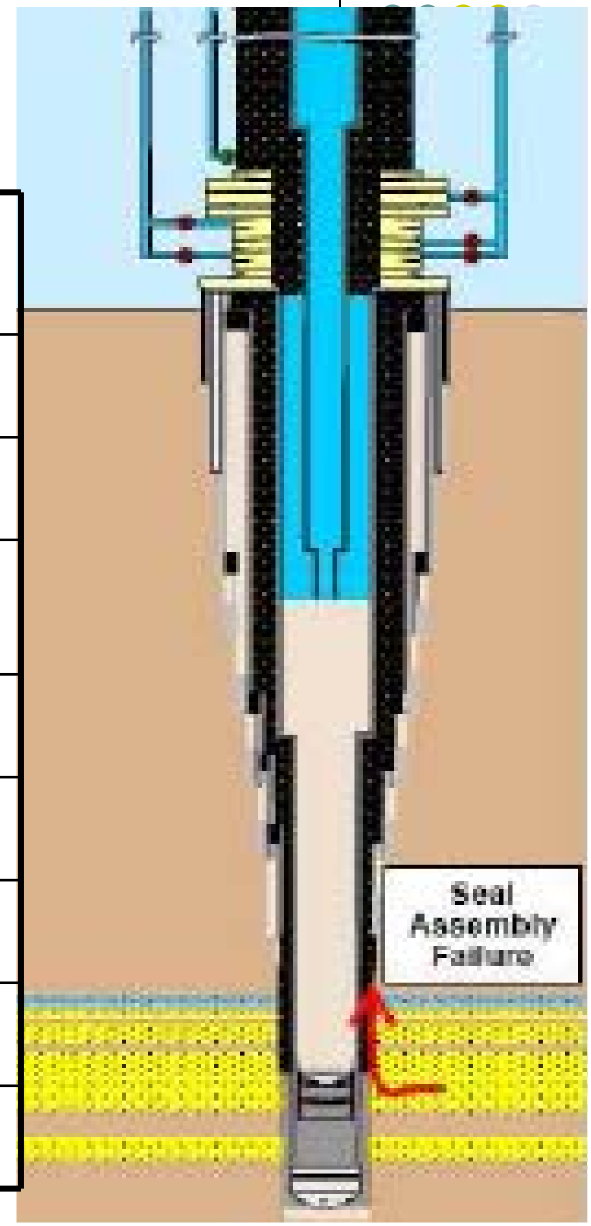

***Cement is pumped down the landing string and casing into the annulus to isolate hydrocarbon bearing sands.***

- Foam slurry recommended was a complex design
- Risk of contamination using small volume of cement
- No fluid loss additives
- Incomplete pre-job cement lab testing
- Foam slurry was likely unstable and resulted in nitrogen breakout

# Flow through shoe trak – supporting evidence

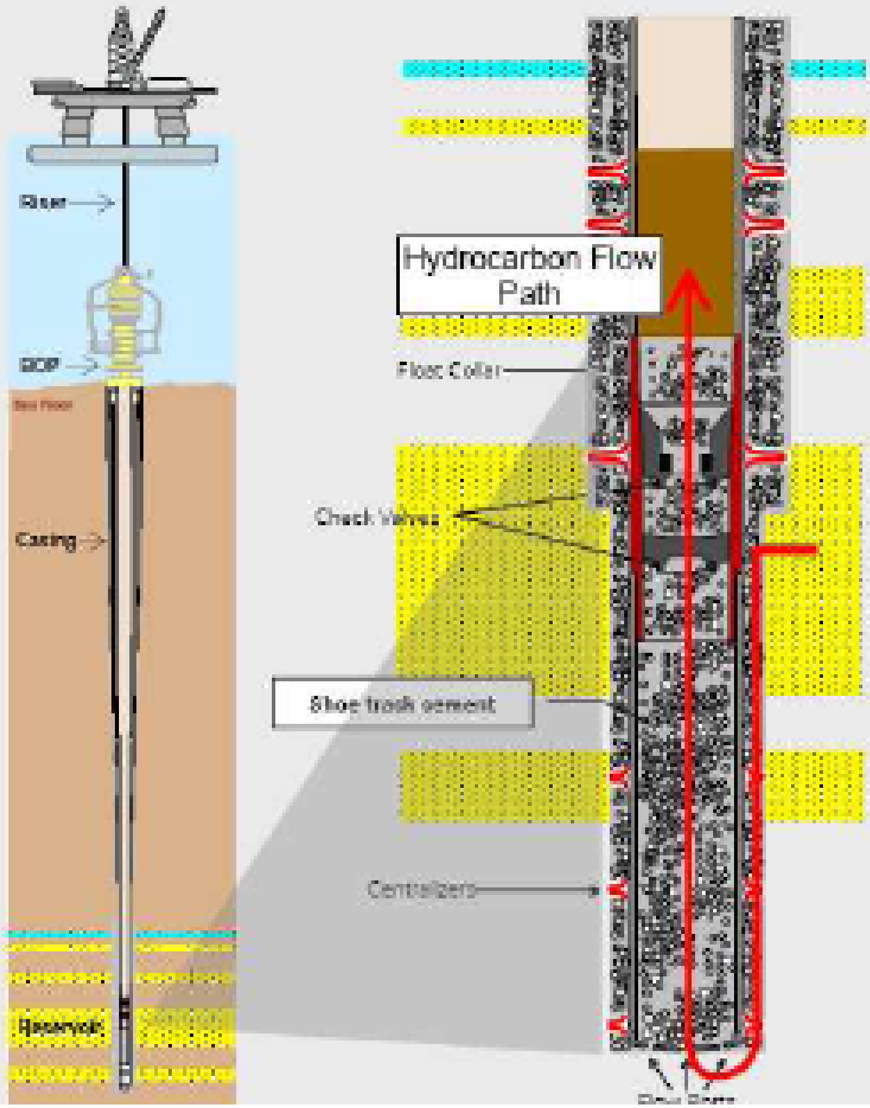



| Casing shoe failure | Key observations for flow through shoe vs seal assembly | Seal assembly failure |
|---|---|---|
| Y | Mechanical barrier feilure mode identified | Y |
| Y | Realistic net pay assumption | N |
| Y | 1400 psi recorded on drill pipe during negative test at 18:30 | N |
| Y | Ability to flow from 20:58 | N |
| Y | Pressure increase from 21:08 to 21:14 | N |
| Y | Pressure response from 21:31 to 21:34 | N |
| Y | Timing for gas arrival to surface | N |
| Y | Static kill | N |



# Key Finding #2

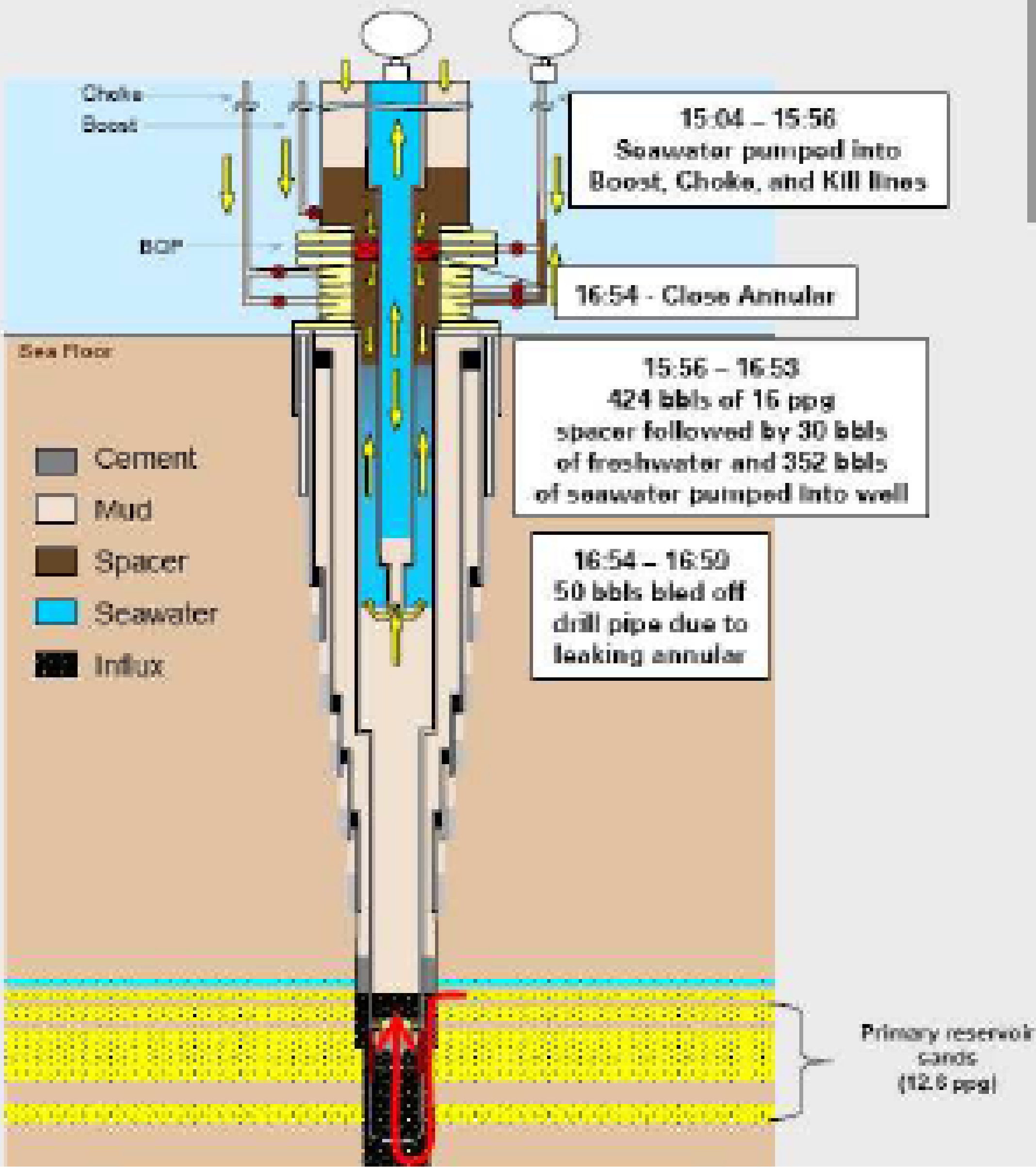
## The shoe track mechanical barriers did not isolate the hydrocarbons




***Tail cement is displaced down the casing into the shoe track. The tail cement is designed to prevent flow from the annulus into the casing. The float collar valves, which provide a second barrier, must close and seal to prevent flow up the casing.***

- Shoe track had two types of mechanical barriers: cement in the shoe track and the double check valves in the float collar
- Shoe track cement failed to act as a barrier due to contamination of the base slurry by break out of nitrogen from the foam slurry
- Hydrocarbon influx was able to bypass the float collar check valves due to either:
    - Valves failed to convert or
    - Valves failed to seal
- Flow through shoe confirmed by fluid modeling and Macondo static kill data

# Negative Pressure Test



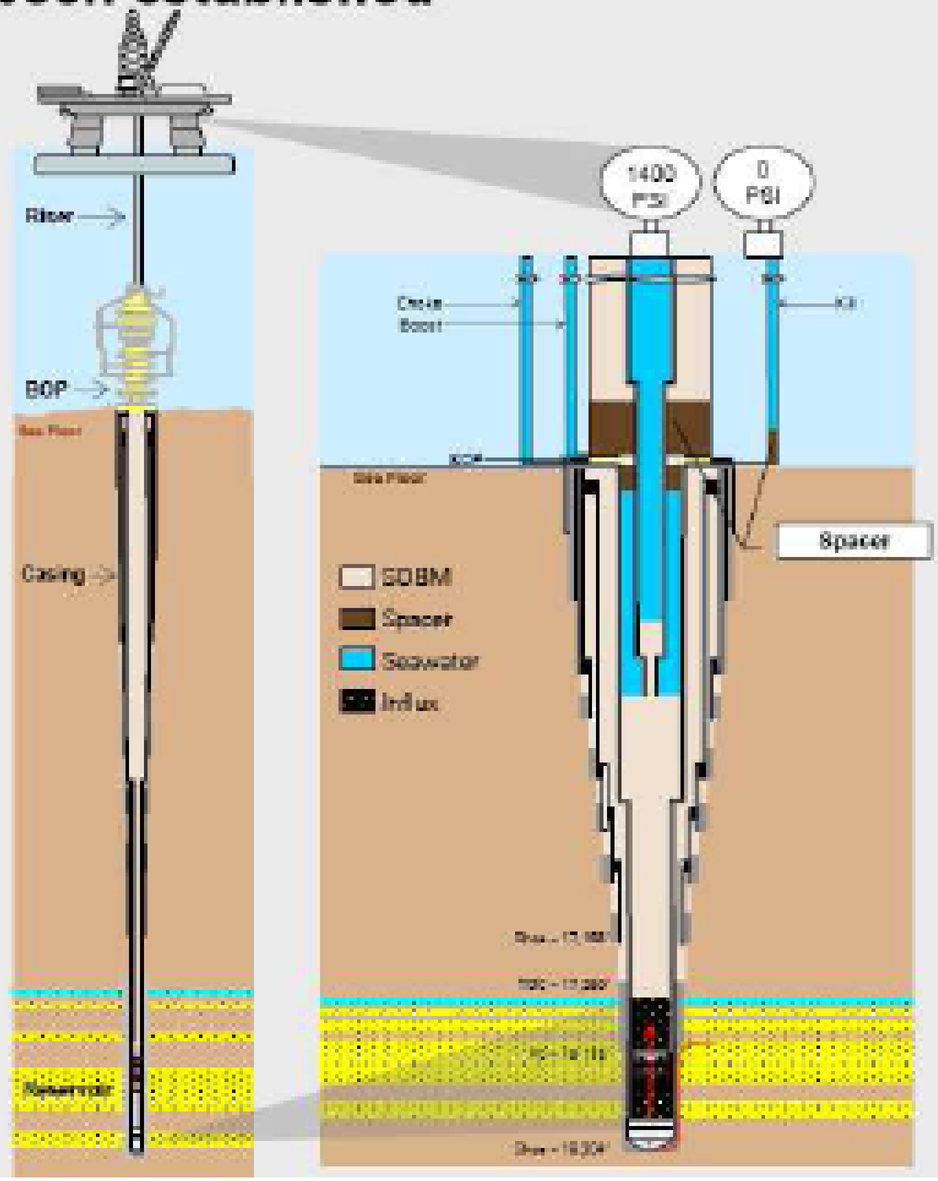

***The negative-pressure test checks the integrity of the shoe track, casing and wellhead seal assembly. This simulates conditions during temporary abandonment when a portion of the well is displaced to seawater.***

**April 20th 15:04 – 19:55**

- Negative test simulates underbalanced condition
- Spacer used between mud and seawater
- Leaking annular at start of test moved spacer across kill line inlet
- Negative test started on drill pipe but changed to kill line
- Bleed volumes higher than calculated
- Drill pipe built pressure to 1400 psi with no flow on the kill line

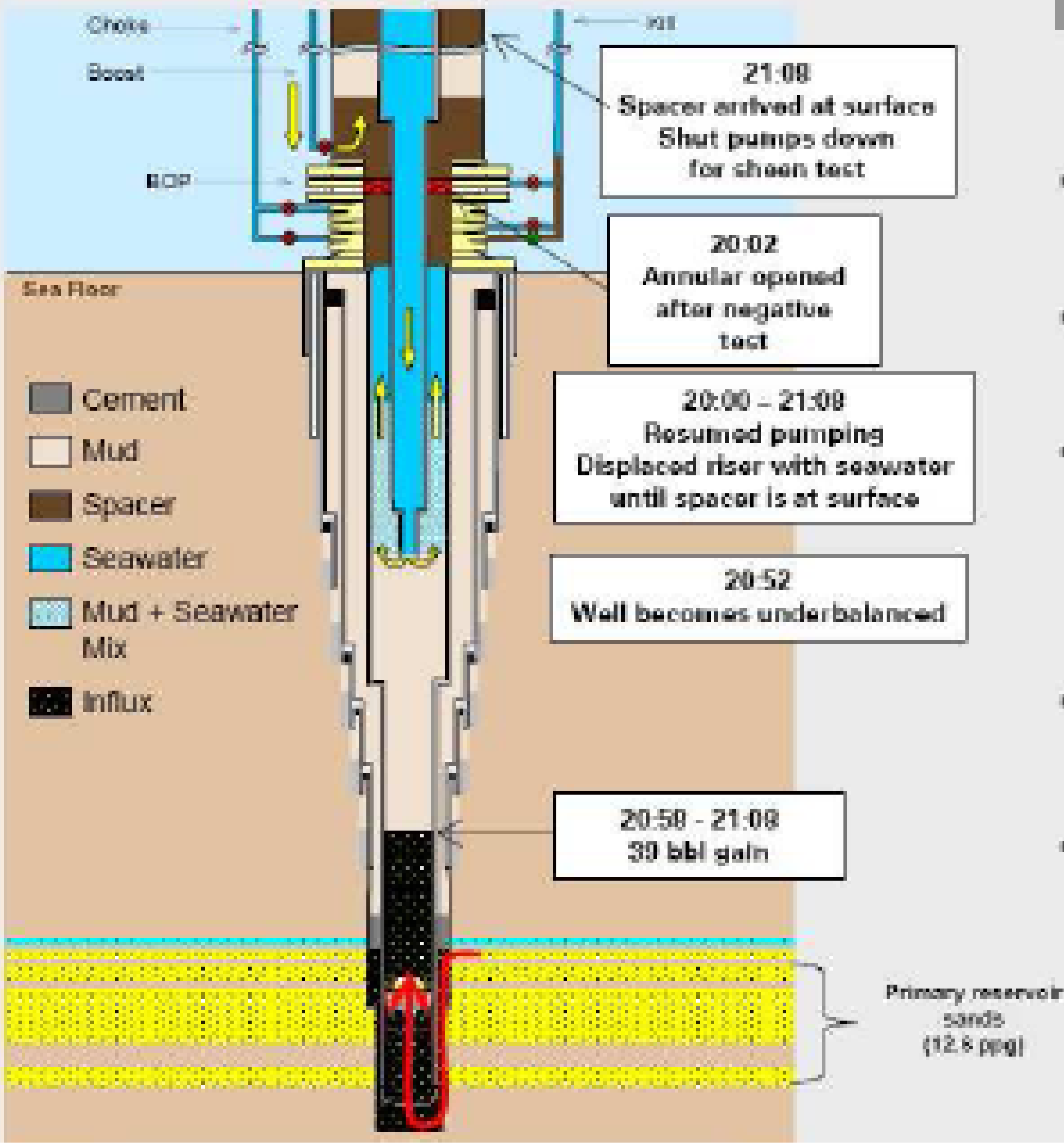
# Key Finding #3

## The negative pressure test was accepted although well integrity had not been established




- Bleed volumes not recognized as a problem
- Anomalous pressure on drill pipe with no flow from kill line
- Test incorrectly accepted as successful
- Negative testing not standardized

# Undetected Flowing Conditions



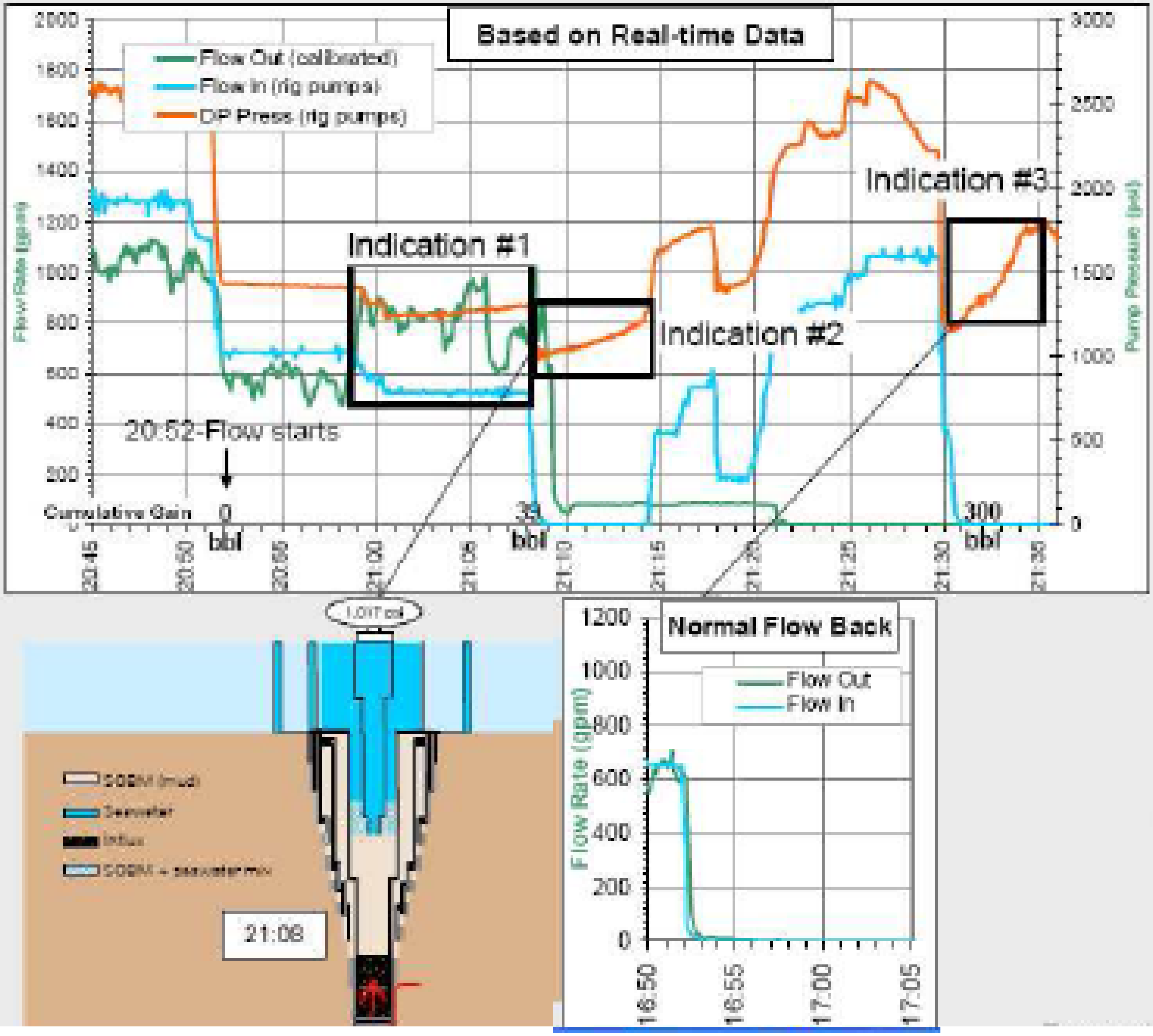

***Mud in the riser is displaced with seawater in preparation for temporary abandonment.***

**April 20th 19:55 – 21:14**

- 20:02 Resume displacement of mud with seawater
- 20:52 Well becomes underbalanced and starts to flow
- After 20:58 gain being taken and pressure begins increasing
  - Flow from well masked by emptying of trip tank
- 21:08 Pumping stops for sheen test
  - Pressure increases with pump off
- 21:14 Sheen test complete, displacement resumes

# Key Finding #4

## The influx was not recognized until hydrocarbons were in the riser



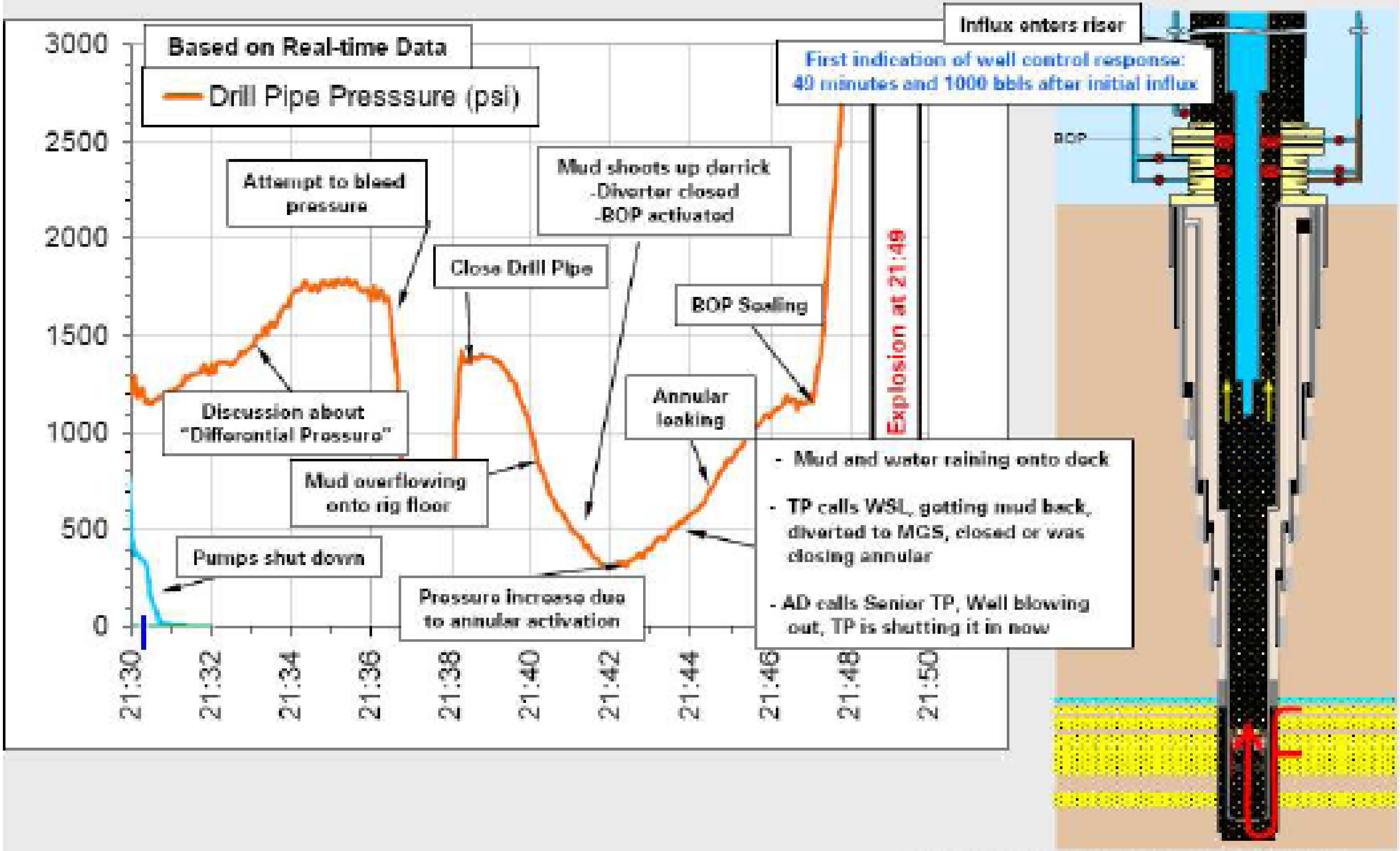

**Flow indications:**

- #1: Drill pipe pressure increased by 100 psi. (expected decreased); ~39 bbl gain from 20:58 to 21:08
- #2: Drill pipe pressure increased by 246 psi with pumps off
  - Flow out does not immediately drop after shutting down pump
- #3: Drill pipe pressure increased by 556 psi with pumps off; ~300 bbl gain

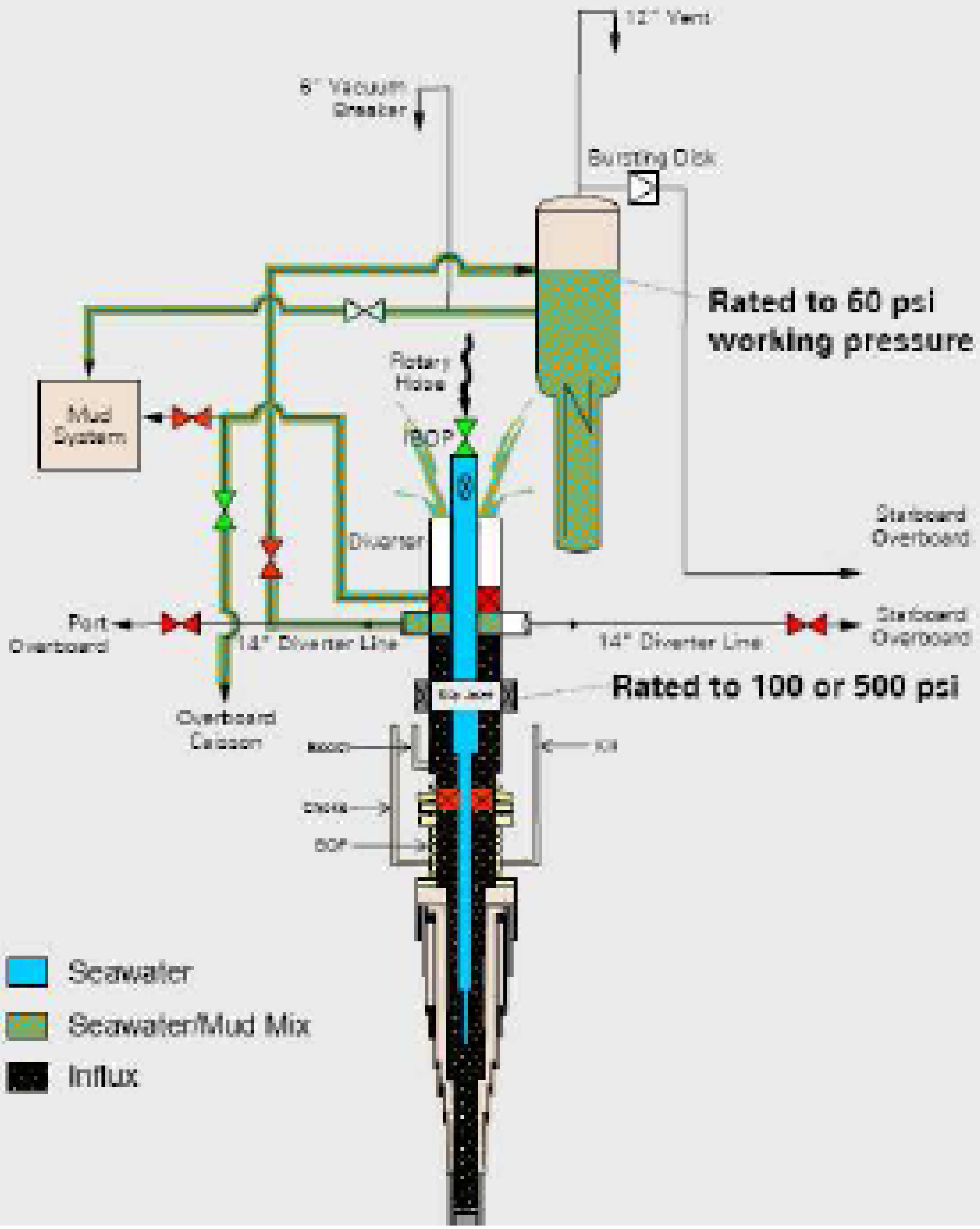
- No well control actions taken

# Key Finding #5

## Well control response actions failed to regain control of the well



# Diverting to the Mud Gas Separator at about 21:42

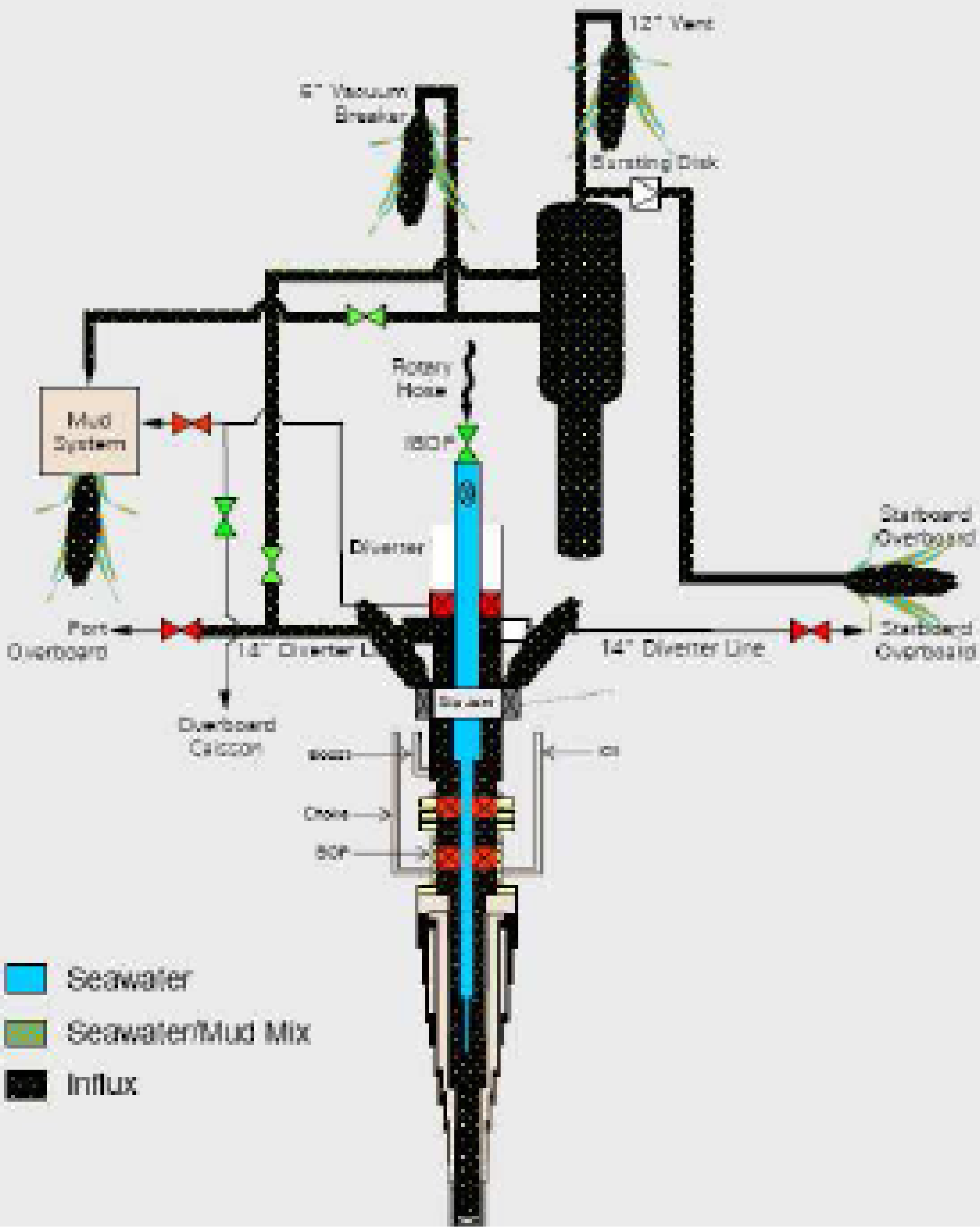



***When responding to a well control event the riser diverter is closed and fluids sent to either the mud gas separator or to the overboard diverter lines.***

**Diversion to the MGS**

- Rig crew has the option to divert flow to port/starboard overboard lines or the MGS
- Diverting to port or starboard will result in fluids venting overboard
- Liquid outlet from MGS goes to the Mud System under the main deck

# Gas flow to Surface at high rate:  21:46 to 22:00



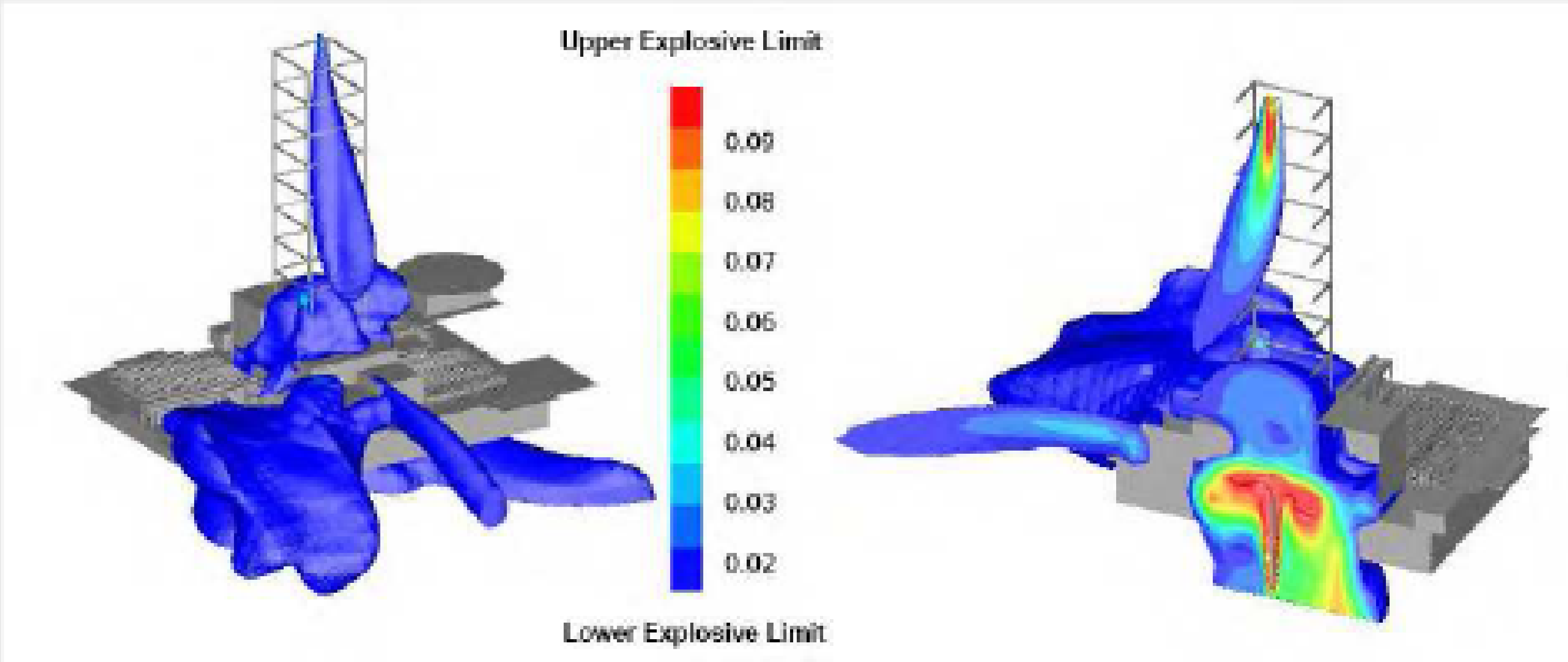

***When responding to a well control event the riser diverter is closed and fluids sent to either the mud gas separator or to the overboard diverter lines.***

**Hydrocarbon flow from surface equipment**

- Instantaneous gas rates reached 165 mmscfd
- Pressures exceeded operating ratings (above 100 psi)
- Gas would probably have vented from:
  - Slip joint packer into the moon pool
  - 12" MGS "gooseneck" vent
  - 6" MGS vacuum breaker vent
  - 6" overboard line through burst disk
  - 10" mud line under the main deck

# Gas Dispersion across the Deepwater Horizon 21:46 to 21:50 hrs

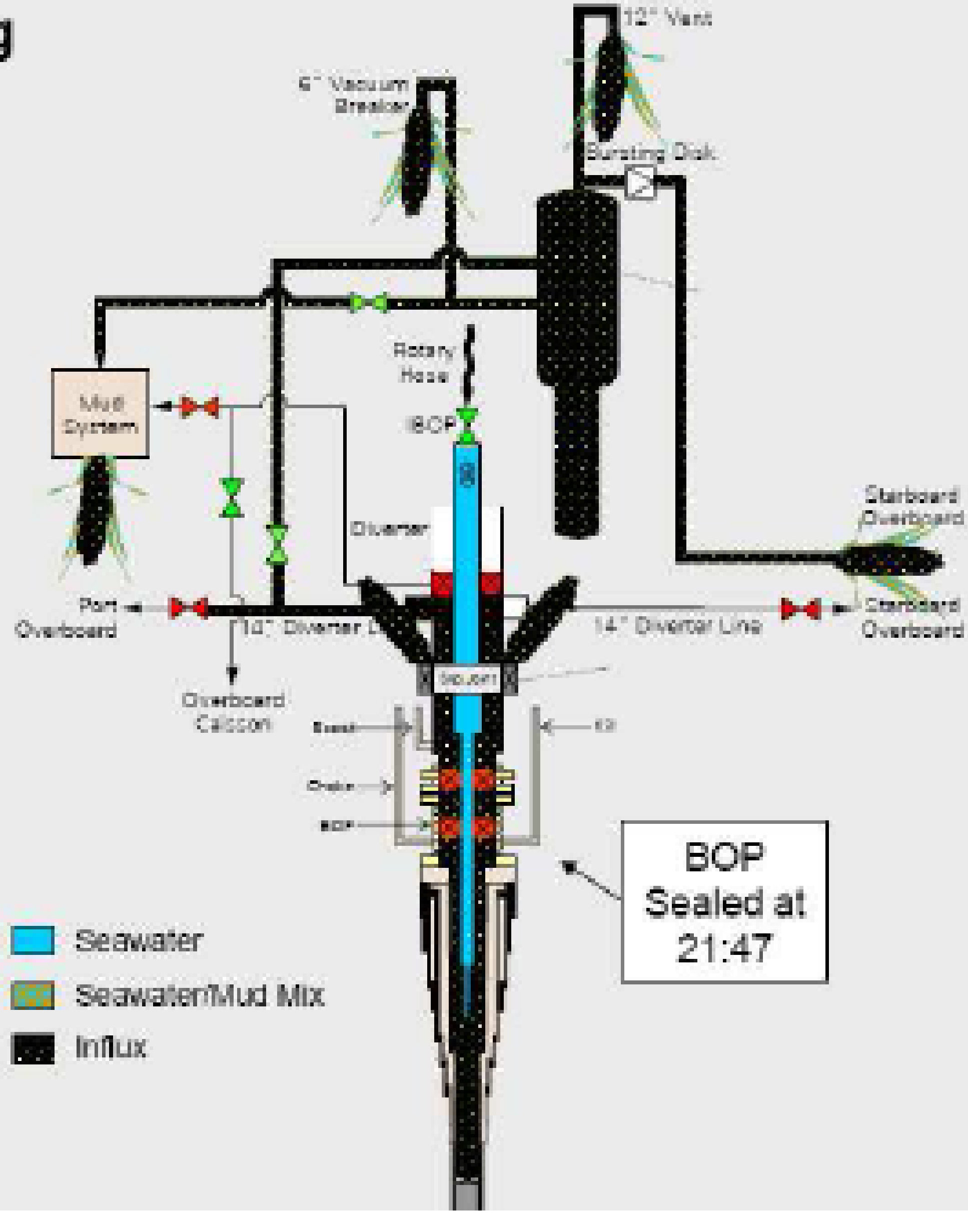
*Animation of Gas Dispersion*




| *3D View* | *Cut Section Through Derrick Towards Aft* |
|---|---|

# Key Finding #6

## Diversion to the mud gas separator resulted in gas venting onto the rig

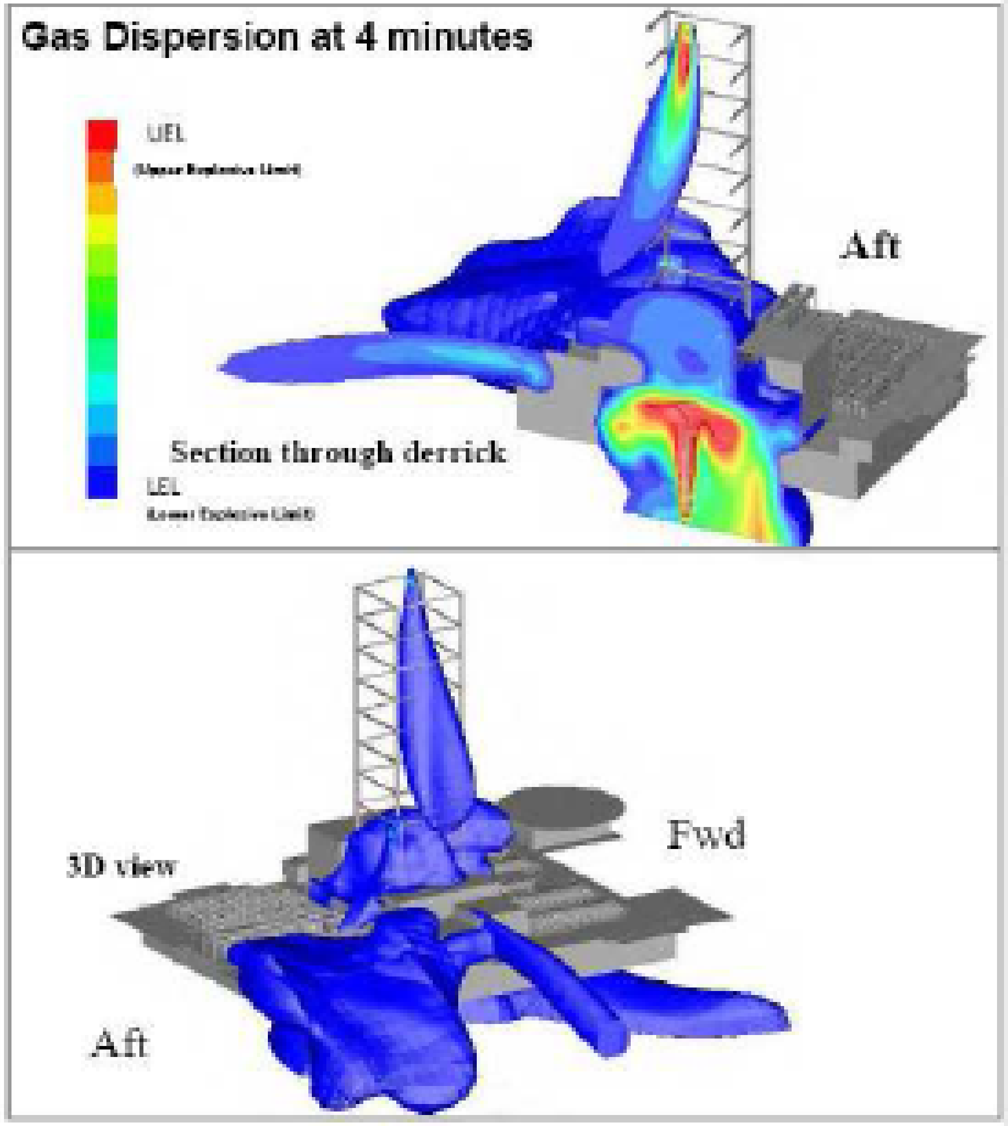



***When responding to a well control event the riser diverter is closed and fluids are sent to either the mud gas separator or to the overboard diverter lines.***

- Hydrocarbons were routed to the mud gas separator instead of diverting overboard
- Resulted in rapid gas dispersion across the rig through the MGS vents and mud system

# Key Finding #7

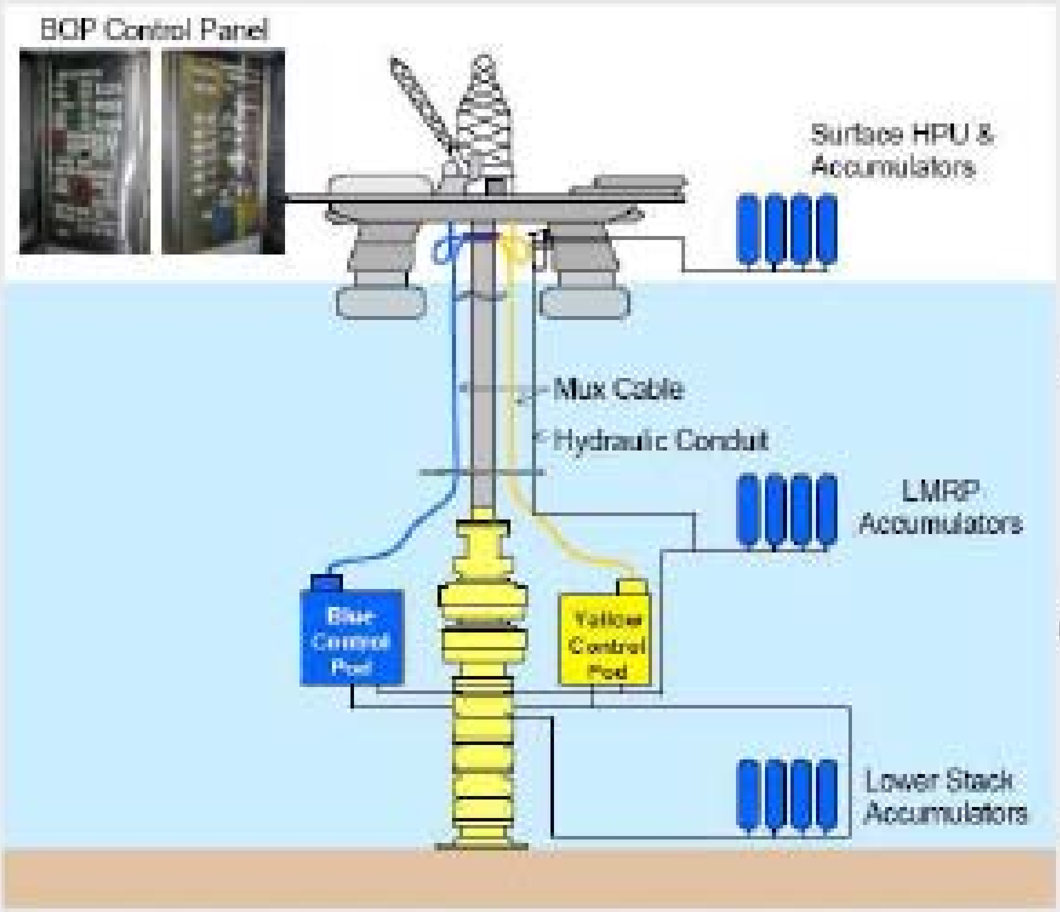
## The fire and gas system did not prevent hydrocarbon ignition

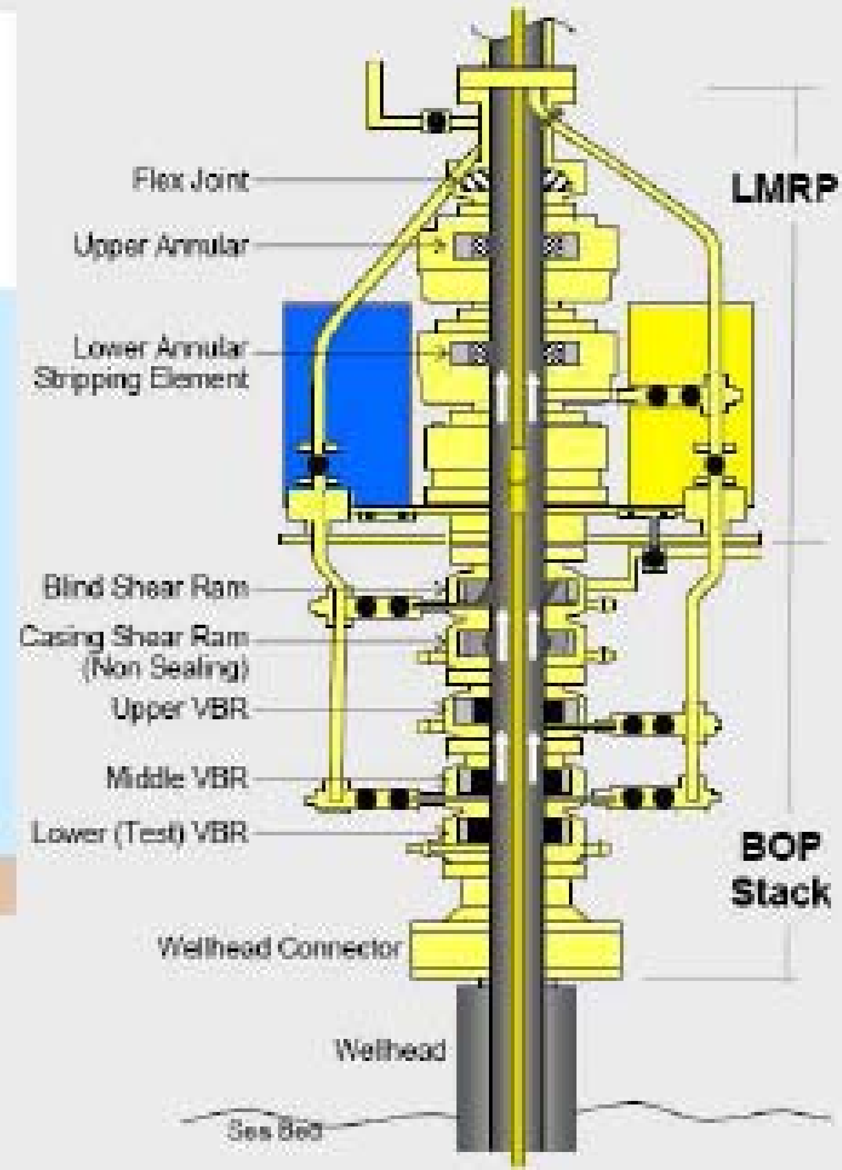



***Secondary protective systems are designed to reduce the potential consequence of an event once the primary protective systems have failed.***

- Gas dispersion beyond electrically classified areas
- Gas ingress into engine rooms via main deck air intakes
- The on-line engines were one potential source of ignition

# Blowout Preventer (BOP)

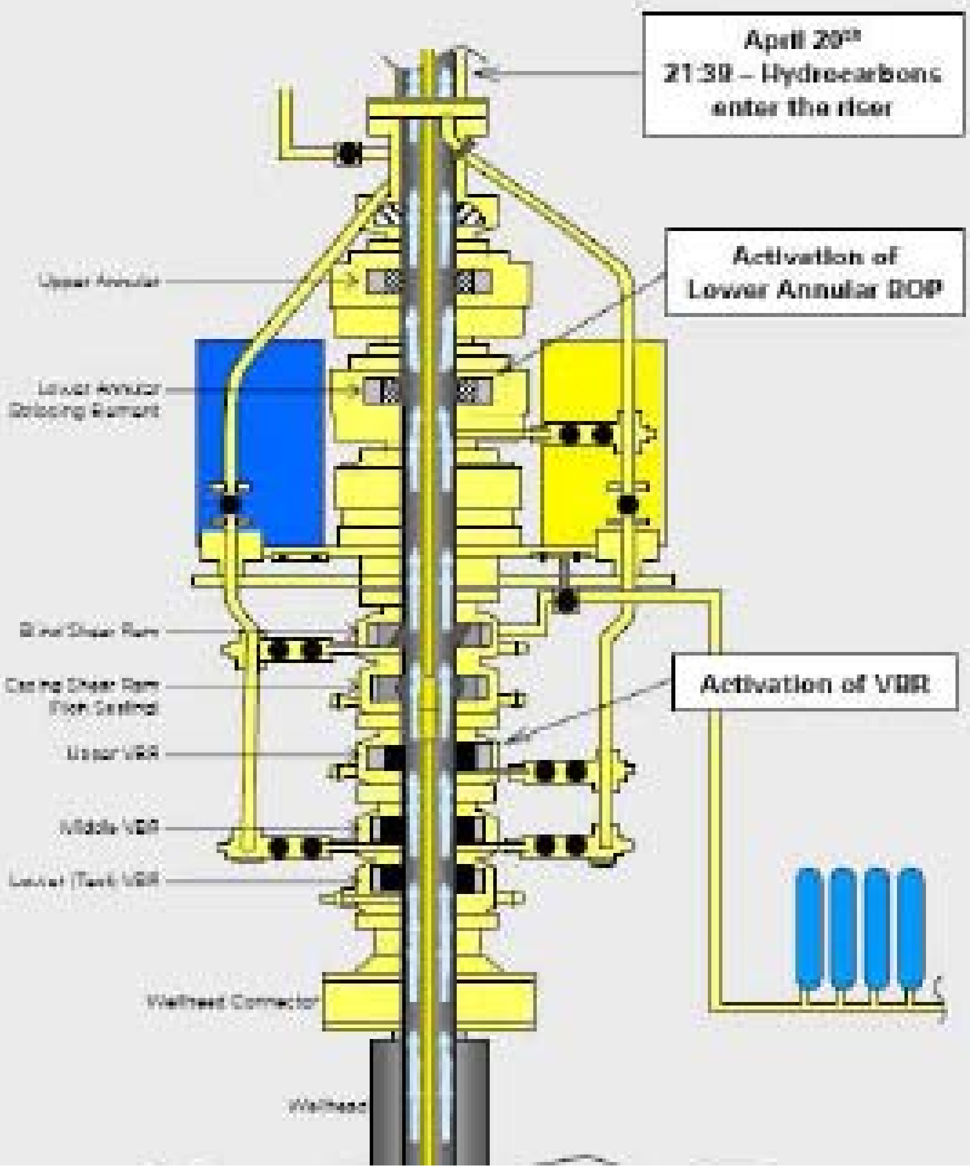



**Emergency Methods of BOP Operation Available on DW Horizon**

| Manual | Automatic | ROV Intervention |
|---|---|---|
| EDS<br>HP BSR Close | AMF | HOT Stab<br>AMF<br>Auto-shear |

# BOP Response (Before the Explosions)

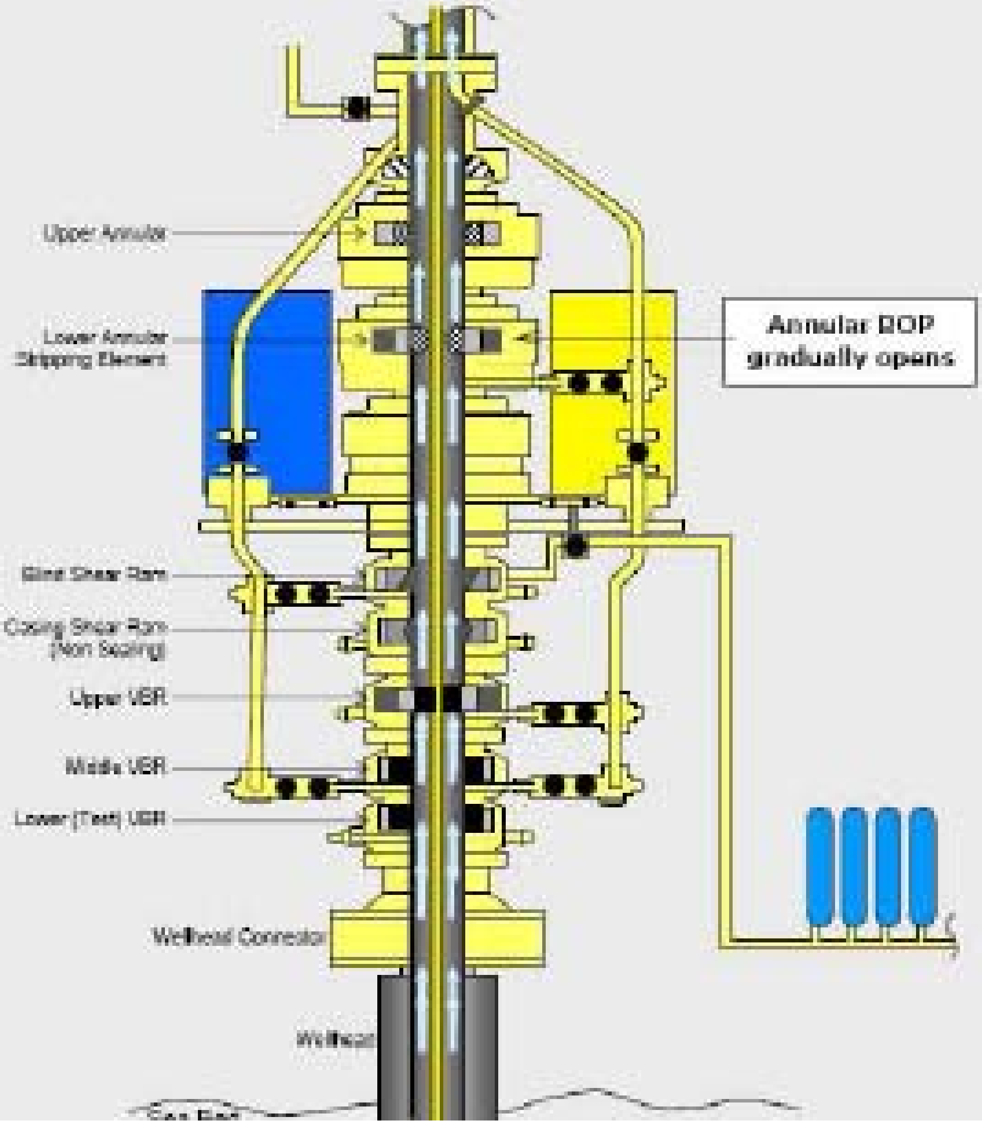



***BOP is designed to seal the wellbore and shear casing or drill pipe if necessary.***

**April 20th**

- 21:41 annular BOP closed but appears not to have sealed the annulus
- 21:47 a VBR likely closed and sealed the annulus

# BOP Response (Impact of Explosions)

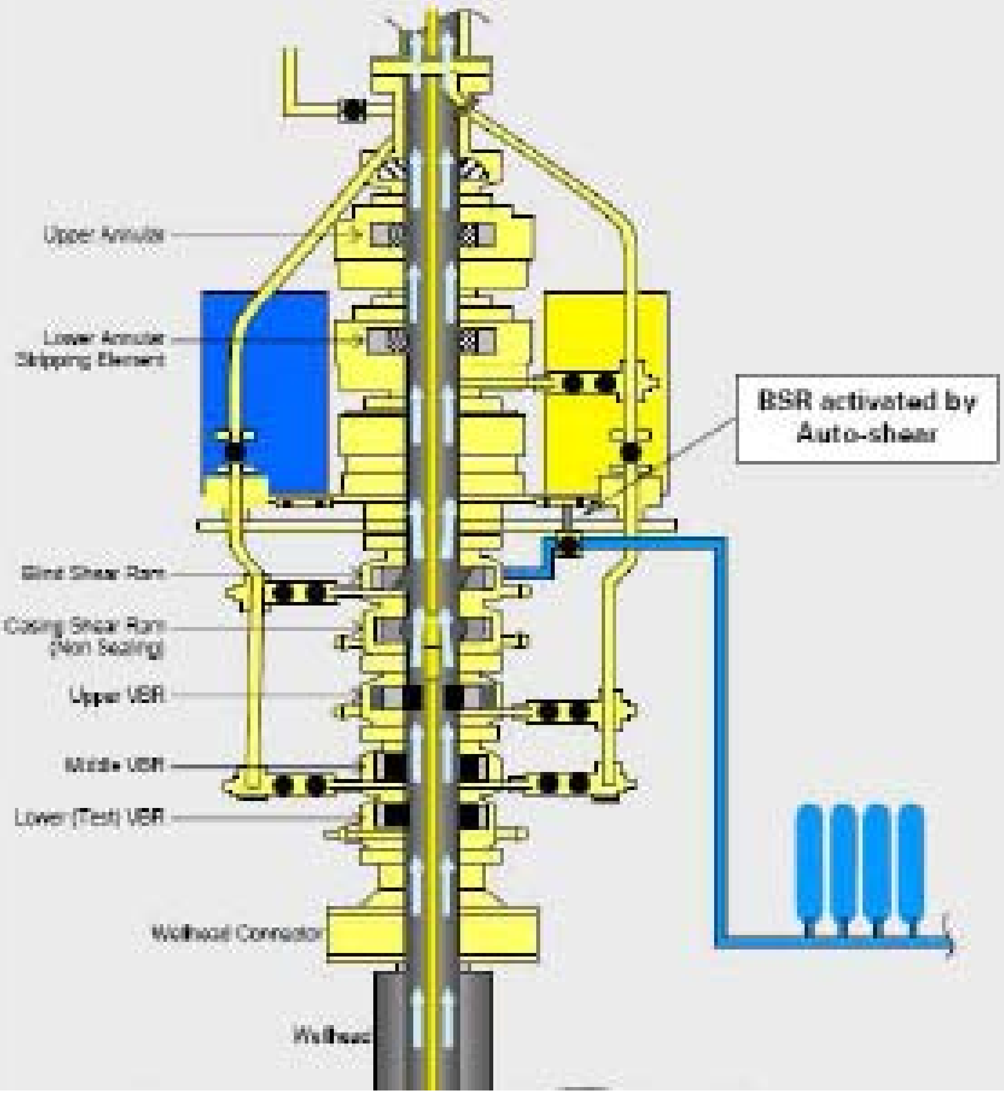



***MUX cables provide electronic communication and electrical power to the BOP control pods.***

**April 20th**

- Damage to MUX cables and hydraulic line
  - Opening of annular BOP
- Rig drifted off location
  - Upward movement of the drill pipe in the BOP

# BOP Response (After the Explosions)




***There are several emergency methods of activating the BSR to seal the well.***

**April 20th**

- EDS attempts failed to activate BSR
- AMF sequence likely failed to activate BSR

**April 21st – 22nd**

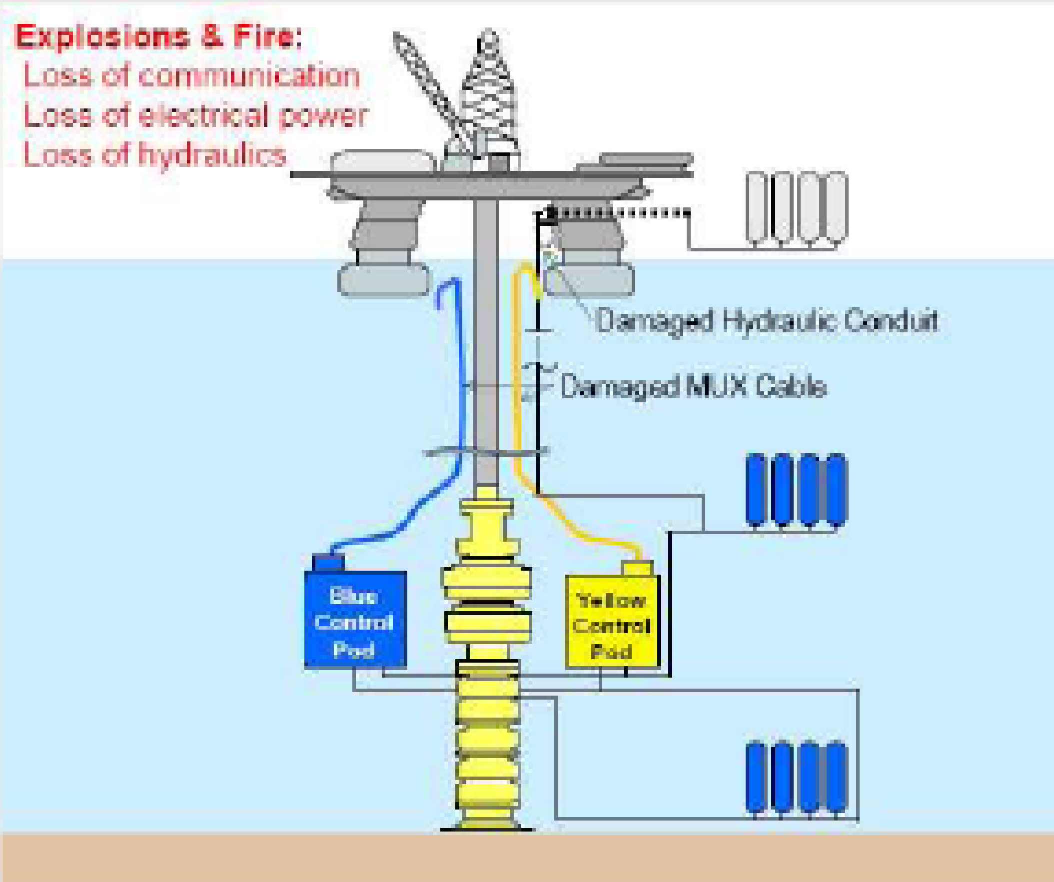
- ROV hot stab attempts to close BOP were ineffective
- ROV simulated AMF function likely failed to activate BSR
- ROV activated auto-shear appears to have activated but did not seal the well

**April 25th – May 5th**

- Further ROV attempts using seabed deployed accumulators were unsuccessful

# Key Finding #8

## The BOP emergency mode did not seal the well




**Emergency Methods of BOP Operation Available on DW Horizon**

| Manual | Automatic | ROV Intervention |
|---|---|---|
| EDS<br>HP BSR Close | AMF | HOT Stab<br>AMF<br>Auto-shear |

***The AMF provides an automatic means of closing the BSR without crew intervention.***

- EDS function was inoperable due to damage to MUX cables
- AMF could not activate the BSR due to defects in both control pods
- Auto-shear appears to have activated the BSR but did not seal the well
- Potential weaknesses found in the BOP testing regime and maintenance management systems

# Recommendations

- BP Drilling Operating Pratice and Management Systems
  - Engineering technical practices and procedures
  - Further enhance deepwater capability and proficiency
  - Strengthen rig audit action closeout and verification
  - Introduce integrity performance management for drilling and wells activities

- Contractor and service provider oversight and assurance
  - Cementing services
  - Drilling contractor well control practices and proficiency
  - Oversight of rig safety critical equipment
  - BOP configuration and capability
  - BOP minimum criteria for testing, maintenance, system modifications and performance

# Thanks!

# Questions?