Gas Field Development - Challenges and Current Best Practices to Maximise Value

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Characterization of a Commingled Gas-Condensate Field Using Production Logging Data: A Case Study From South-East Asia

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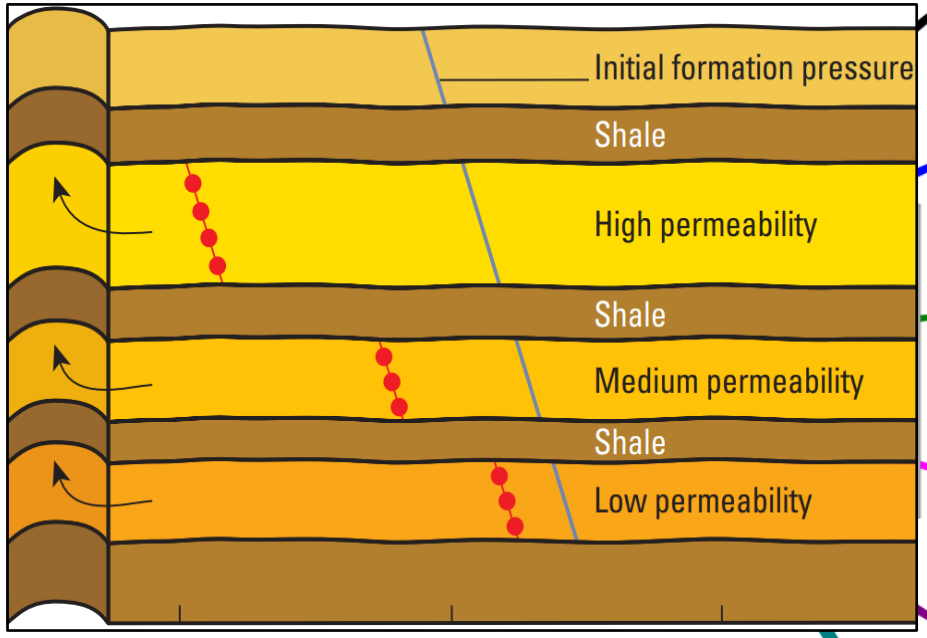
Well Test Knowledge International

Commingled Reservoir Challenges



Commingled Well Behaviour

- Composition varying with time
- Unable to characterize individual layer performance
- Difficult allocation problem
- Zone rates varying with time
- Differential depletion
- Uncertain GIIP distribution

Field A Introduction

- Field A, an offshore gas-condensate field located in South-East-Asia
- Multiple wells commingle production from stacked hydraulically-isolated sandstone reservoirs
  - Not all layers are perforated in all wells
  - See illustrative completion matrix (right)
- Monobore completion with 5-1/2” making up both production liner and production tubing
- Permanent downhole gauges (PDHG) installed in all wells
- Perforation and flow back/cleanup took place during “year 1”

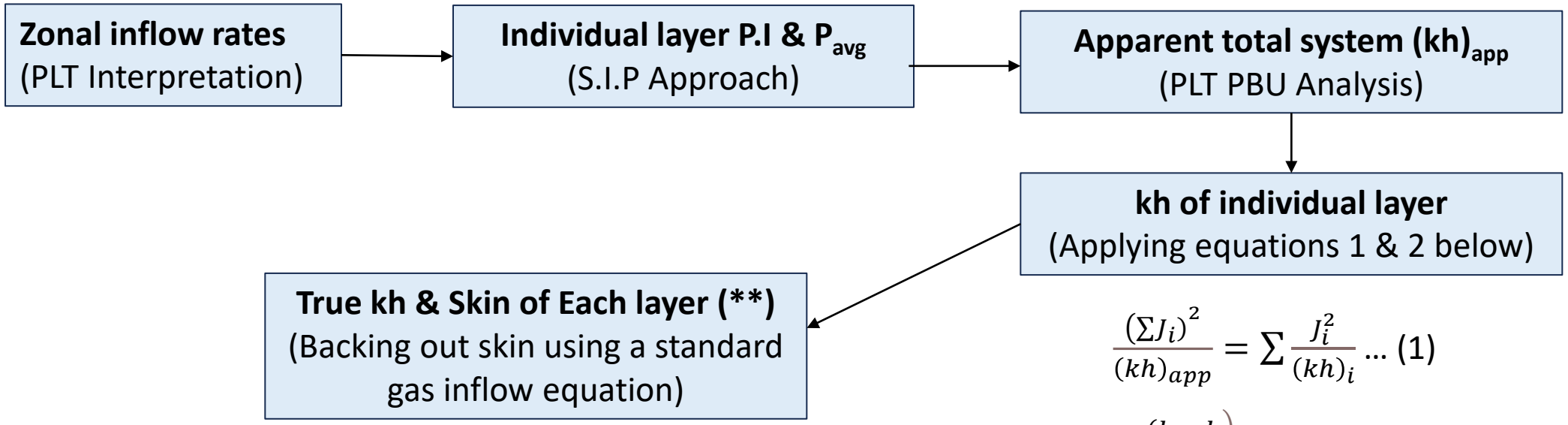
Completion Matrix					
Perforations					
	Well A-1	Well A-2	Well A-3	Well A-4	Well A-5
Zone 1					
Zone 2					
Zone 3					
Zone 4					
Zone 5					
Zone 6					

Perfed Unperfed

Year 3 PLT campaign for Field A

- Production Logging (PL) campaign acquired recently after 2 years of production (in “year 3”).
- PL surveys at multiple rates in all wells to derive productivity indices (PI – also termed “J” in later equations) and local drainage area pressures (P_{avg}).
- PI and P_{avg} are derived using a standard Selective Inflow Performance (SIP) technique.
- Pressure Buildup (PBU) using PL tool in all wells (tool positioned mid-perfs) to provide total system apparent kh, which we call $(kh)_{app.}$
- This case study focuses initially on Well A-1.

Workflow for PBU Interpretation and Evaluation of True Kh and Skin*



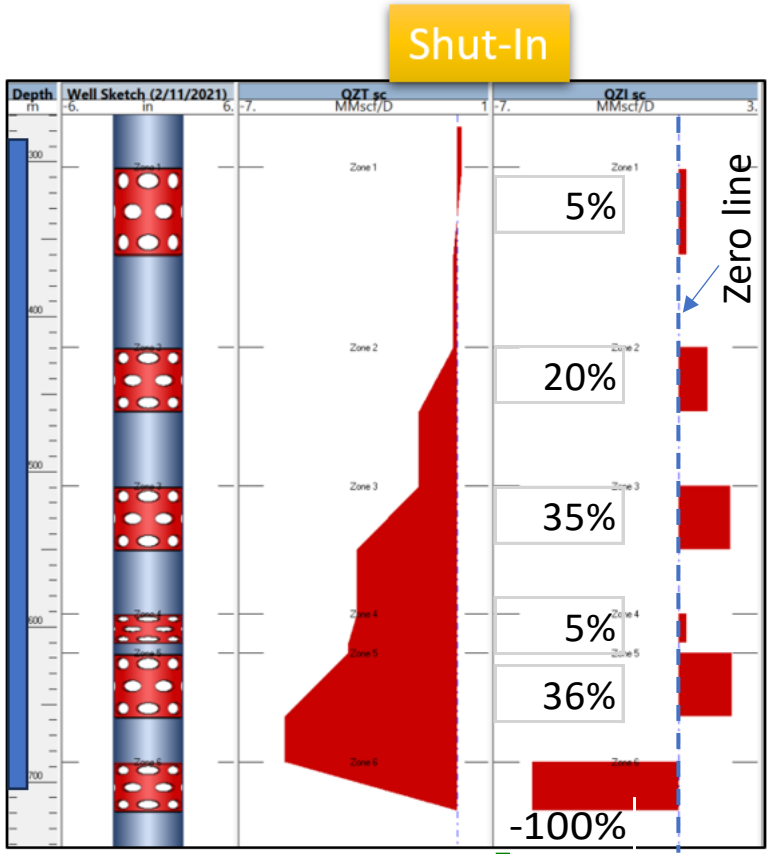
$$\frac{(\sum J_i)^2}{(kh)_{app}} = \sum \frac{J_i^2}{(kh)_i} \ldots (1)$$

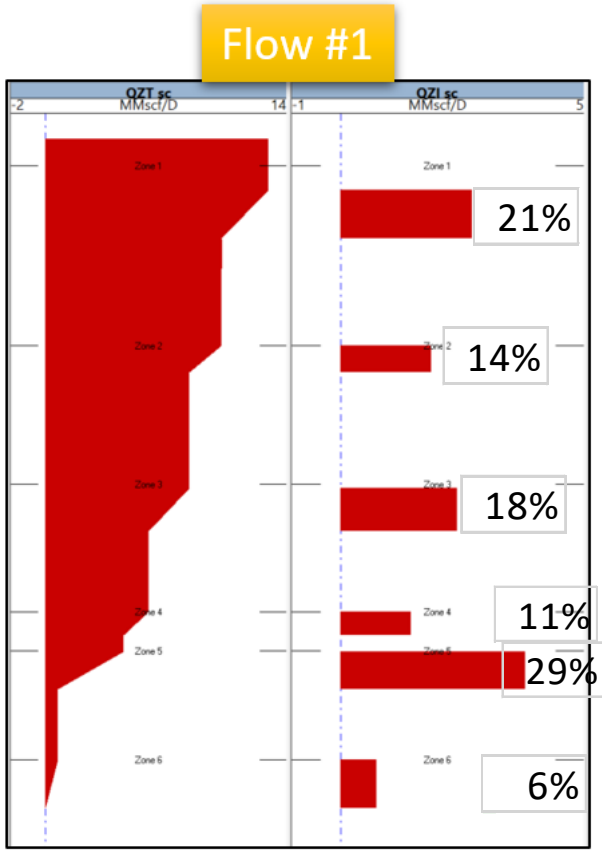
$$\frac{(k_{pp}h)_1}{(k_{pp}h)_i} = \frac{(kh)_1}{(kh)_i} \ldots (2)$$

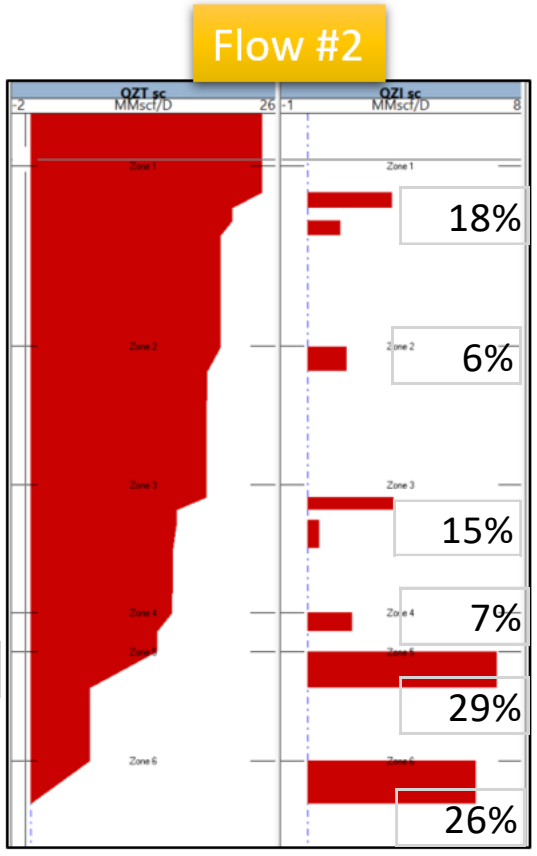
(*) This methodology is based on SPE 210634 (A Simplified Approach to the Analysis of Commingled Wells Whose Layers Have Contrasting Skins – Last & Jongkittinarukorn, 2022). Equation (2) is stating the assumption that the ratios of True kh between layers are the same as the ratios of a petrophysically-derived kh (log, core): ($k_{pp}h$)

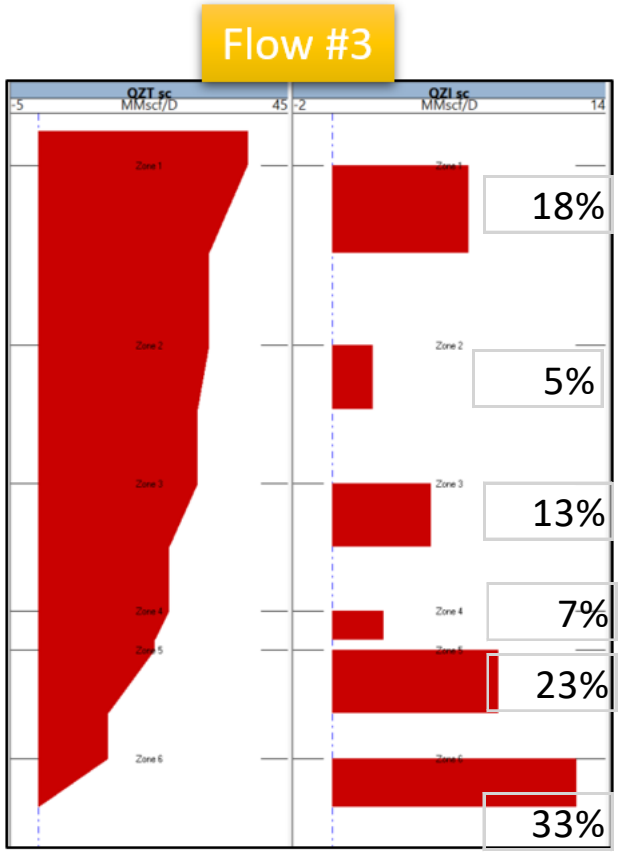
(**) The resulting layer kh's and skins are used as starting points for layer properties in the Commingled Well Model. That methodology will be discussed in later slides.

PL and PBU Results for Well A-1, Field A

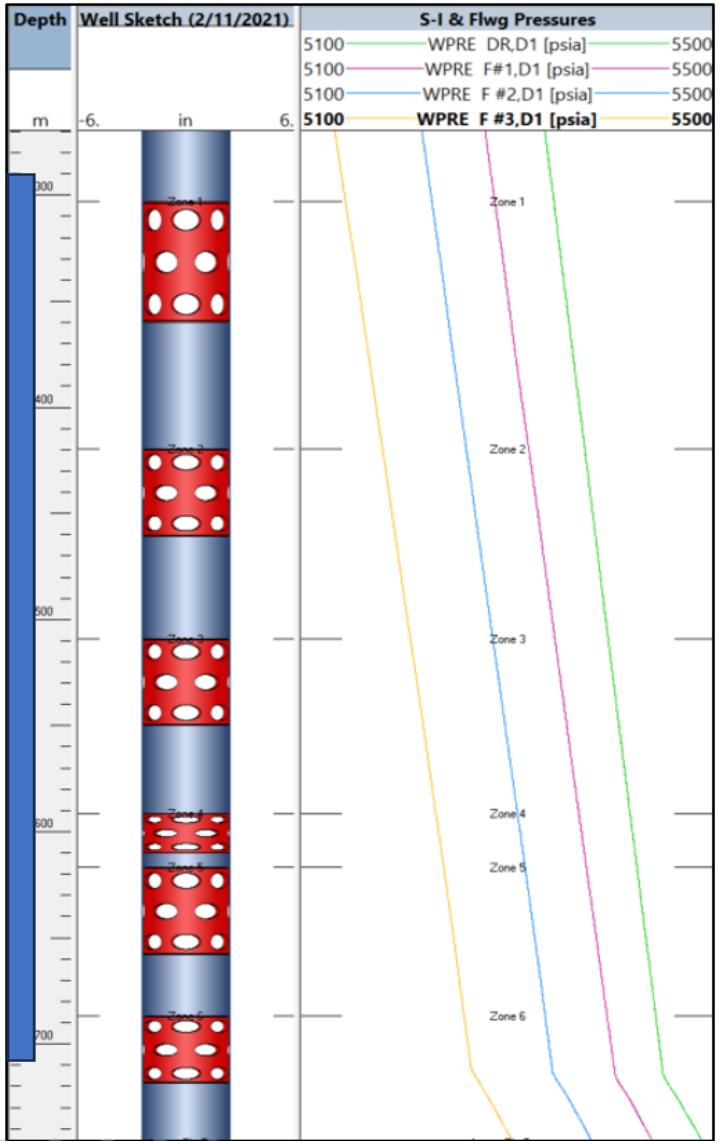


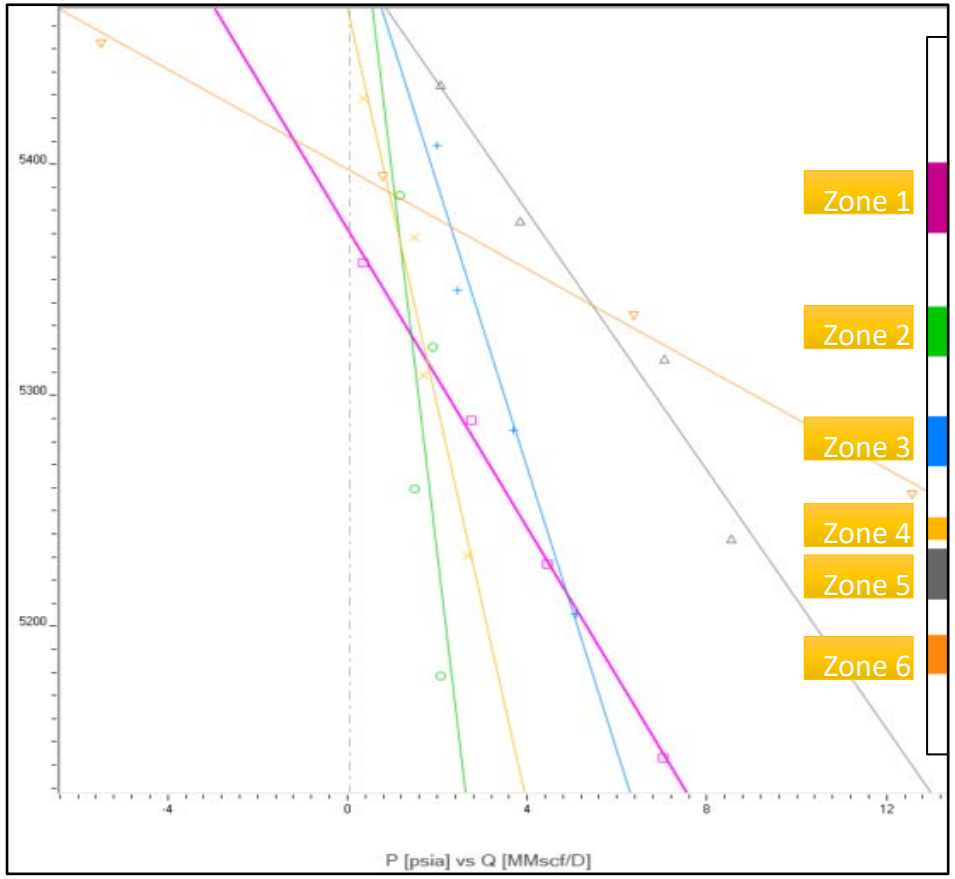






SIP Analysis for Well A-1





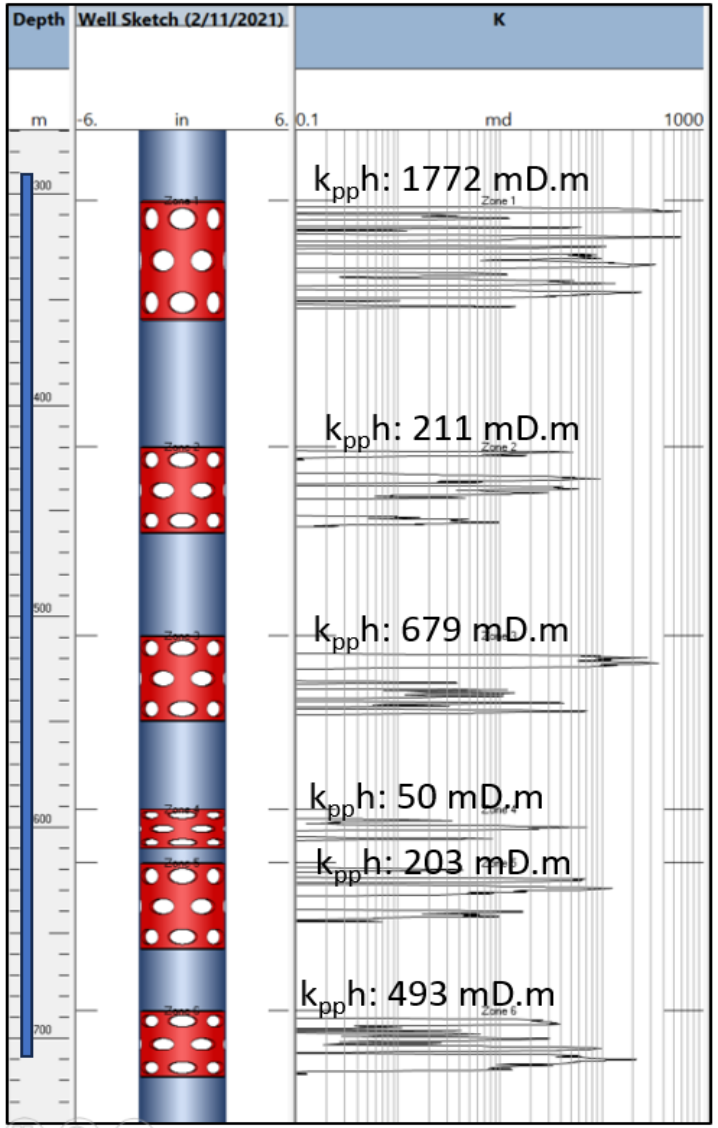
- Inflow rates (q's) for each zone, and at each rate, are obtained from the PL analysis (previous slide)
- Pressure (p) at each zone is recorded during each rate.
- Resulting p's and q's are plotted to derive zonal pressures and PI's.
- Results below

	Well A-1	
	Zone Pressure	PI
	psia	Mscf/d/psi
Zone 1	5371.4	30.9
Zone 2	5550.9	6.1
Zone 3	5512.3	16.2
Zone 4	5464.0	11.6
Zone 5	5490.8	35.8
Zone 6	5398.2	92.6
Total Well		**193.2**

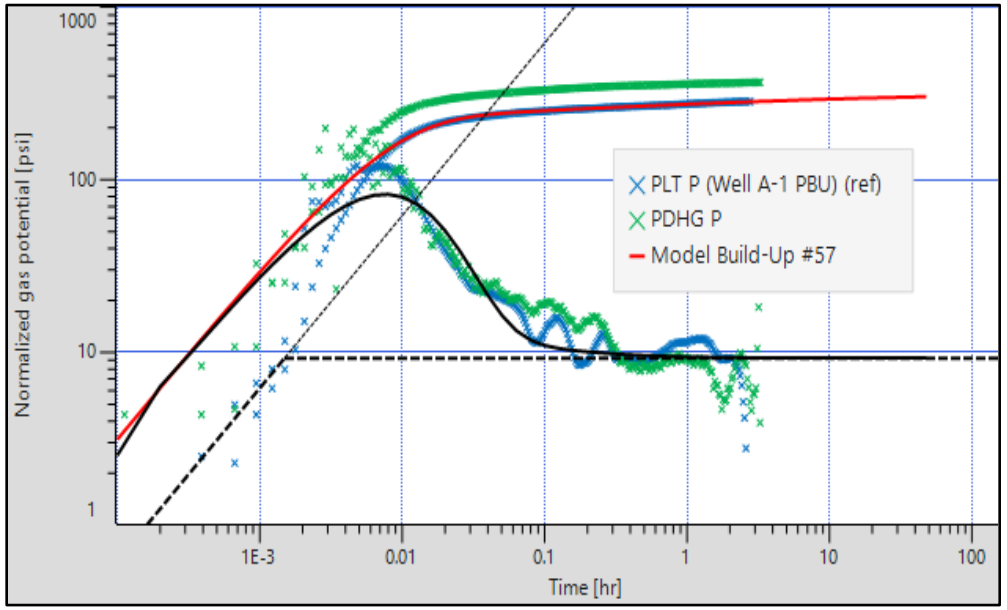
Analysis for kh: Well A-1

Petrophysically-Derived kh ($k_{pp}h$)

Total Well $k_{pp}h$: **3409** mD.m



PBU-Derived kh, $(kh)_{app}$

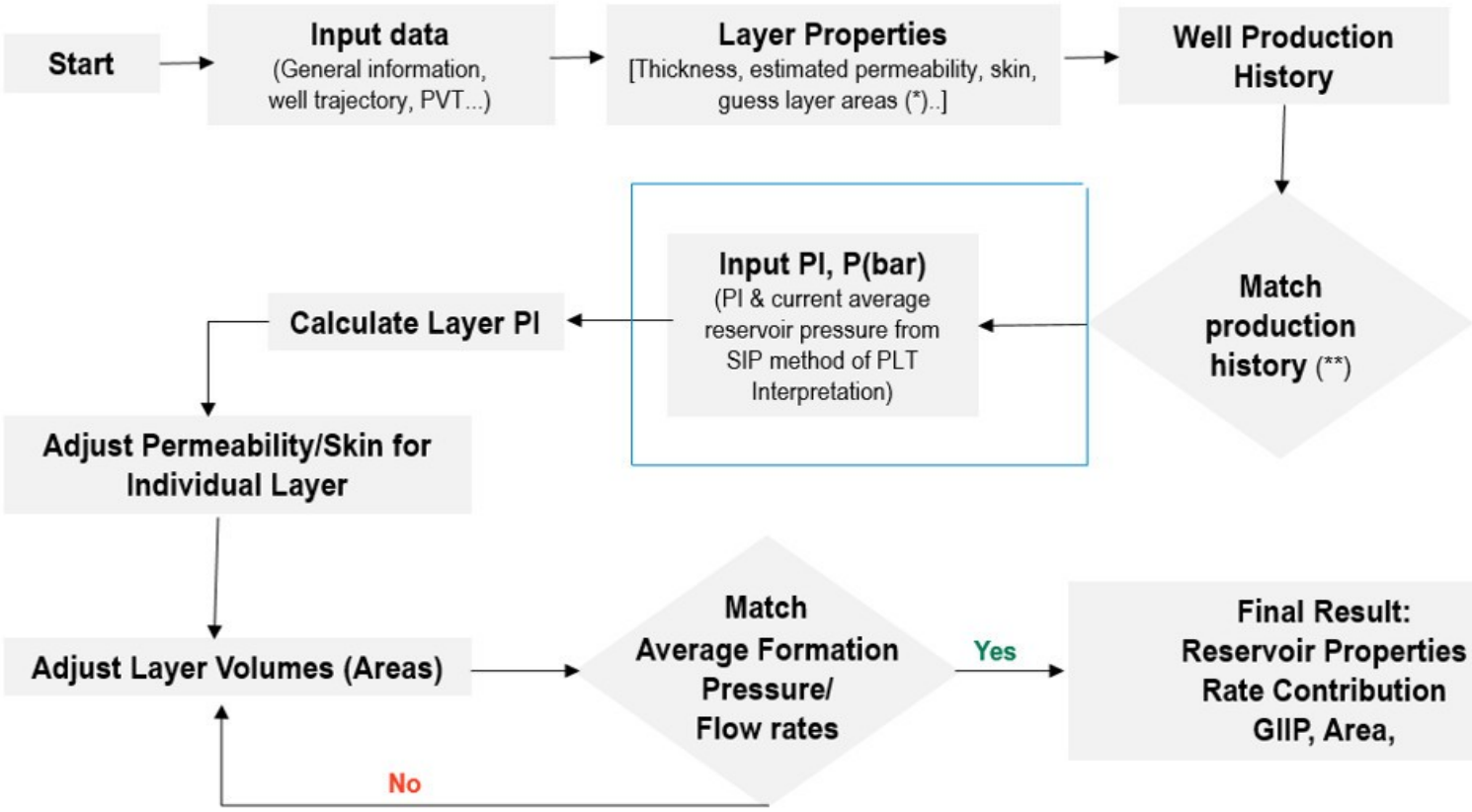


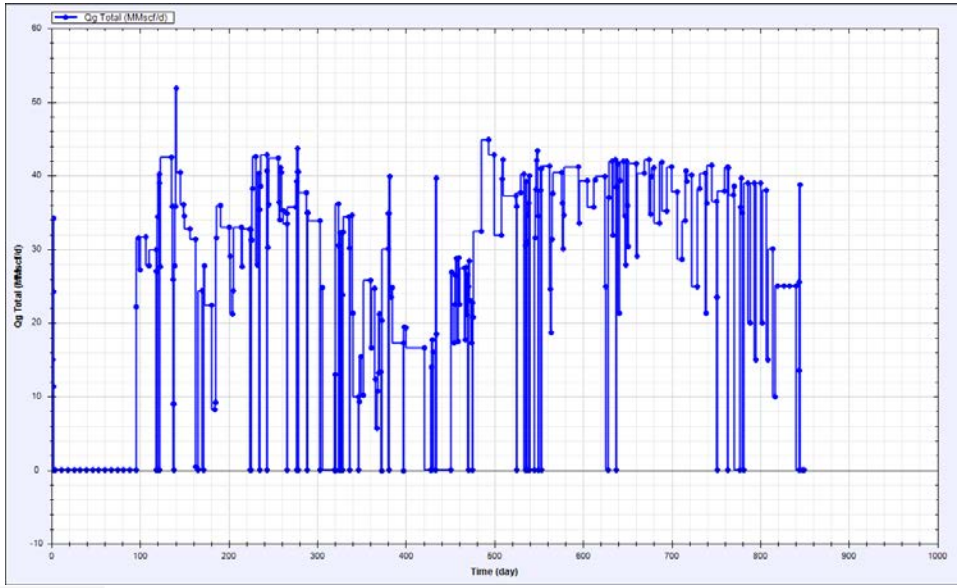
Total well kh from PBU, $(kh)_{app}$: **2793** mD.m and Skin 8.3

- Equations (1) & (2) (slide 6) are now applied
- Analysis results (right) show that the PBU severely underestimates total well kh (and skin)
- This arises because of a very large contrast in skin between zones
- Low skin in deeper zones and high skin in shallower zones because of:
  - Contrasting initial pressures
  - Completion methodology

Well A-1 Results by Zone		
	True zonal kh	Skin
	mD.m	
Zone 1	3643	108.3
Zone 2	434	62.5
Zone 3	1396	77.0
Zone 4	103	0.6
Zone 5	418	3.4
Zone 6	1014	2.7
Total Well	**7008**	

Commingled Well Analysis Methodology





(*): Estimated permeability, skin, guess layer area from offset well, PTA…
(**) Matching production history for every time step of each layer. If no production history exists, this step is used for production rate prediction, especially new wells

The workflow is based on SPE Paper 158733 (Estimating Zonal Gas-in-Place in a Commingled Well Using Results from Production Logs - Last, 2012) and is implemented in a suitable Commingled Well Model

A suitable commingled well model will include, for multiple timesteps:

- *Material balance for each layer*
- *Inflow equations for each layer*
- *Wellbore pressure drop calculations*
- *Ability to open/close zones when perforated or shut off*

… as well as the functionality to match modelled and measured SIP results

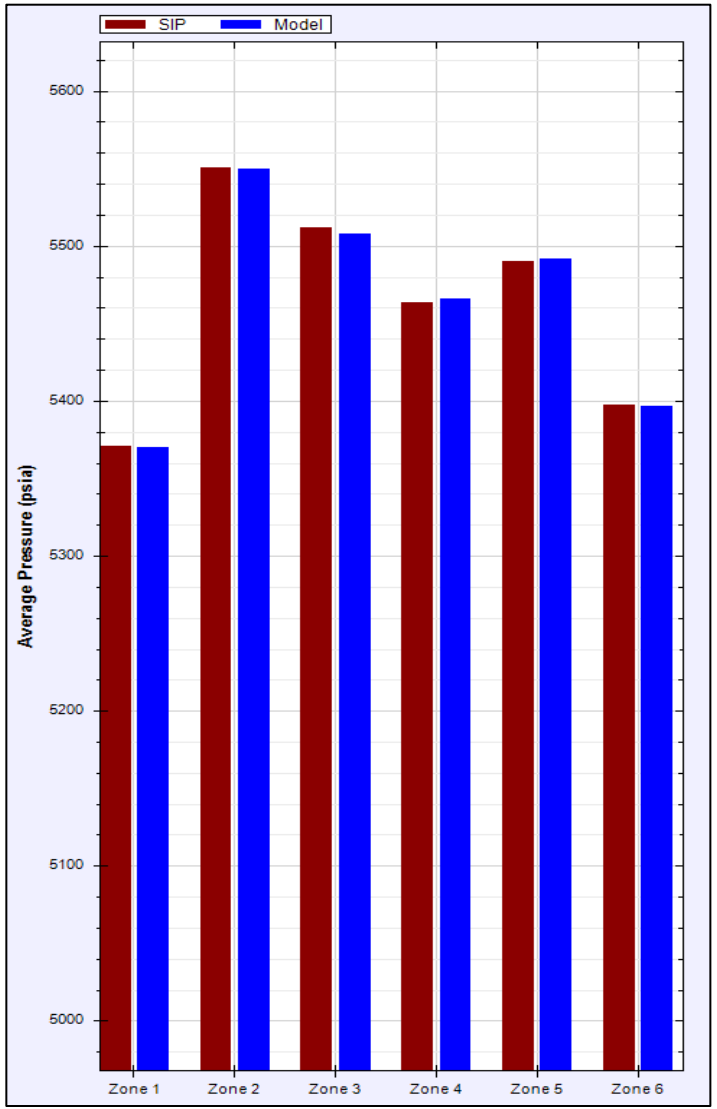
Commingled Well Analysis for Well A-1

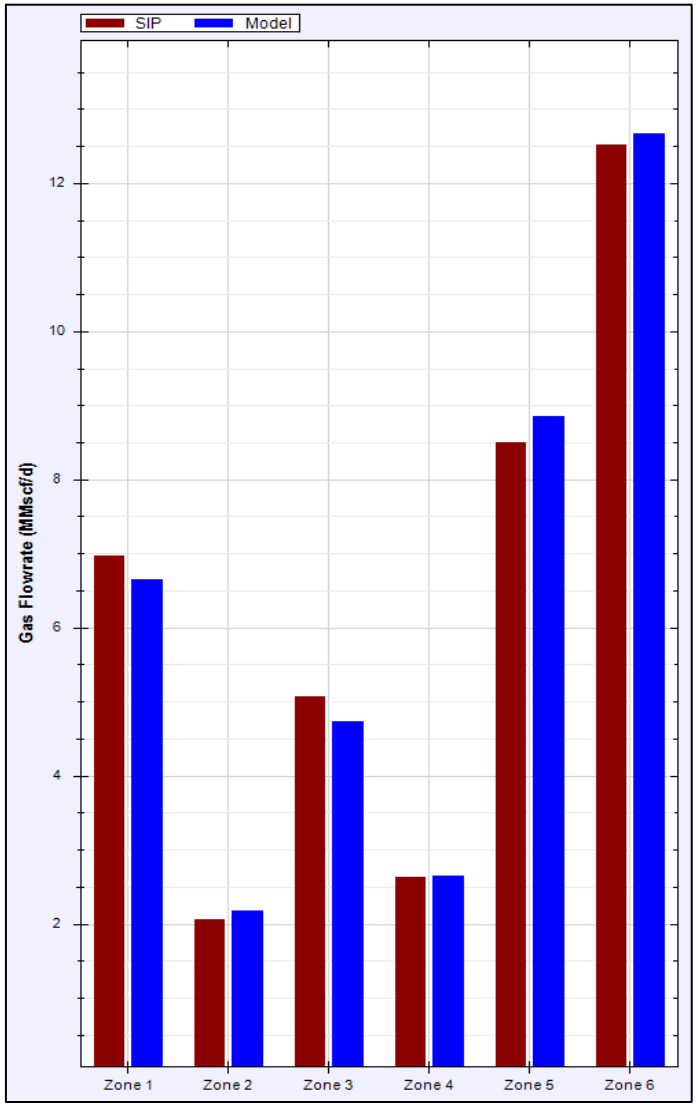
Adjust Layer areas until a match between modelled and measured SIP pressures is achieved

Analysis Results

Well A-1 Results by Zone		
	Drainage Area	Associated GIIP
	acres	MMscf
Zone 1	241	23,981
Zone 2	151	9,103
Zone 3	355	19,575
Zone 4	629	10,865
Zone 5	889	36,899
Zone 6	620	41,593
Total Well		**142,018**

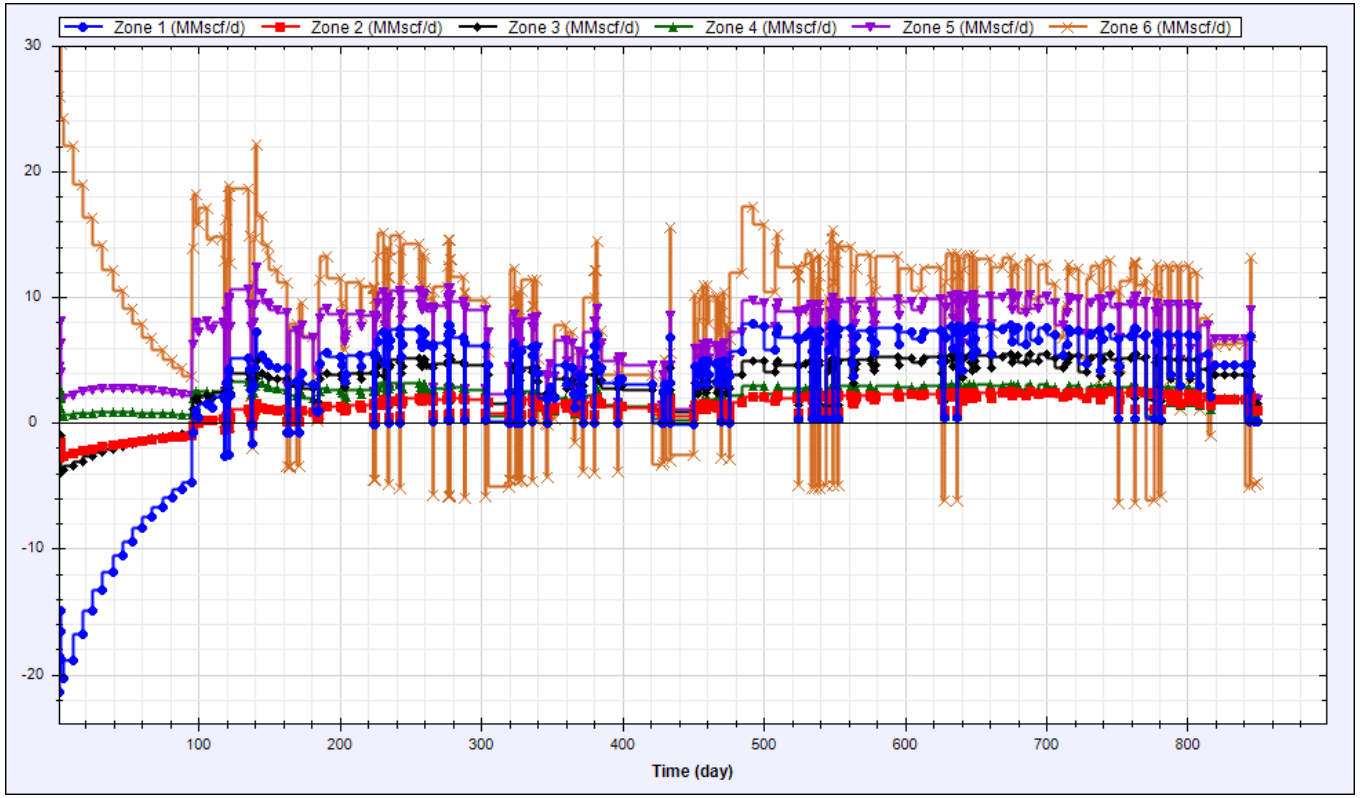
Match of layer rates is a QC and should be reasonably close





Gas Volume (GIIP) by Well and Full Field

- The preceding methodologies are applied for each zone and each well.
- For each zone, in each well, we obtain:
  - kh and skin
  - Gas initially in place
- GIIP's for each layer and each well are then summed arithmetically to obtain full-field GIIP by layer.
- Results can then be used to:
  - Back-calculate zonal allocation
  - Predict future performance and allocation



Conclusions

- The distribution of gas volume for each layer and well is obtained from the analysis.
- Layer drainage areas around the individual wells are estimated.
- The total field GIIP of the currently open zones, as estimated from the analysis of the Field A PLT campaign, proved to be a good match (within 5%) with the Operator's P50 static model estimates
- The total field GIIP was well-matched with other analytical methods such as rate transient analysis and flowing material balance.
- Analysis results helped to improve the history match of the Field A simulation model and the production forecasts.
- The "True kh and skin" (SPE 210634) approach can be applied to both gas and oil producers, as well as to water or CO_2 injectors.
- The GIIP analysis methodology (SPE 158733) is applicable for gas fields.