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# URTEC-198210-MS

# Optimisation of Dewatering Rates to Maximise Coal Seam Gas Production

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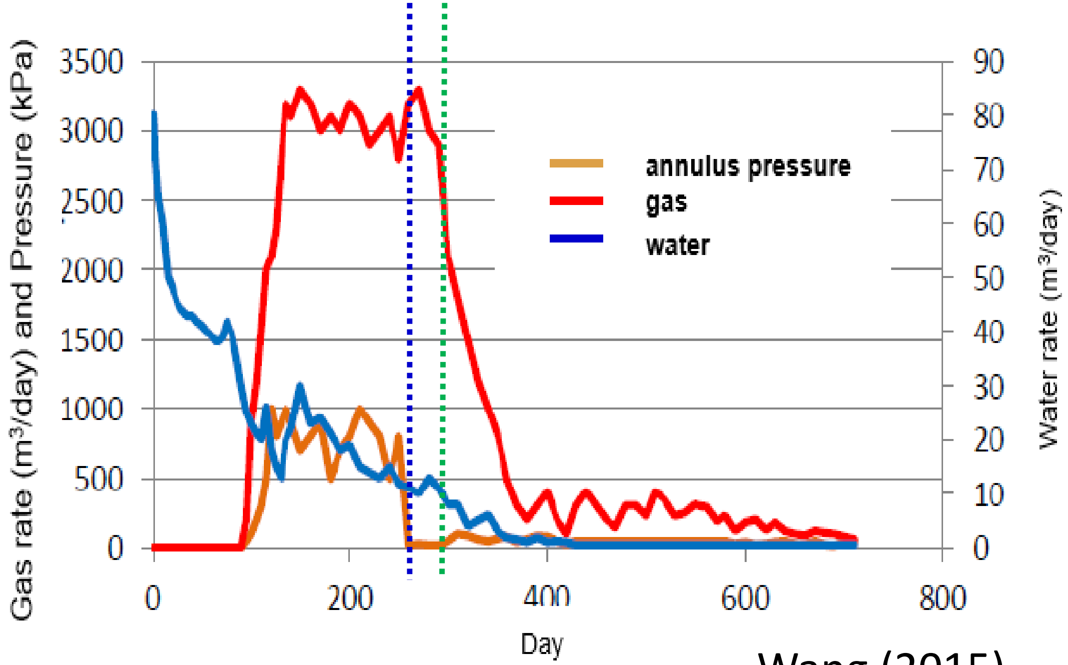
# Outlines

- ✓ Background
- ✓ Objectives and Methodology
- ✓ Model Implementation and Simulation Scenarios
- ✓ Results and Discussion
- ✓ Conclusions

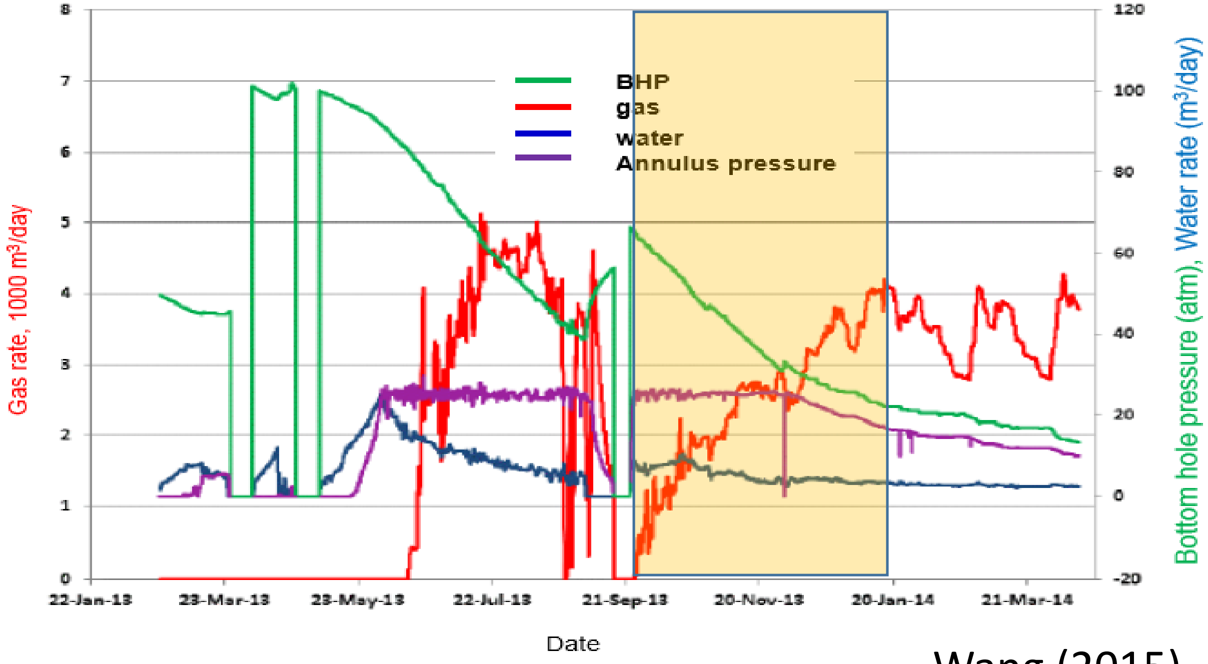
# Background

The impact of dewatering rate on CSG productivity has been reported.

Reduction in BHP too quickly may dramatically reduce gas peak rate in the short term and reduce total production in the long term.




Wang (2015)




Wang (2015)

# Background

Possible reasons are:

1. Fluid pressure in cleats near wellbore decreases sharply, effective stress exerted upon the cleats increases and results in absolute permeability reduction
2. Early two-phase flow occurrence around the wellbore provides internal pressure maintenance and decreases the relative permeability to water
3. Other factors: wellbore stability and blockage of coal fines etc.

These, in turn, limit significant pressure propagation, limit desorption area and constrain water flow toward the well far from the fields.

# Objectives and Methodology

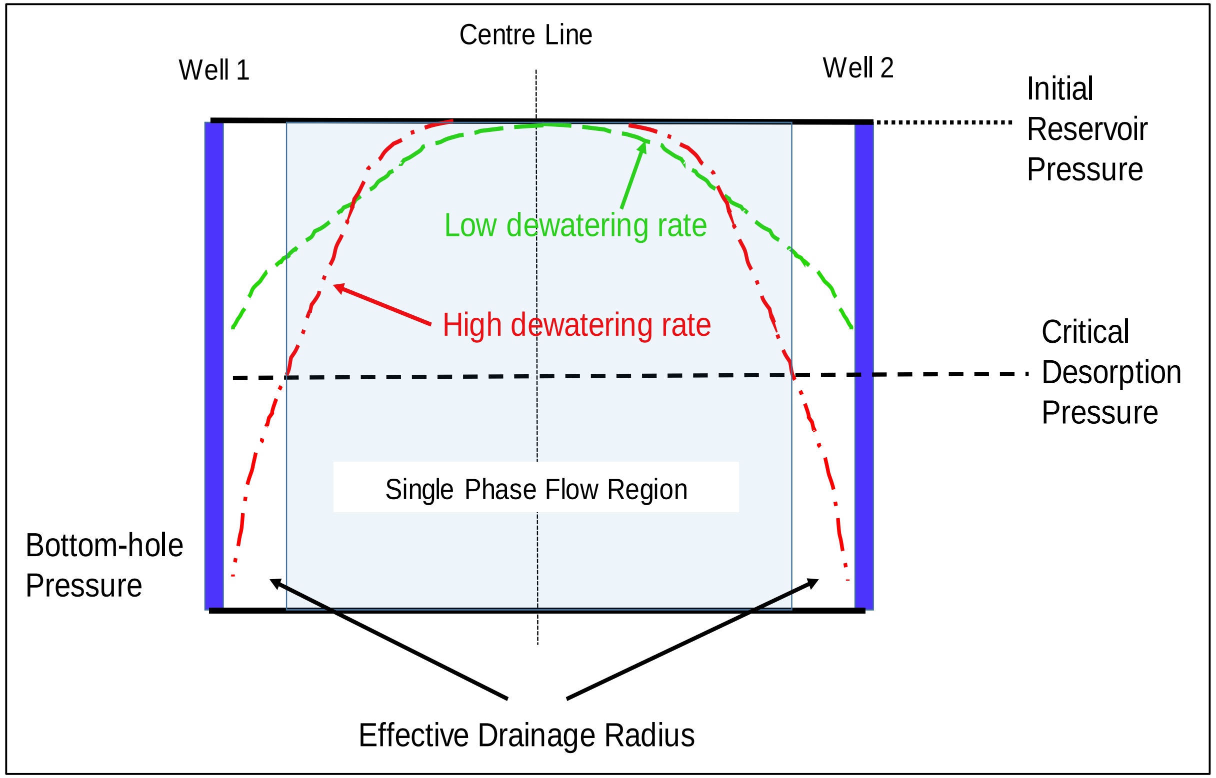
## ❖Objectives

Investigate whether or/and how the Bottom-hole pressure (BHP) needs to be managed to maximise gas production from different CSG reservoir conditions.

## ❖Methodology

Develop a 2D numerical model to evaluate the sensitivity of coal perm to relative perm curves and coal matrix shrinkage under different stress conditions, e.g., constant volume, constant stress and uniaxial strain.

For each case, separately simulate production behaviour under (i) various drawdown strategies, (ii) accounting for different relative permeability characteristics, (iii) geo-mechanical properties and (iv) isotherm properties.



# Model Implementation

## ❖Model Geometry and Reservoir Condition

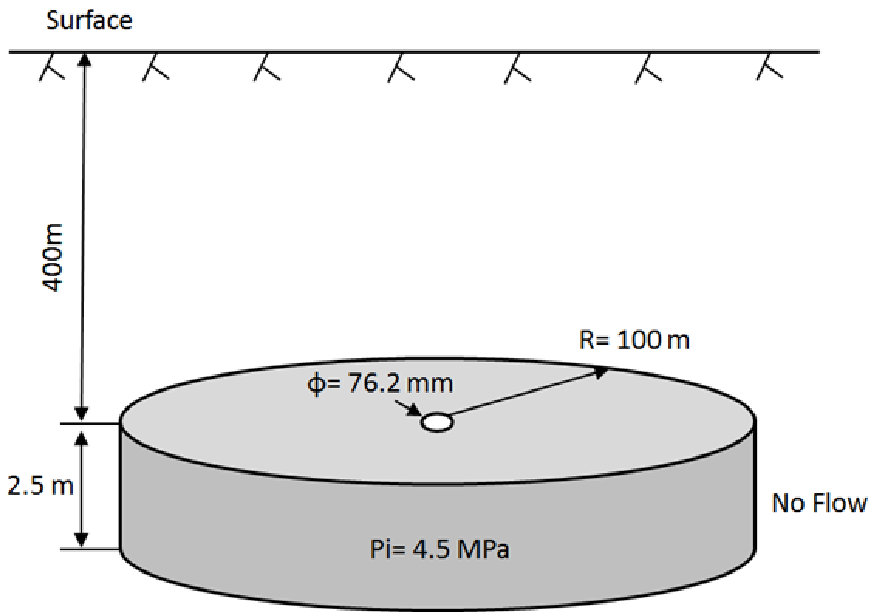



Illustration of numerical model geometry. The compositional simulator GEM from the Computer Modelling Group (CMG) suite was used. The radial grid system has **100 grid cells** in the **radial direction**, **3 grid cells** in the **angular direction** and **1 grid cell** (layer) in the **vertical direction**, making a **total of 300 grid cells** in the model.

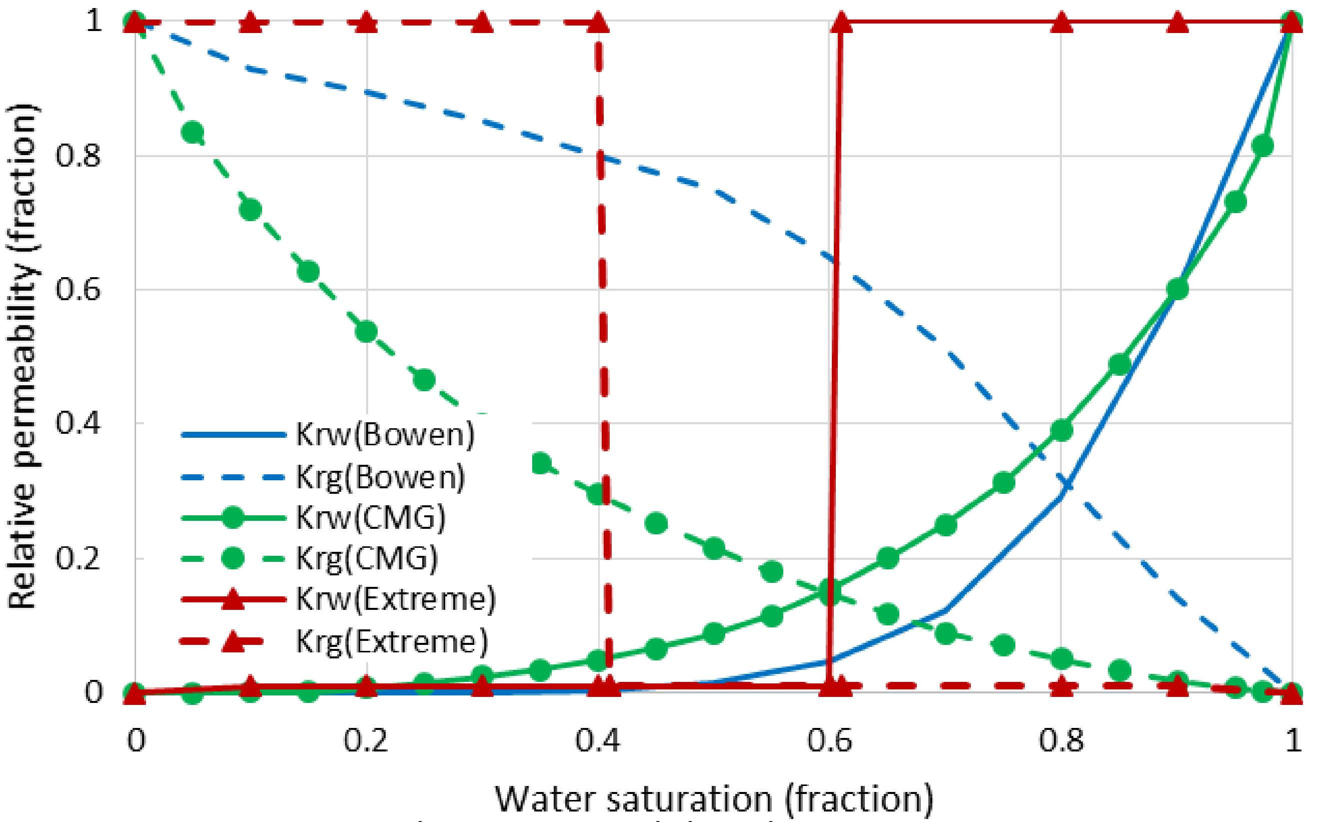
**Table:** Initial reservoir properties

| Input | Value |
|---|---|
| Radius (m) | 100 |
| Thickness (m) | 2.5 |
| Reservoir depth (m) | 450 |
| Reservoir pressure (kPa) | 4500 |
| Reservoir temperature ($^0$C) | 40 |
| Coal compressibility (1/kPa) | $2\times10^{-5}$ |
| Horizontal fracture permeability (mD) | 2 |
| Vertical fracture permeability (mD) | 2 |
| Matrix porosity (fraction) | 0.01 |
| Fracture porosity (fraction) | 0.005 |
| Fracture spacing (m) | 0.2 |
| diffusion coefficient (cm$^2$/s) | $2\times10^{-8}$ |
| Coal density (kg/m$^3$) | 1400 |
| Water density (kg/m$^3$) | 1000 |
| Water viscosity (cp) | 0.6 |

# Model Implementation

## ❖Relative Permeability Characteristics

- **For a real coal example, blue curves** data published by *Meaney and Paterson (1996)*, determined by history match production data from German Creek Seam in Bowen Basin.
- **As an intermediate case, green curves** are specifically used by CMG for coal seam gas reservoir modelling.
- **An idealised case, red curves** represent an extreme hypothetical relative permeability case to investigate effects of jamming fluid flow in the reservoir.



Relative permeability characteristics

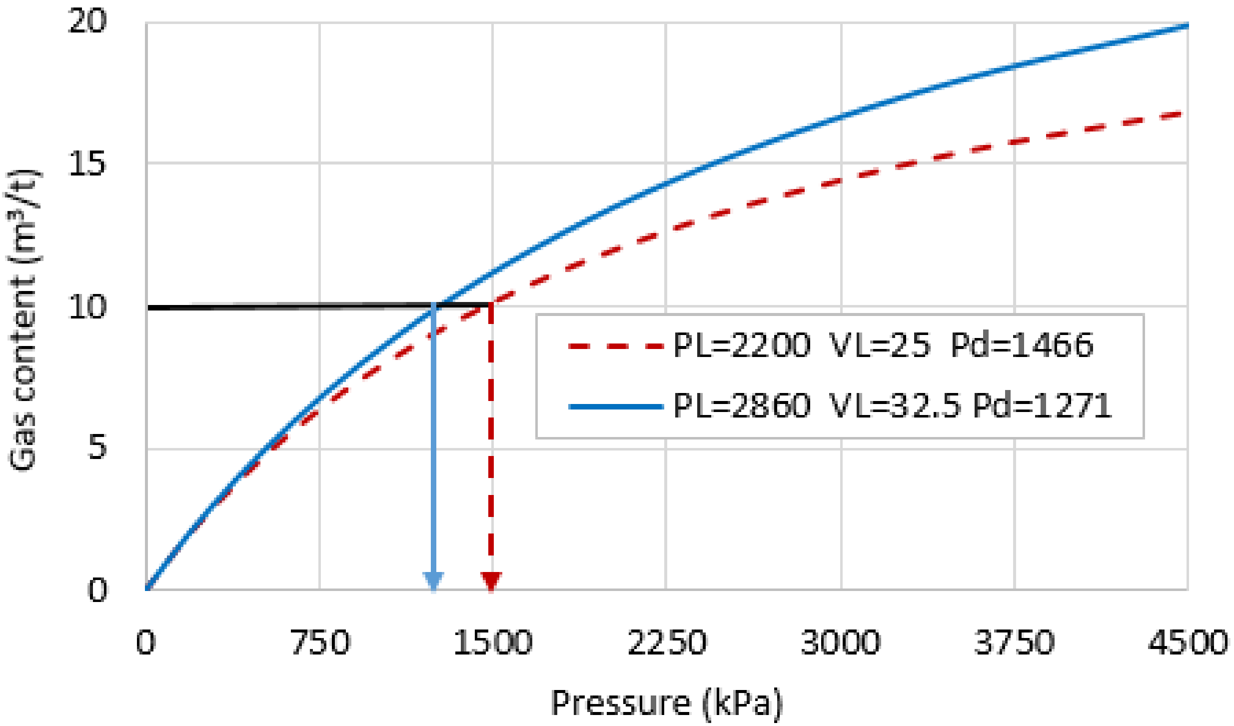
# Model Implementation

## ❖Langmuir Isotherm and Geomechanical Properties

- Values in the Table below are related to coal seams from Bowen Basin and were obtained from core samples and history matched data (*Connell et al 2013, Mazumder et al 2012, Jeffery et al 1995, Morales et al 1993*).
- The two extreme values are within 30% of the mean values.

Geomechanical properties

| Parameters | Low | Mean | High |
|---|---|---|---|
| Young's Modulus, *E* (MPa) | 2,072 | 2,800 | 3,528 |
| Poisson's Ratio, ν | 0.26 | 0.35 | 0.44 |
| Sorption-induced Strain, ε | 0.0089 | 0.0120 | 0.0151 |




Shows the Langmuir isotherm curves. The **red isotherm curve** ($V_L$ and $P_L$) is based on Bowen datasets (unpublished data). The **blue curve** has 30% higher $V_L$ and $P_L$. Both curves were calculated with gas content GC=10 $m^3/t$

# Model Implementation

## ❖ Production Well Arrangements

**Table:** Proposed well completion and input properties

| Parameter | Value |
|---|---|
| Grids well definition | 1 1; 1 |
| Production duration | 20 years |
| Well radius (m) | 0.0762 |
| Skin | 0 |
| $CH_4$ mole fraction | 1 |
| Bottom-hole Pressure (kPa) | 300 kPa |

- ✓ Initially, the well is operated with a primary constraint of a **300 kPa** BHP as an **immediate decline**.
- ✓ For **gradual decline**, we modelled three rates of BHP drawdown (**20**, **35**, and **50 kPa/day**), as shown in the **Figure**.

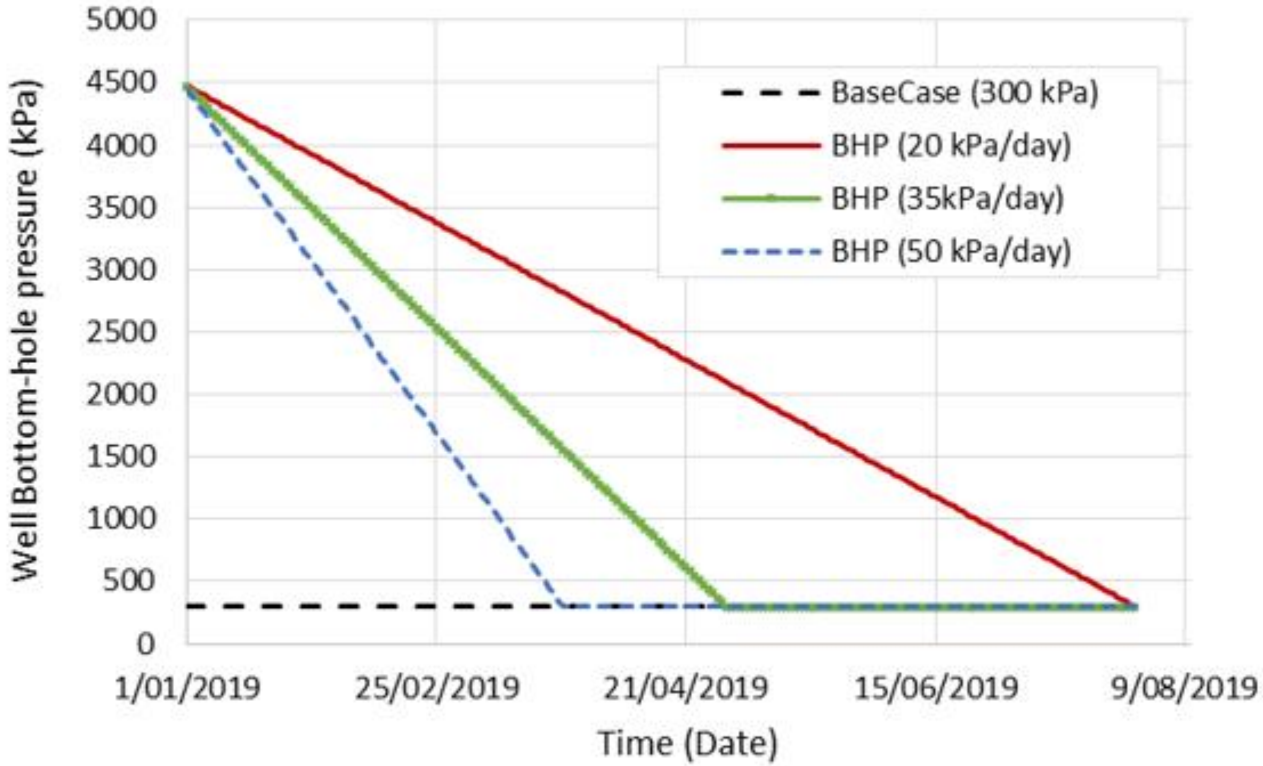
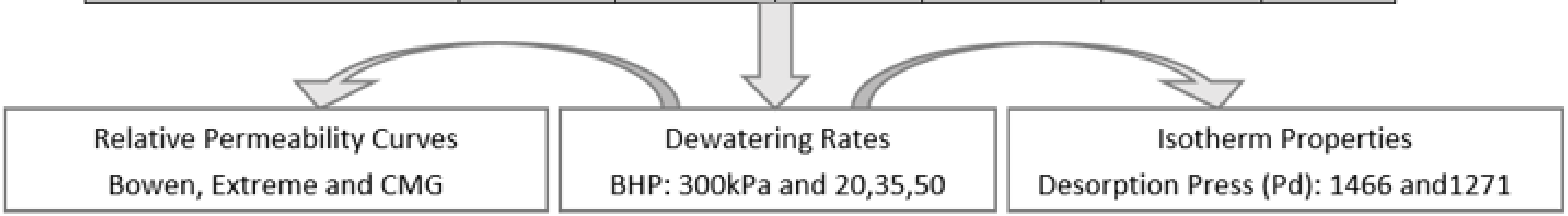



**Figure:** Immediate and gradual decline in well BHP

# Simulation Scenarios

- Different case scenarios were systematically simulated for the whole matrix of conditions.
- A total of 144 (3*4*2= 24 runs for each case) separate runs were investigated for different drawdown scenarios.

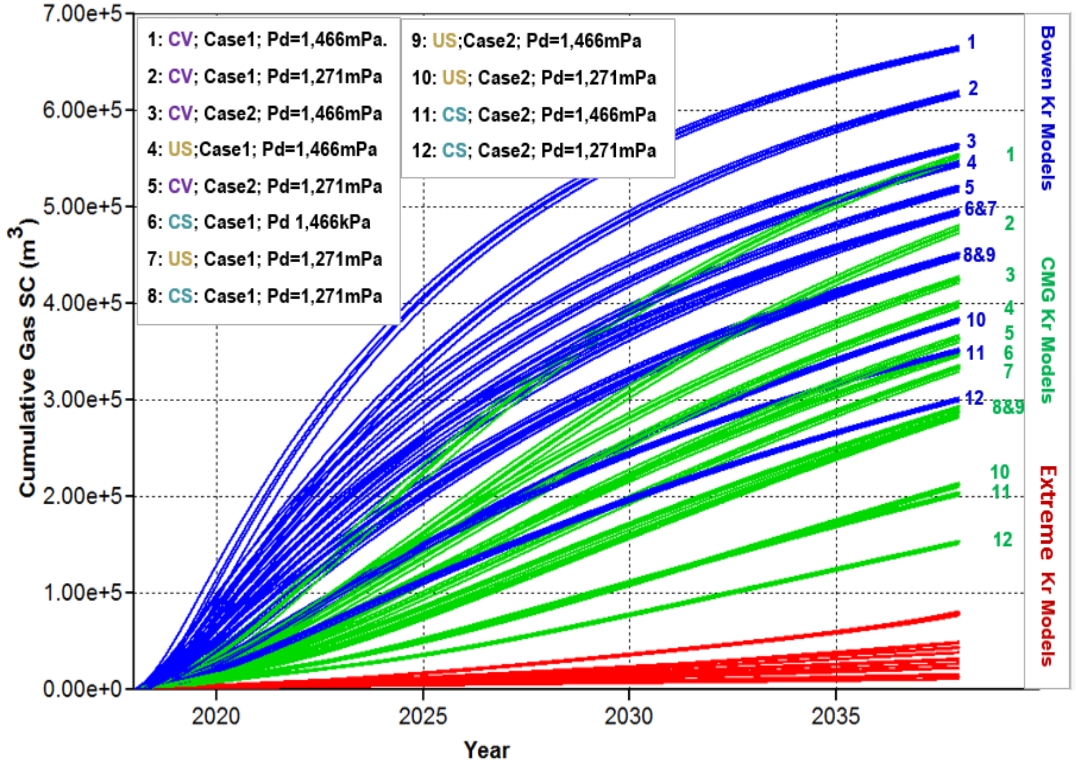
| Stress Conditions Versus Geomechanical properties | Constant volume (CV) | | Constant stress (CS) | | Uniaxial strain (US) | |
|---|---|---|---|---|---|---|
| | Case1 | Case2 | Case1 | Case2 | Case1 | Case2 |
| Poisson's Ratio, ν | 0.26 | 0.44 | 0.44 | 0.26 | 0.44 | 0.26 |
| Young's Modulus, E (MPa) | | | 3,528 | 2,072 | 3,528 | 2,072 |
| Sorption-induced Strain, ε | 0.0151 | 0.0089 | | | 0.0151 | 0.0089 |



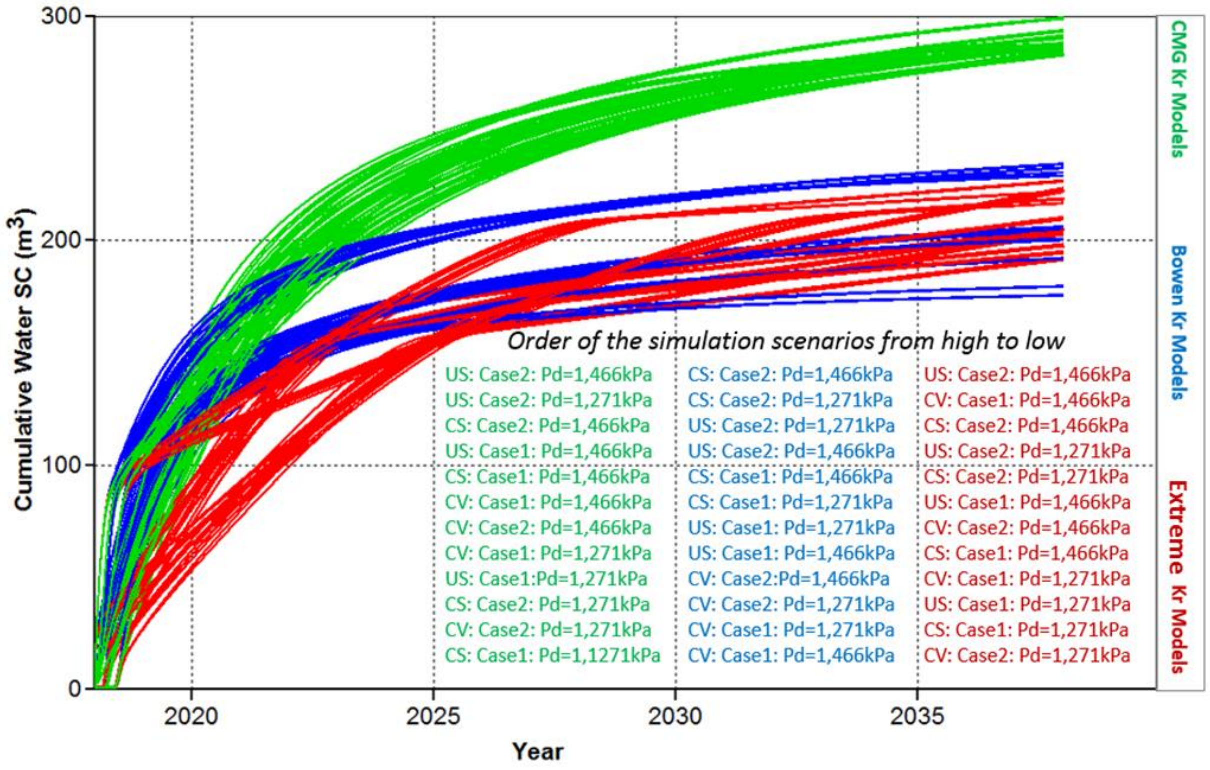

Simulation strategy

# Results and Analysis

## ❖Cumulative Gas and Water Production Over 20 Years

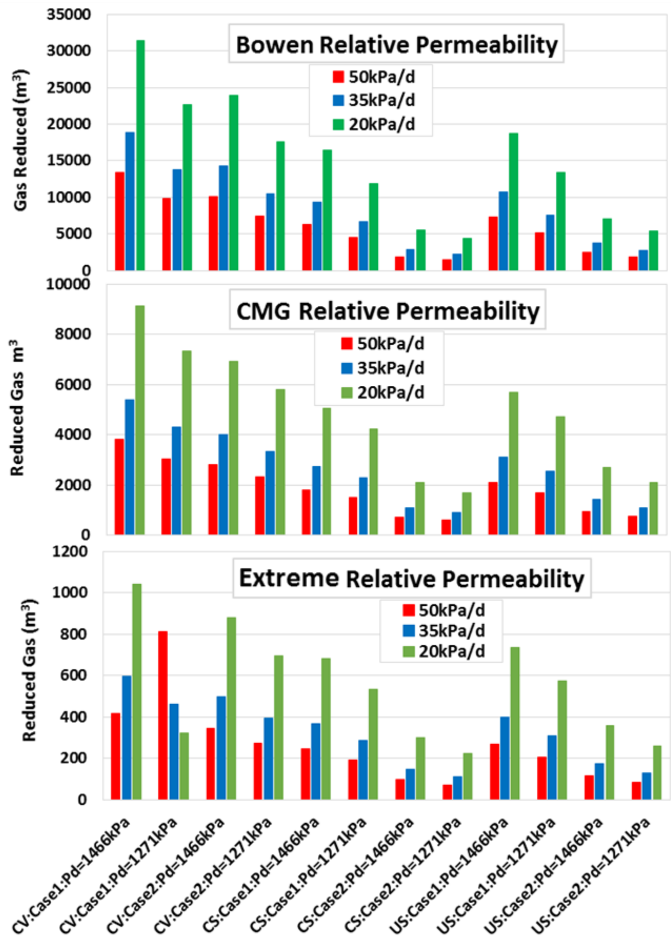



Cumulative gas production for different reservoir conditions under different dewatering rates over 20 years

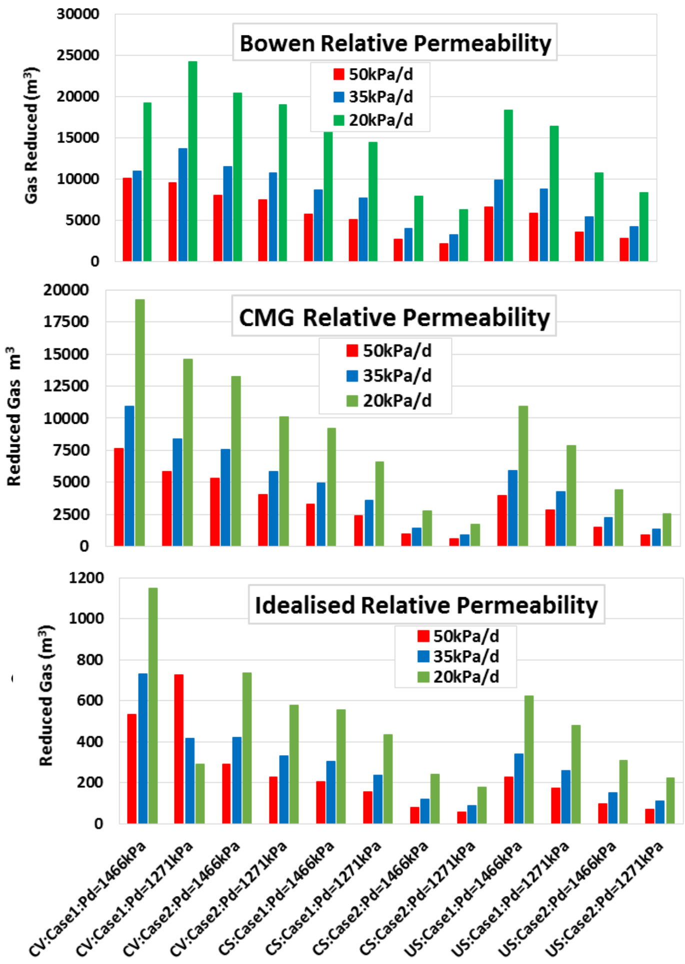



Cumulative Water production for different reservoir conditions under different dewatering rates over 20 years

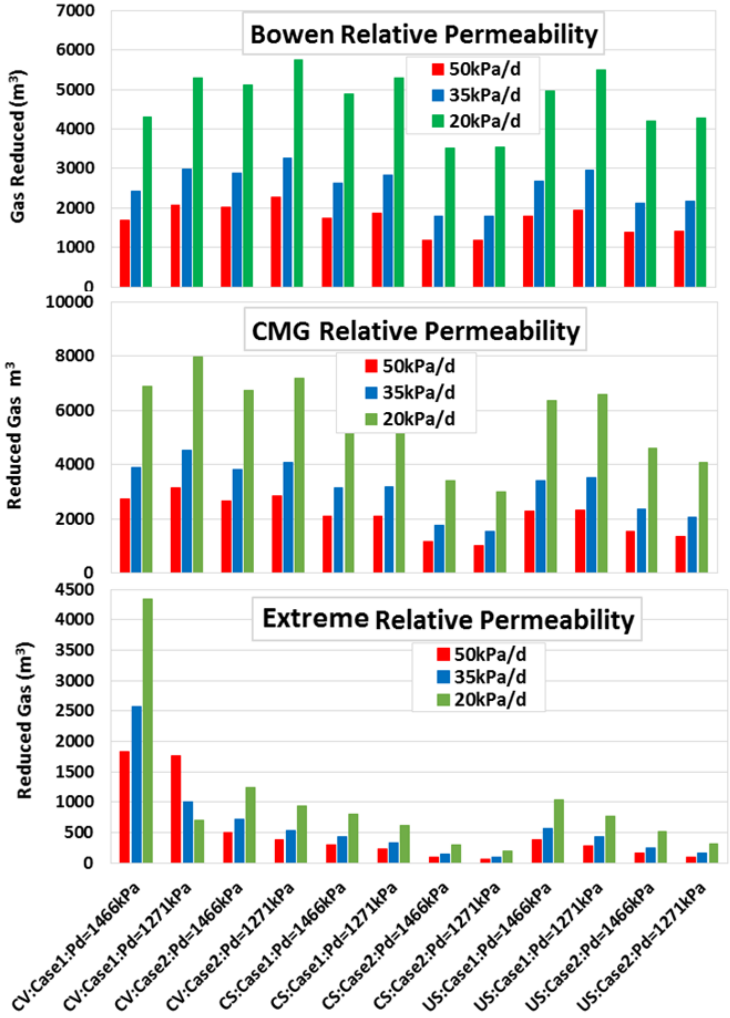
# Results and Analysis- Gas




Gas reduction vs. BHP control after **1 year**

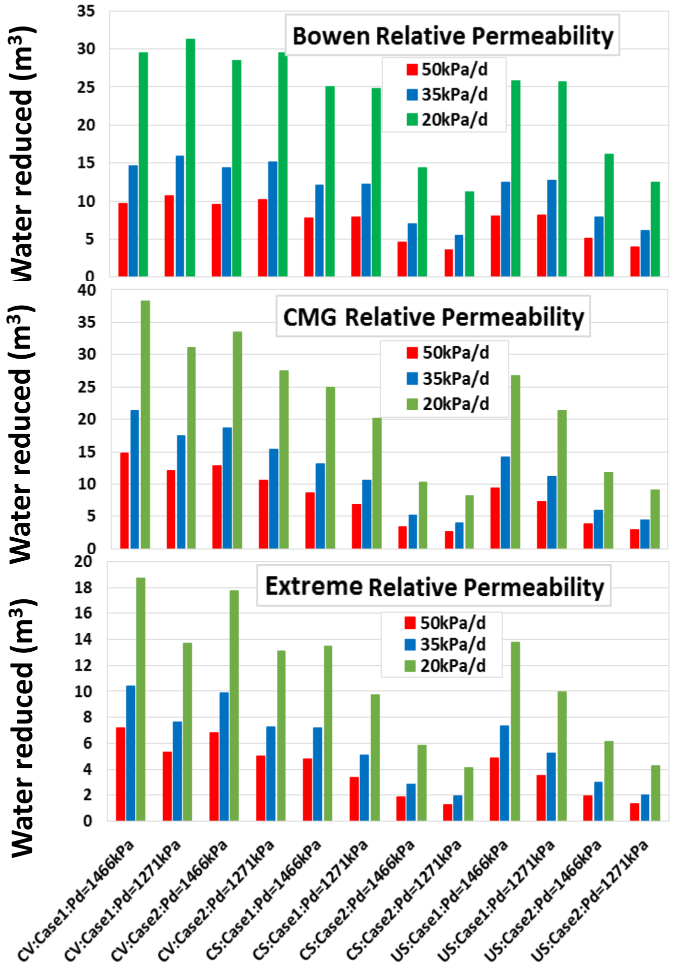



after **5 years**

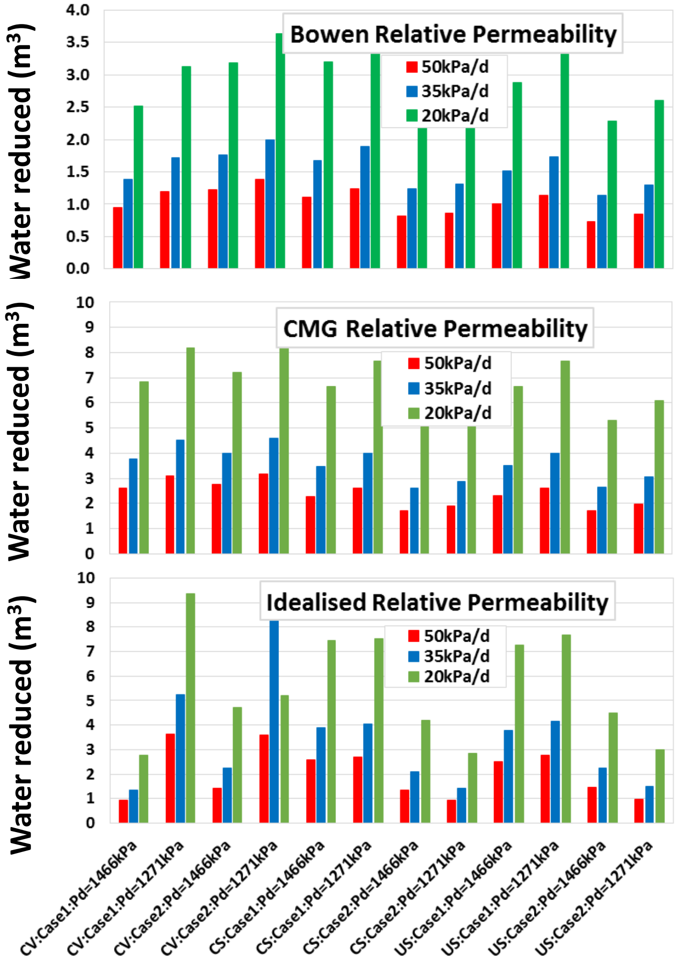



after **20 years**

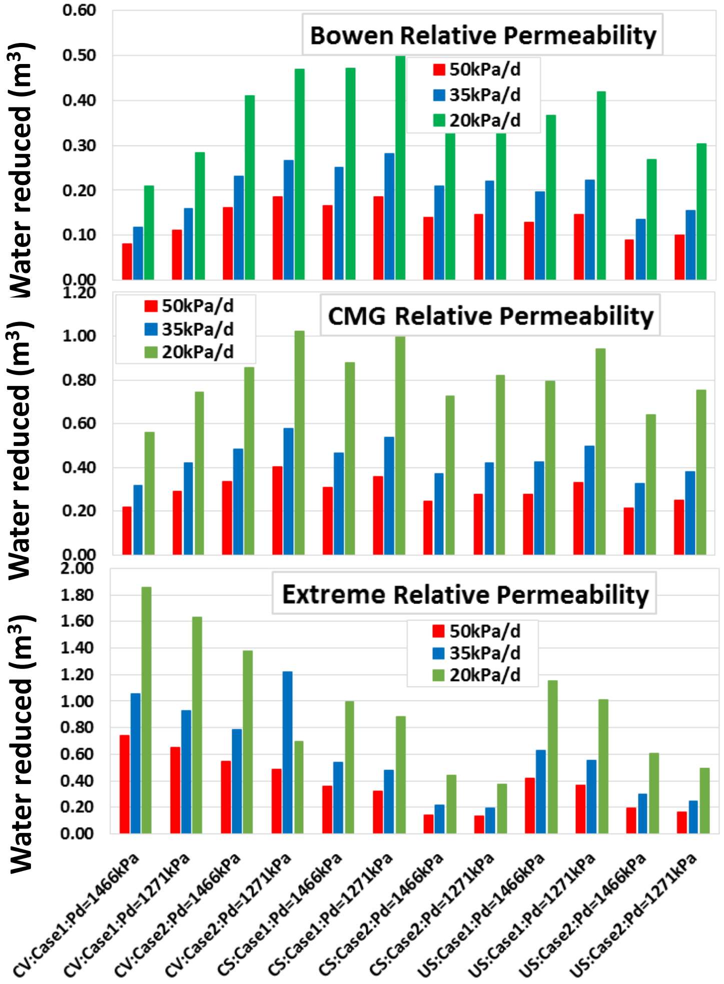
# Results and Analysis- Water




Water reduction vs. BHP control after **1 year**



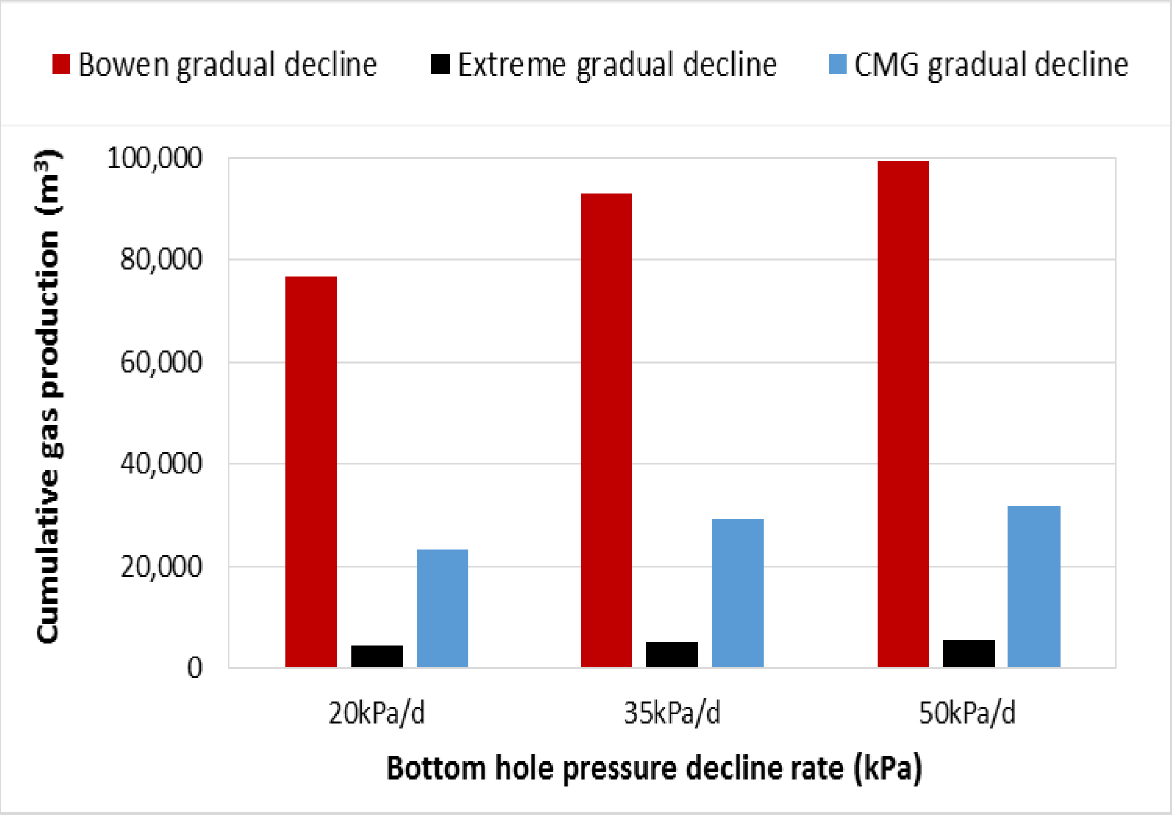

after **5 years**



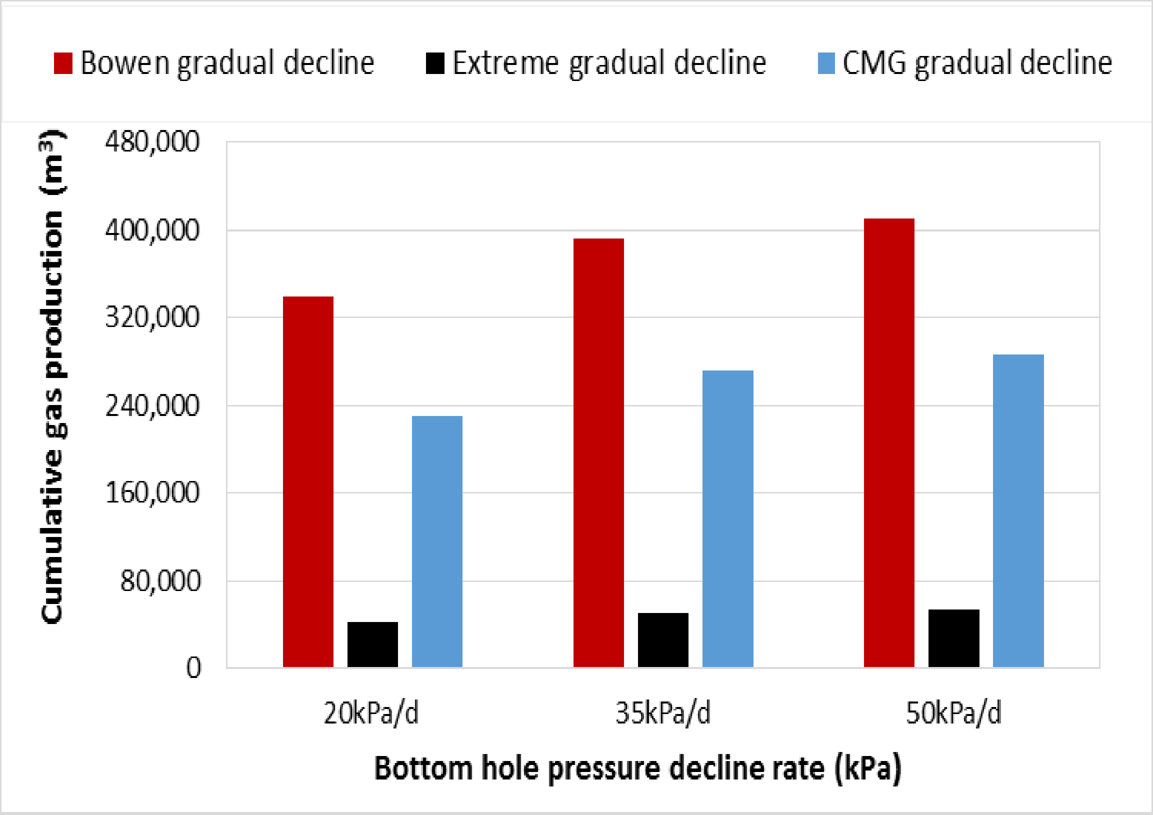

after **20 years**

# Results and Analysis- Absolute Perm

## Ka=1 mD




## Ka=10 mD



# Conclusions

- ✓ Both absolute permeability changes and relative permeability curves have significant impact on dewatering efficiency and gas productivity behaviour.
- ✓ Under all the simulated scenarios, the lower the BHP the better gas production is achieved.

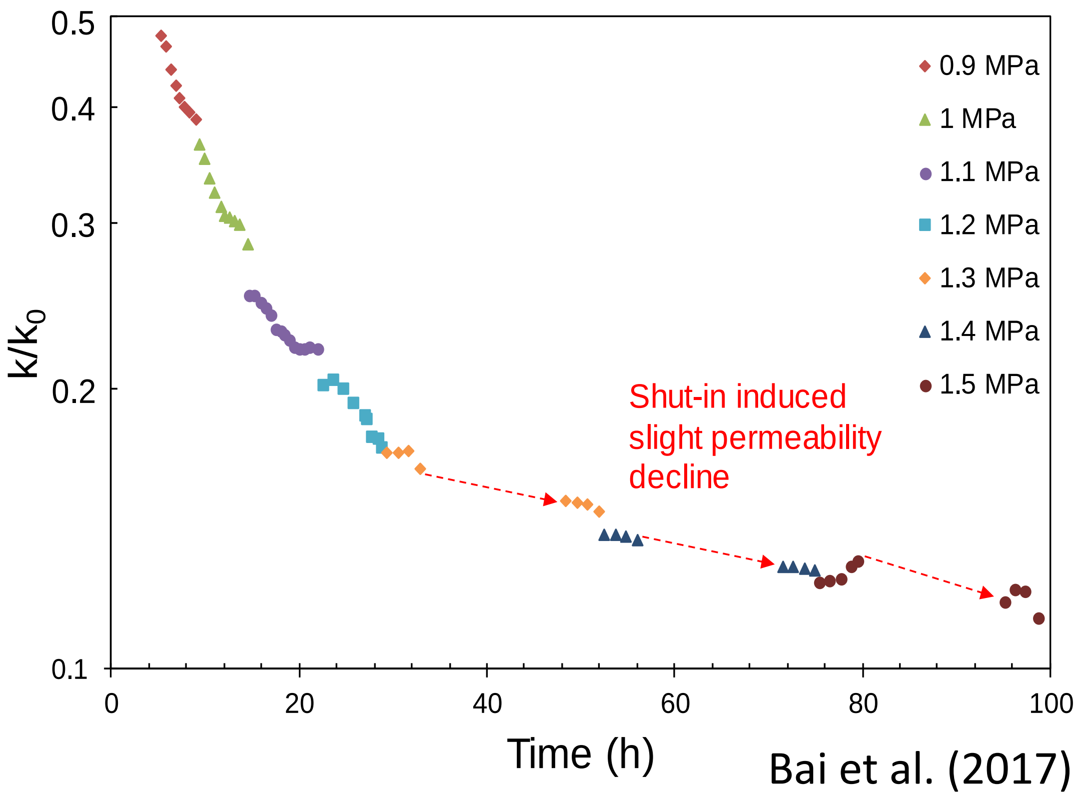
From an operating perspective, where subject to other constraints such as well stability and fines generation is excluded:

- ✓ There is no advantage to manage the BHP – other than to make it as low as possible and as quickly as possible.

# Recommendations

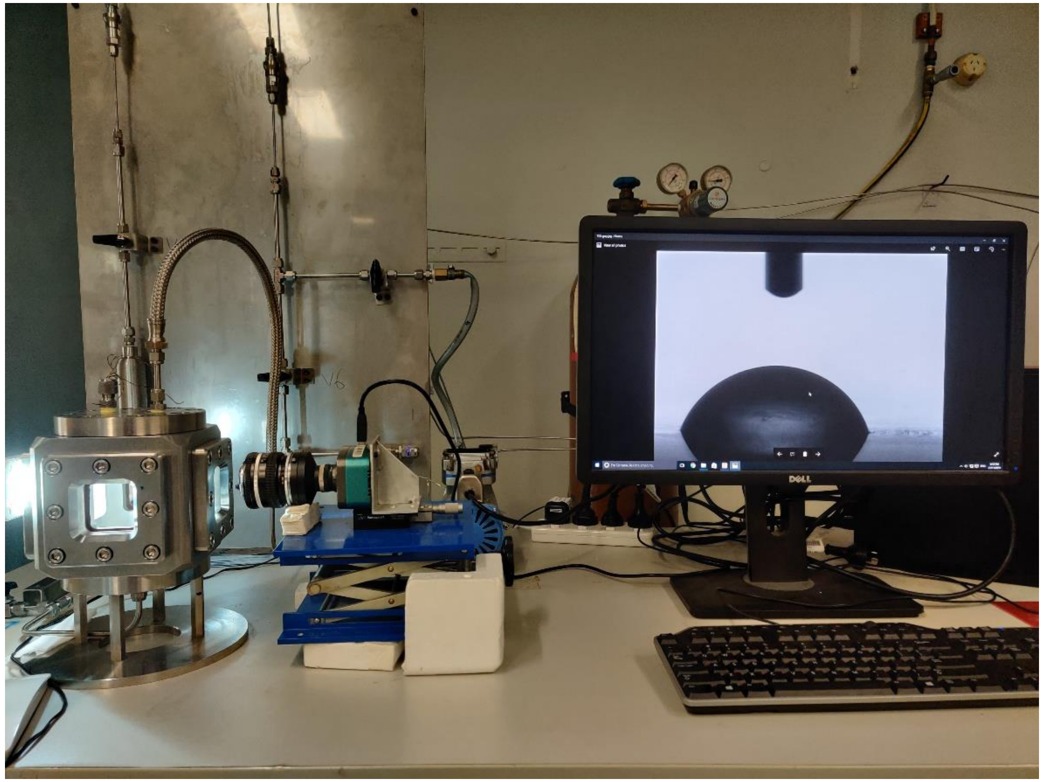
This conclusion contradicts with some field observations that there may be benefits to be gained in terms of productivity in staging the reduction in BHP.

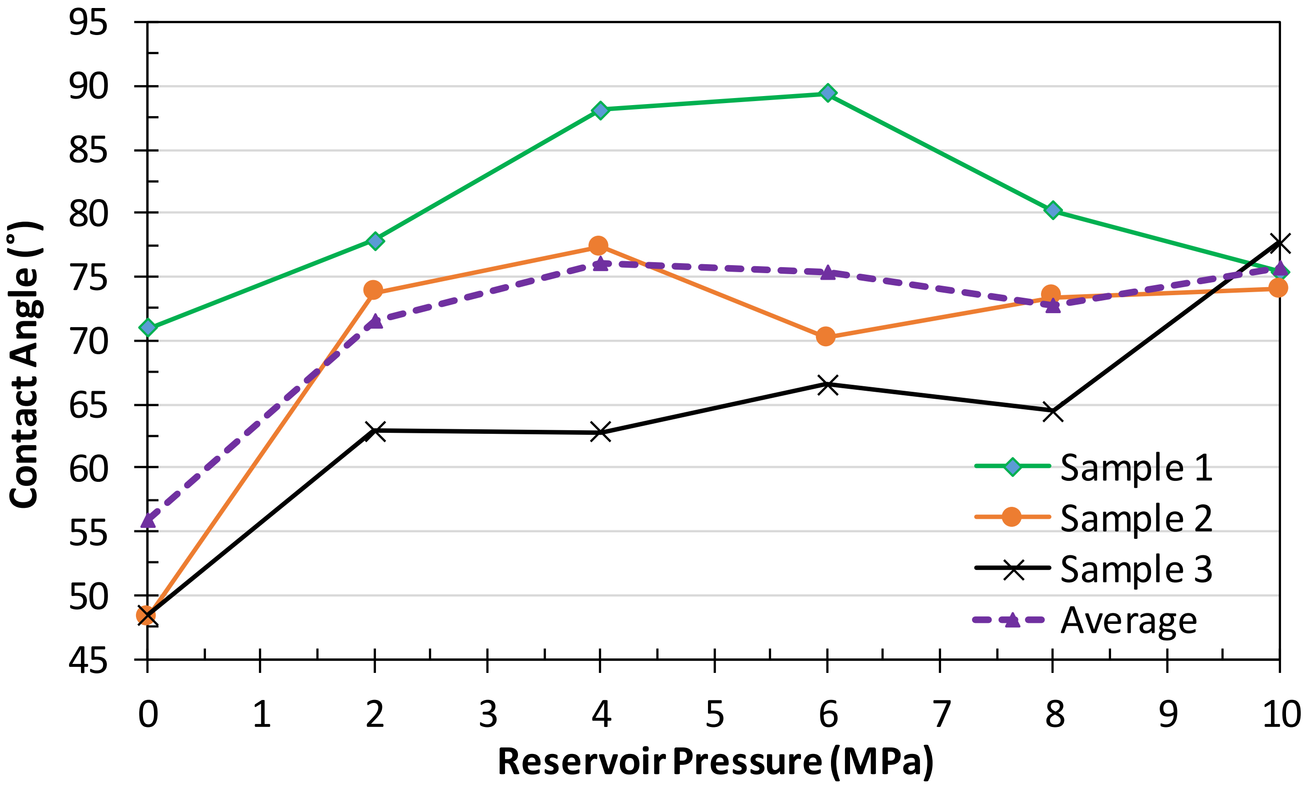
The possible reason(s) is that the work does <u>not include any consideration of factors like the dynamic change of the intrinsic perm and relative perm, wellbore instability or fines generation</u> from stress imbalances that may arise from rapid pressure changes.




Bai et al. (2017)

# Recommendations- cont'd






- Coal becomes more hydrophilic (i.e. more wetting) during depletion

# Acknowledgments

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Thanks!
Questions?