



# Reservoir Pressure Response

8-July-2010



# Outline

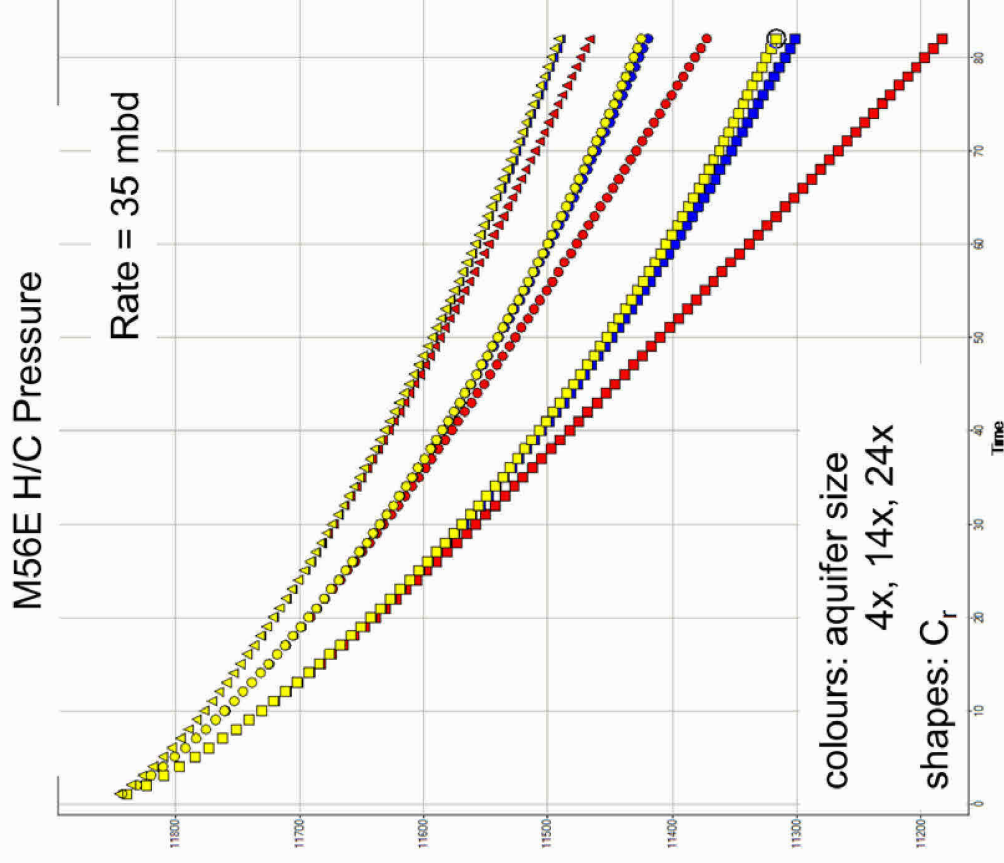


- Modelling used preliminary slab model
  - Structural model incomplete Wed. evening
  - PIE used to cross-check
- Fixed Parameters:
  - M110 Size (45 mmrb)
- Sensitivity Parameters:
  - Aquifer: **3.8x**, 13.7x, 24x (larger aquifers with some K red'n)
  - Cr: 6, **12**, 18  $\mu$ sips
  - Oil Rate: 35, 50, 60 mbd
  - Skin: 0, 10, 20
  - Xflow 0, ??, ?? rb/d (approximate, controlled with skin)

# Depletion



- Aquifer Impact (referenced to 4x Aquifer, 6  $\mu$ sips, @35 mbd)
  - No Aquifer: -800 psi
  - 13.7x Aquifer +120 psi
  - 24x Aquifer +130 psi
- Compressibility
  - 12  $\mu$ sips +200 psi
  - 18  $\mu$ sips +300 psi
- S.I. BHP Range (M56E, @5 hrs)
  - Near well: 7,900 - **11,030** - 11,120
  - Reservoir: 9,360 - **11,360** - 11,590
  - Recommend: new “most likely” : 3.8x aquifer, 12  $\mu$ sips, 35 mbd



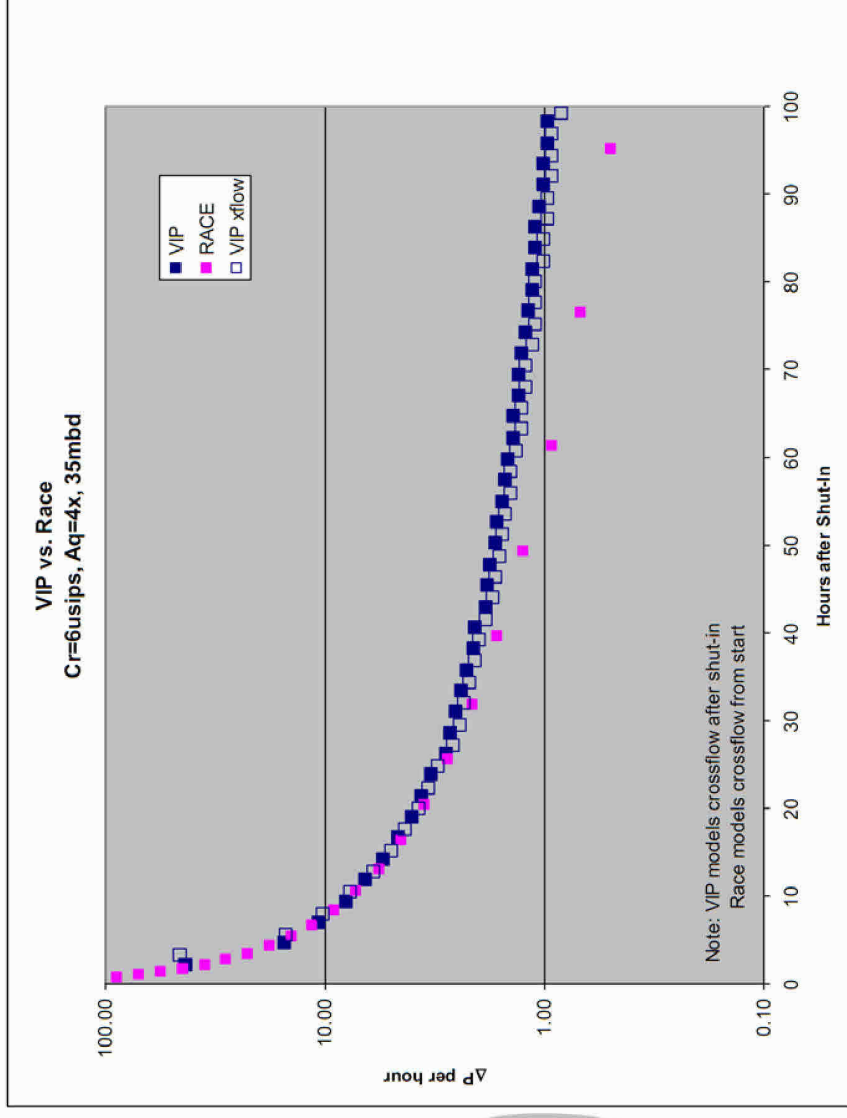
note: values reflect additional 15 days of depletion

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# Post Shut-In Behaviour



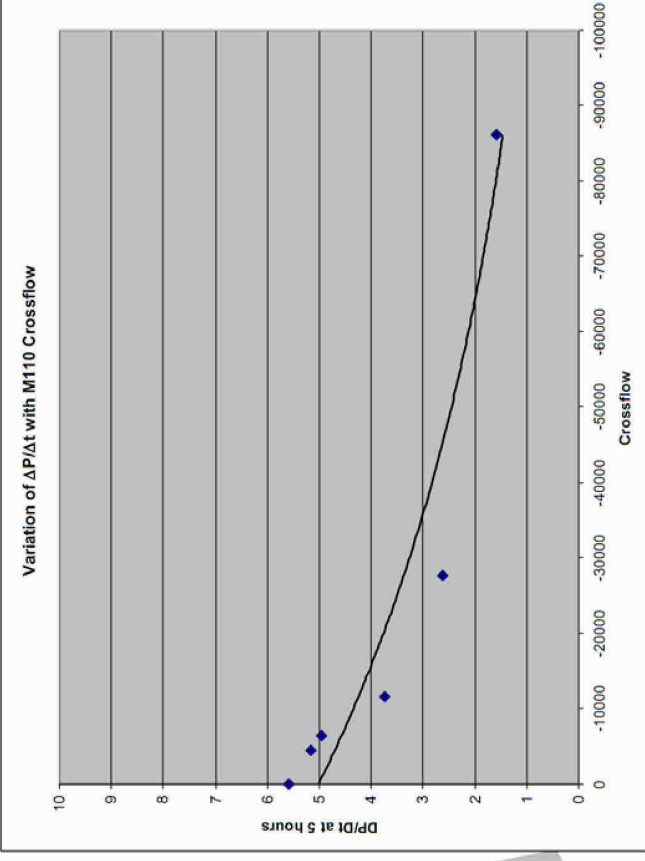
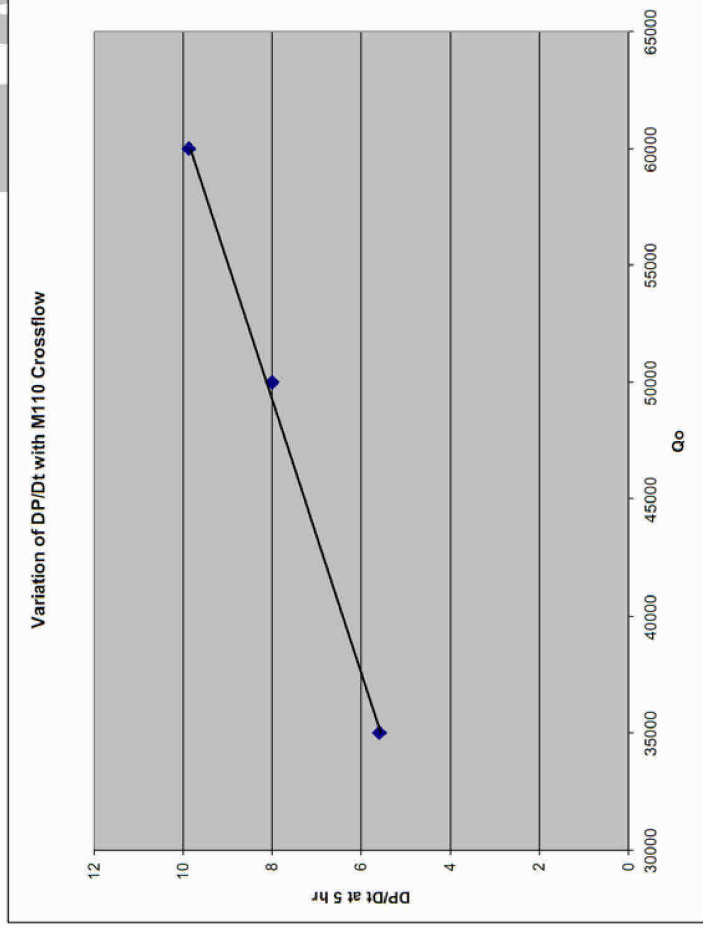
- Bottomhole pressure changes very rapidly for first 3 hours
  - $\Delta P/\Delta t > 30,000$  psi/hr
- Differences
  - Layer crossflow
    - 2 layers v. many
  - Solution method & timesteps
- Similar solutions during critical period ( $5 < t < 100$  hrs)



# Variation of DP/Dt with Parameters: $Q_o$ & Xflo



$\Delta P/\Delta t$  of ~5 - 10 psi/hour for rates between 35 & 60 mbd at 5 hours of shut-in



$\Delta P/\Delta t$  of ~1-3 psi/hour for crossflow between 0 & 30 mbd at 5 hours of shut-in

## $\Delta P/\Delta t$ at 5 hours




- Inensitive to:
  - Aquifer (1 psi/hr)
  - Compressibility (1 psi/hr)
- Largest sensitivities:
  - Crossflow
  - Average production rate
  - Sensitivity to  $Q_o > X_{f10}$

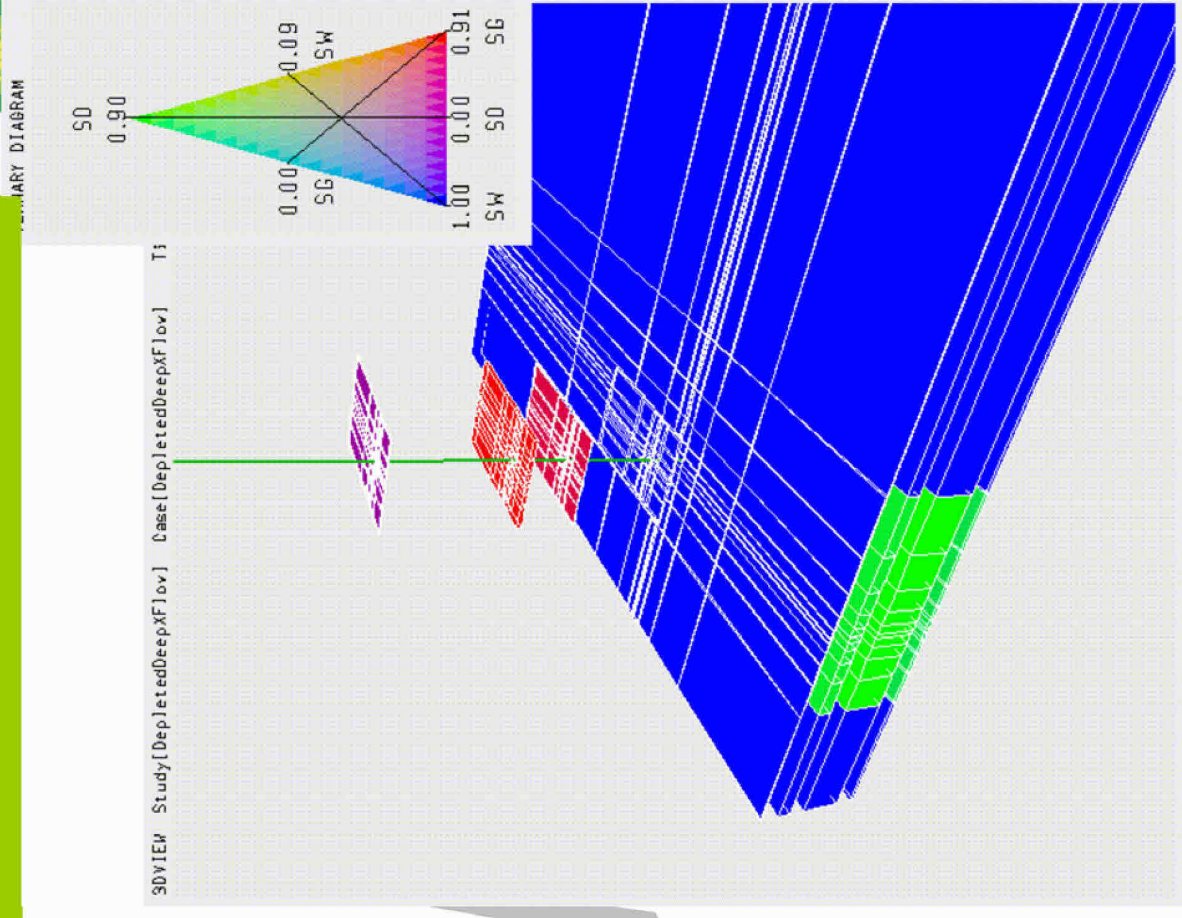
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# Input Data

- Data provided by GoMx Reservoir Team
- Rock Properties
  - Developed from MC252 logs
  - Permeability
    - 275 mD in main M56E sand
    - 397 mD in M56A gas/oil sand (only 2.5')
    - 86 – 110 mD in other oil sands
  - Compressibility:
    - Cr:  $6 \times 10^{-6} \text{ psia}^{-1}$
    - Cw:  $3 \times 10^{-6} \text{ psia}^{-1}$
    - Cf:  $\sim 13 \times 10^{-6} \text{ psia}^{-1}$
  - Fluid properties generated by EoS; volatile, near critical fluid
- tubing performance matched to GAP / Prosper work of T. Liao, A. Chitale & M Gokdemir 

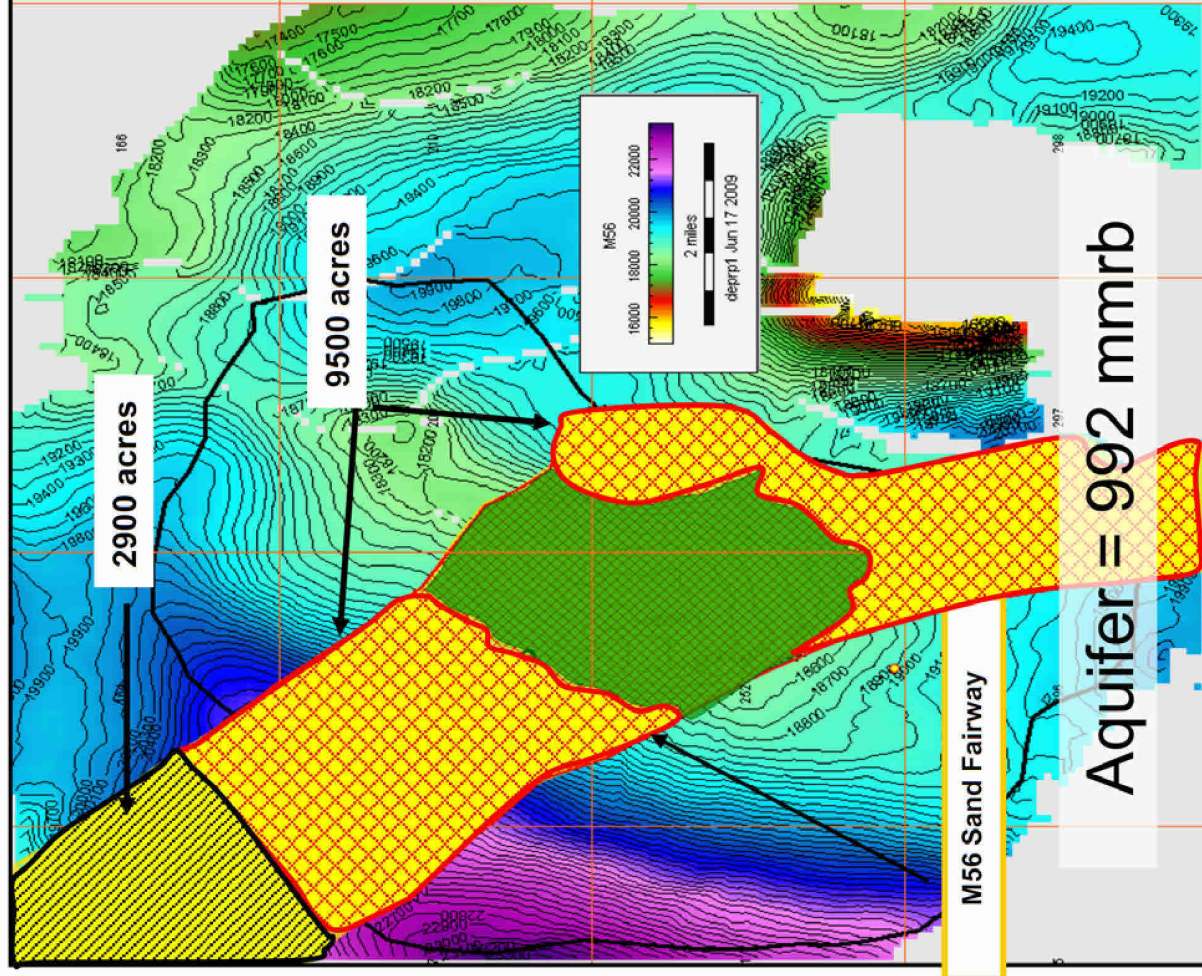




# Macondo RF – Aquifer Size



**Oil Accumulation**  
110 mmstb = 258 mmarb



| 9500 acre Aquifer       |             |              |
|-------------------------|-------------|--------------|
| Net Sand Thickness, ft. | Porosity, % | Aquifer Size |
| 44                      | 13          | 1.5x         |
| 44                      | 17          | 2.0x         |
| 66                      | 17          | 2.9x         |

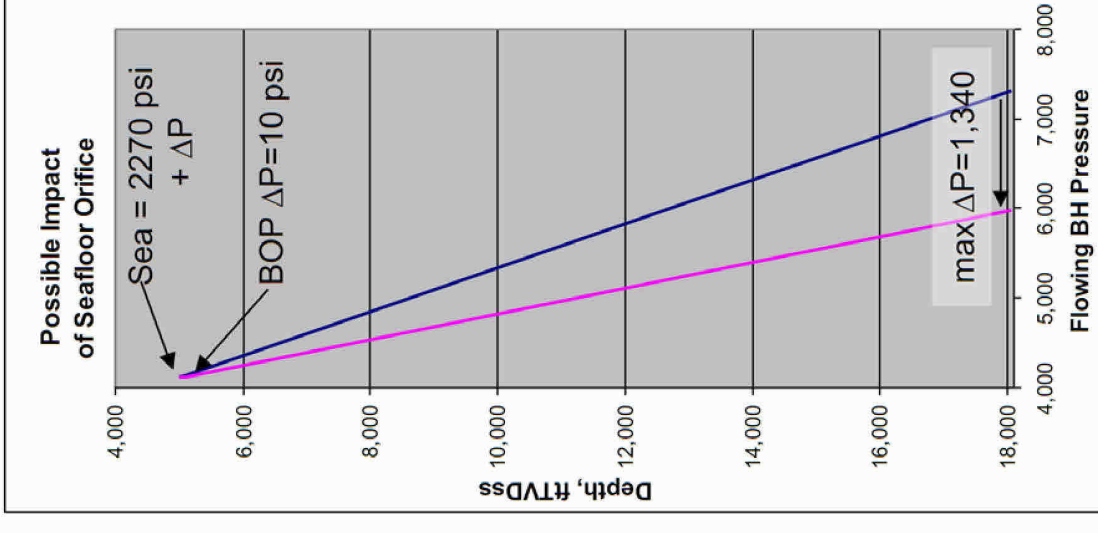
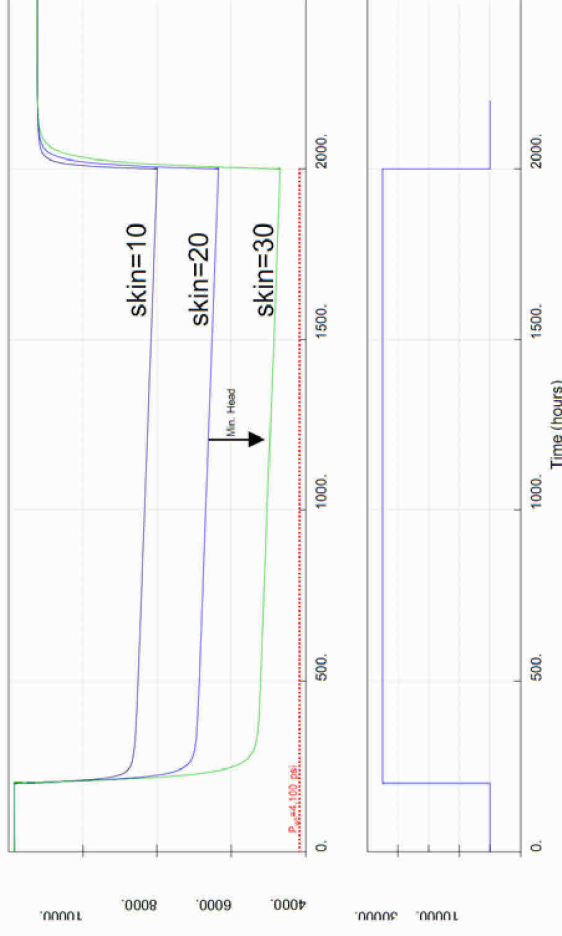
| 12400 acre Aquifer      |             |              |
|-------------------------|-------------|--------------|
| Net Sand Thickness, ft. | Porosity, % | Aquifer Size |
| 44                      | 13          | 1.9x         |
| 44                      | 17          | 2.5x         |
| 66                      | 17          | 3.7x         |

Largest Aquifer Size – used as base case  
(will minimise depletion)

# Depletion Response @wellbore



- PIE gives similar results to VIP
  - Constant compressibility (too low)
  - Single phase
- $P_{wf}$  drops ~8 psi/day (for 35mmbd case)
- Lack of observed depletion could be due to fixed seafloor pressure and large orifice

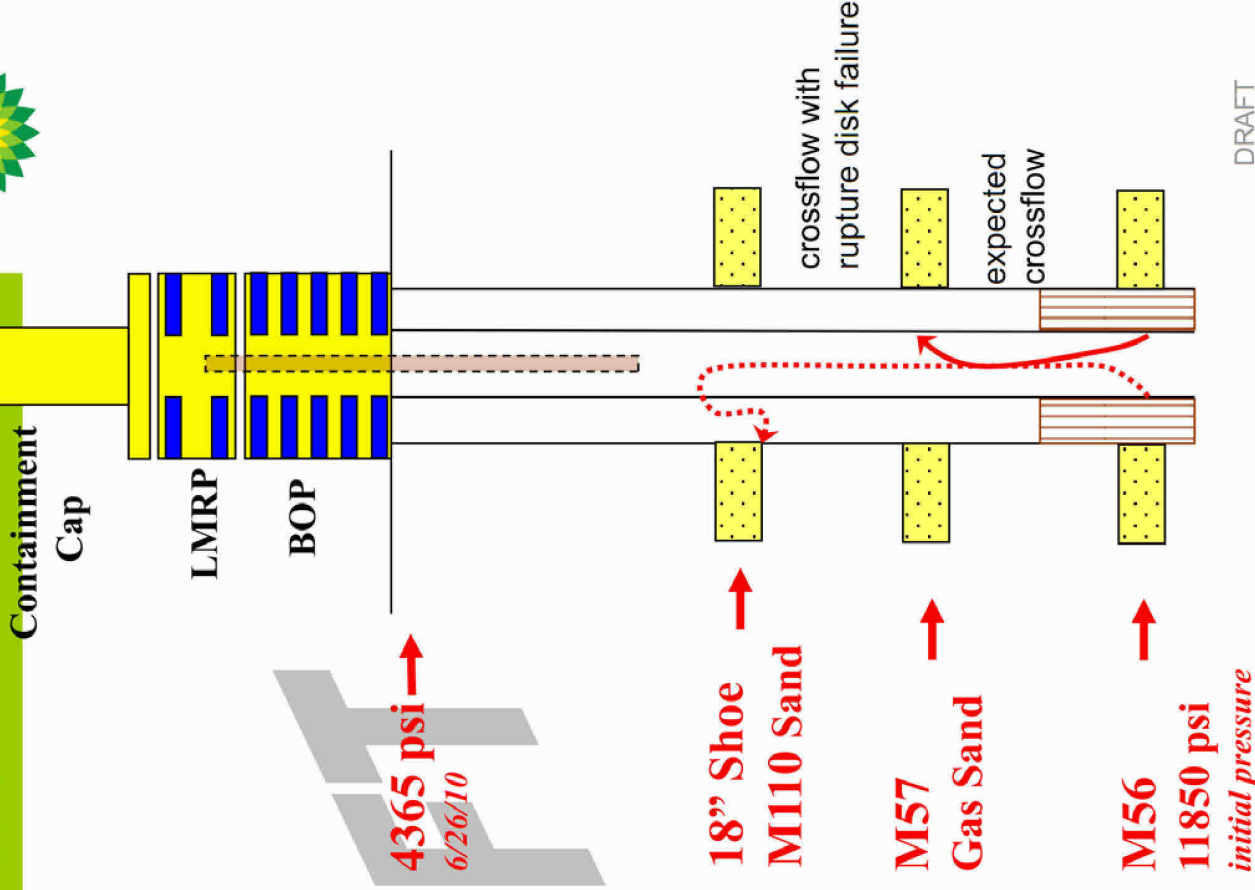


# Conclusions

2270 psi  
ambient



- Actual reservoir depletion dependent on:
  - Flow rate
  - Oil column size
  - Aquifer
- Limited depletion observed in wellhead could be controlled by non-reservoir mechanisms
  - Large orifice
  - Flow path / choke between BOP & reservoir
  - Broken gauge
  - Crossflow
- Largest uncertainties: flow rate and pressure drop

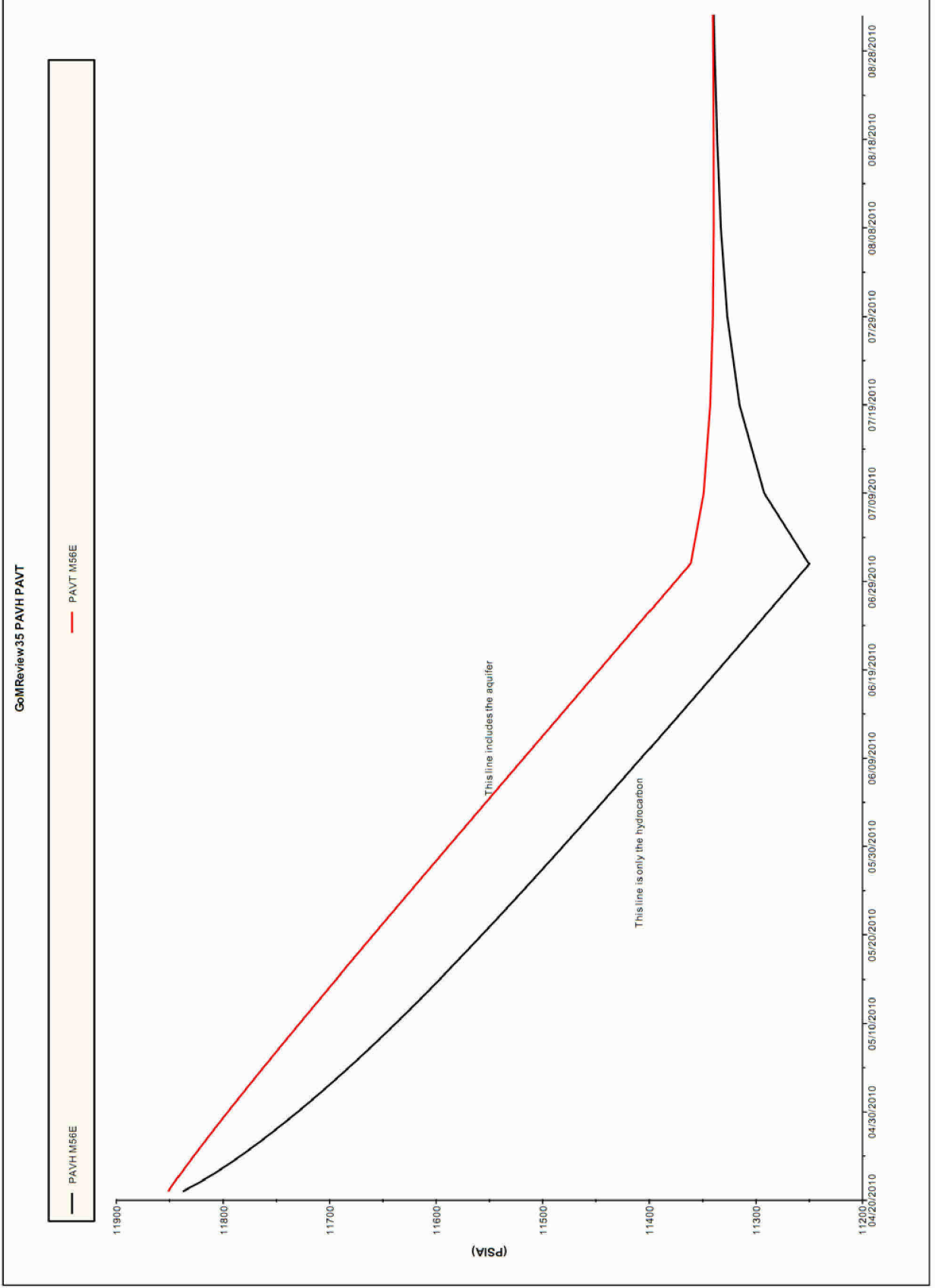


# Back-Up



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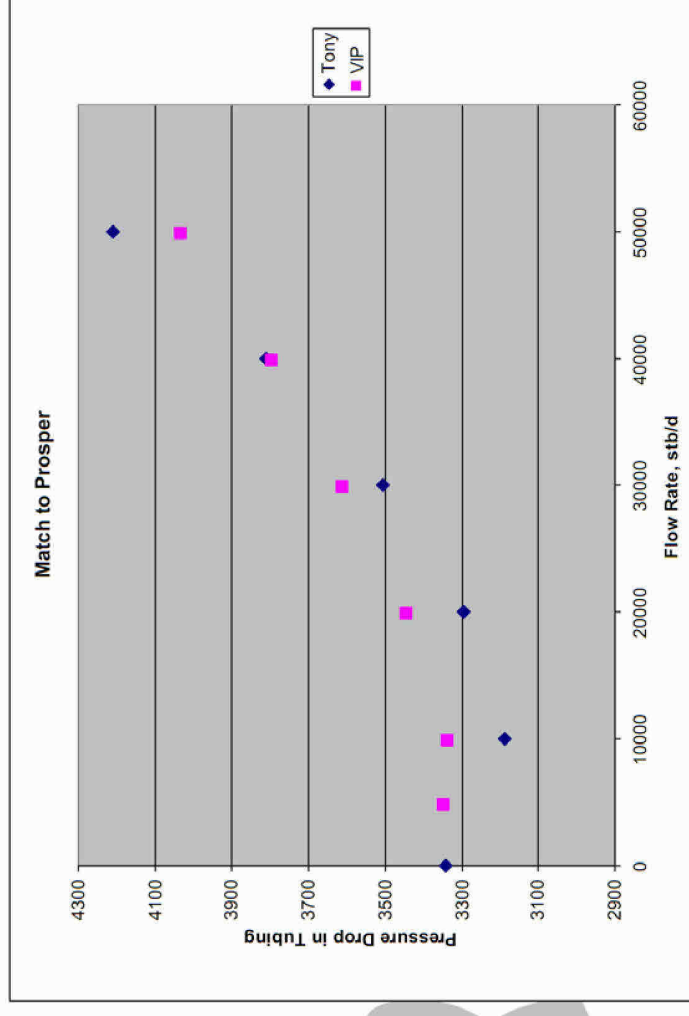
# Difference between Aquifer & H/C Pressure



# Match to “Tubing Performance”



- Flow path is a major (principle?) source of THP uncertainty
- Various cases considered:
  - Annular flow
  - Casing flow
  - Annular + casing flow
- VIP wellbore modelling capability limited in comparison with Prosper / Gap
  - Matched lift with simple tubing string
  - Equivalent diameter & roughness



# Influences on Observable Shut-In Pressure



## At Shut-In

### High Wellhead Pressure

- Limited crossflow
- Well integrity above 18" shoe
  - small leak into small zone
- Large aquifer
- Lower production (higher skin)

### Low Wellhead Pressure

- Integrity failure (crossflow into M 110)
- Smaller aquifer
- Higher production (& lower skin)

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## After Shut-In

### Rising THP

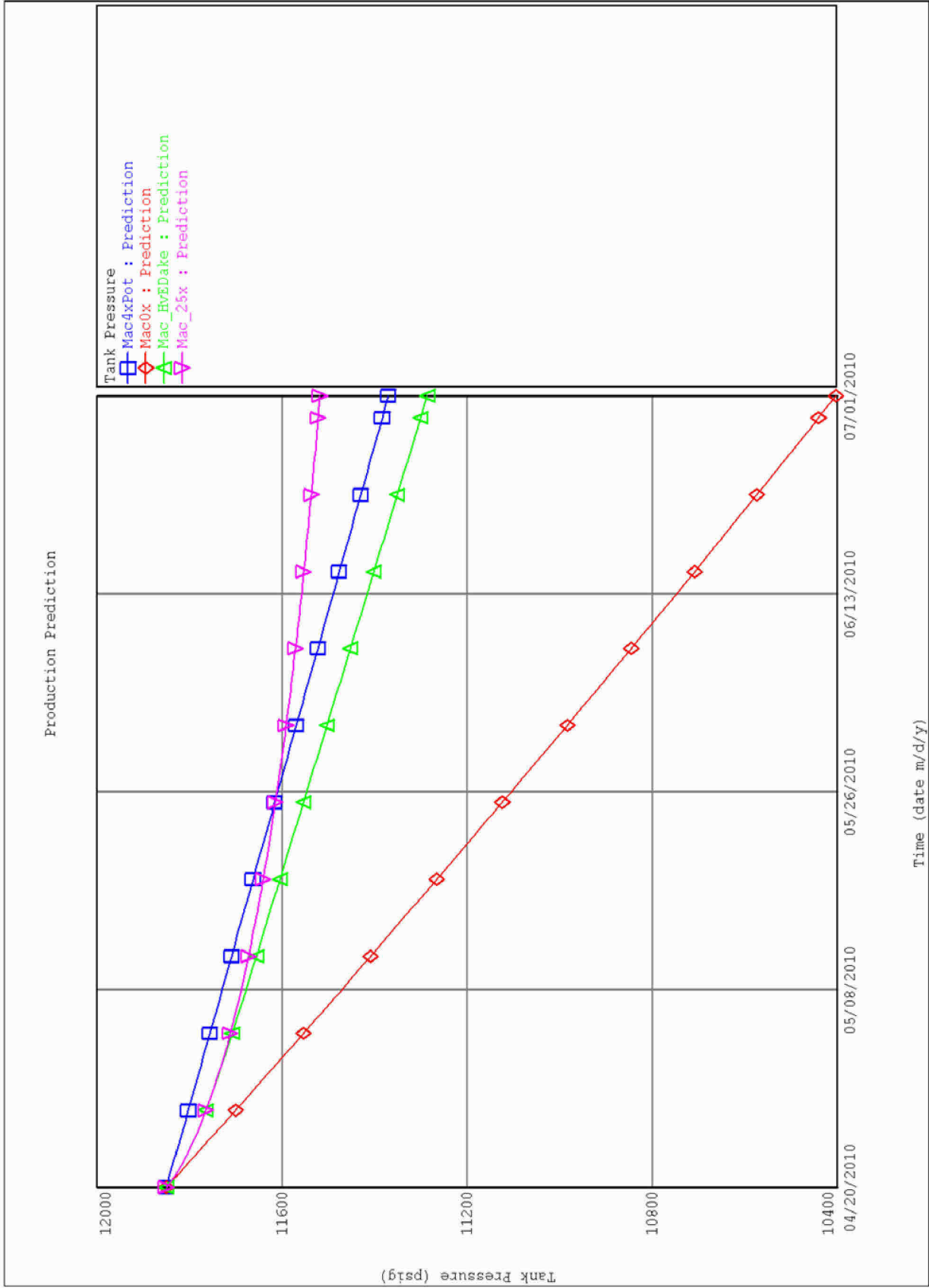
- Fluid Segregation
  - Only if  $P_{thp} < 6,650$ psia
  - Increase would begin at low rates or at flow cessation
- Reservoir Response (radius of investigation)
  - Aquifer size will influence  $P_{final}$
- Cessation of crossflow (pressure equilibration)

### Falling THP

- Wellbore temperature equilibration (cooling)
- Large leak with limited inflow

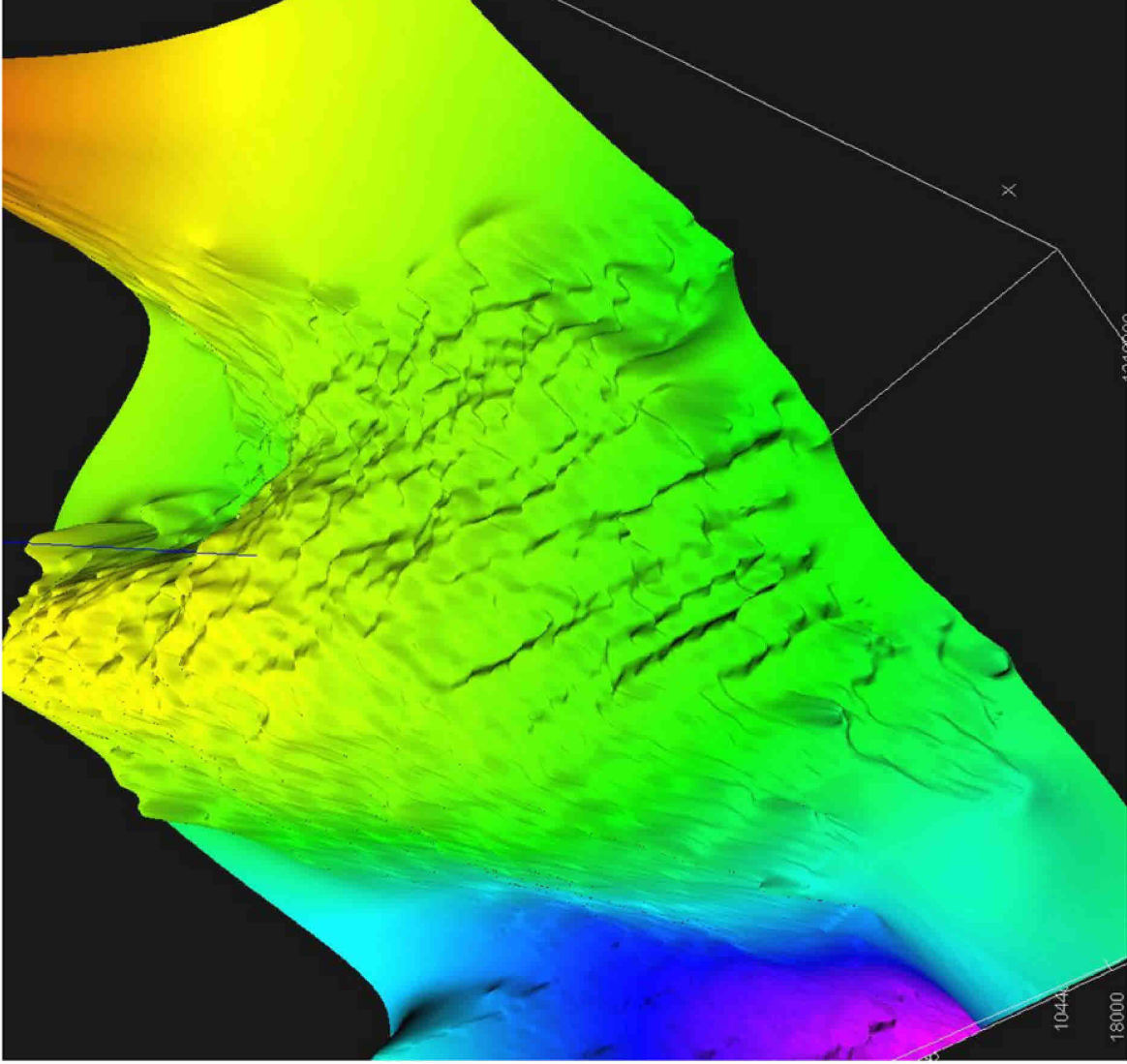


# MBal Results for Various Aquifers



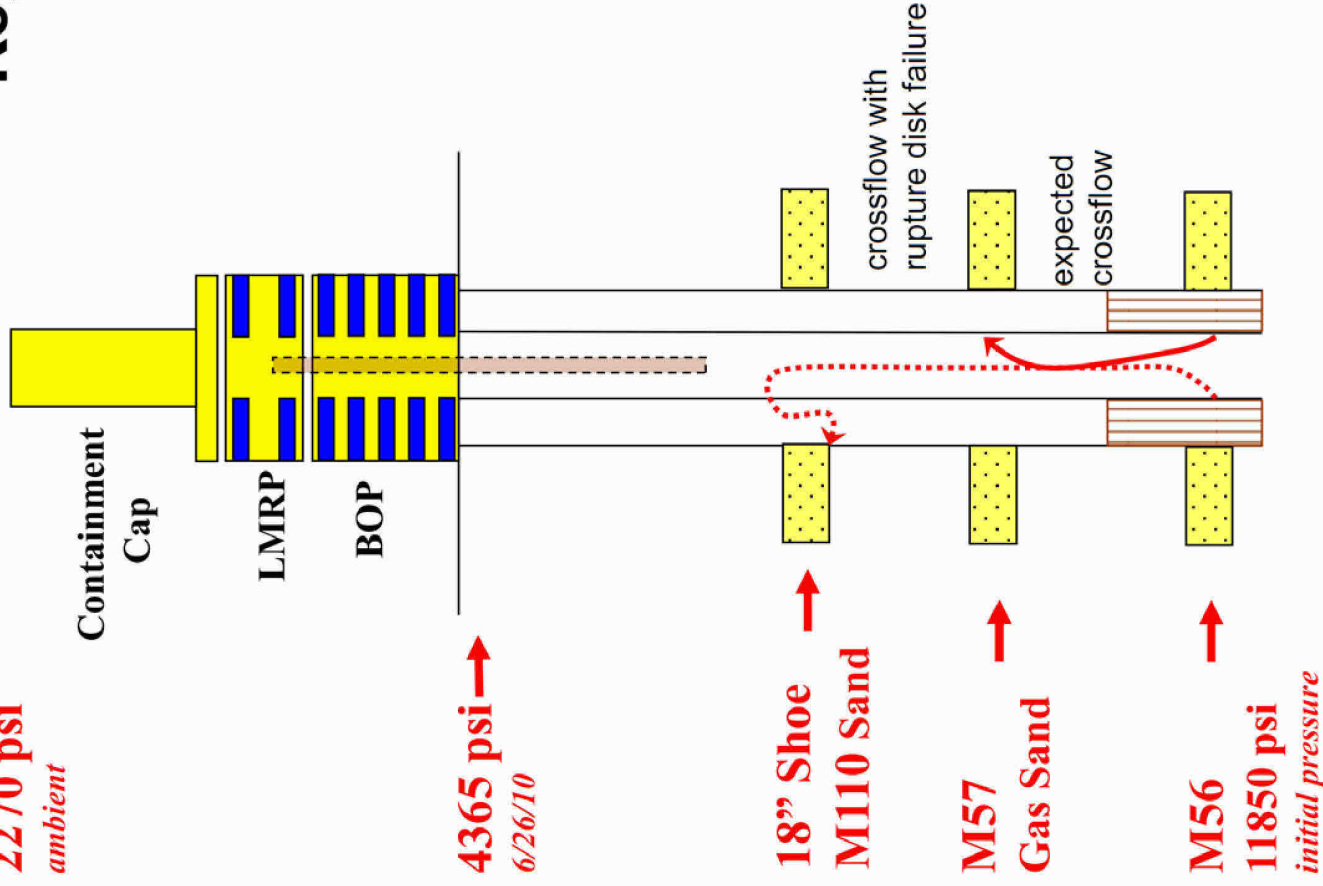


# Future Work: Add Structure



# Key Conclusions wrt SIWHP

2270 psi  
ambient



- Impact of crossflow:
  - Reservoir fluid fills the M110, charging it above fracture capacity
  - Possible broach to surface
- M110 sand is small (5' thick), in one scenario could fill to fracture pressure in 10 days (resvr flow > 32mmbd).

## Can we detect this scenario?

- Leak off will not be detectable (constant charge from M56)
- Crossflow at 18" shoe would be detectable if "large enough"
  - Max  $Q_o$  through 6 disks: 6000 bpd
- Would manifest itself as a lower than "anticipated" SI BOP pressure
- Uncertainty in SI BOP pressure is driven by aquifer & rate

# Model Approach & Purpose



- Model constructed to address impact of crossflow of M57B & M56A gas sands during “top kill”
  - Response of observed pressures
  - GOR variation with time
- Requested to investigate whether depletion was consistent with known pressures below BOP
- Requested to avoid making any conclusions regarding likely rates
  - Role of flowrate investigation team
- Approach
  - Simple: tight timing, multiple unknowns
  - Single layer per reservoir (M57B to M56F, with intervening shales)
  - 10 x 12 x 17; no structure