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

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Integrated uncertainty analysis and risk-anticipated field development plan

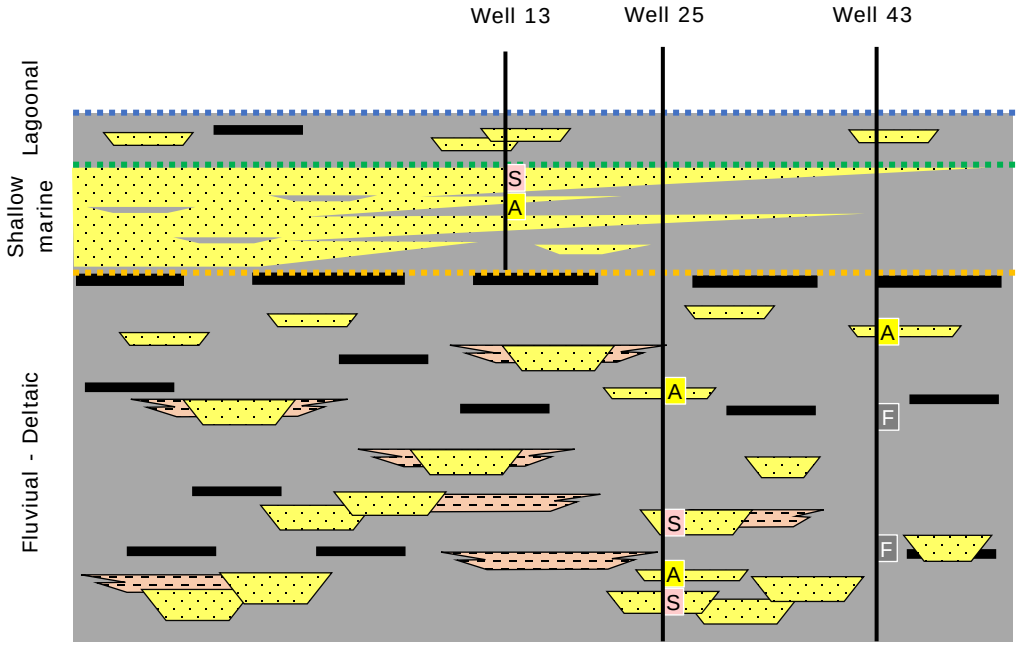
an example of Field ‘B’, Malay Basin

Kento Kaneko[1], Kyogo Amikawa[1], Dewanto Odeara Kartikasurja[1], W Zuraidah Bt Ahmad[2], Norlia Bt Azizan[2], Dr. Shota Yamashita[1]

1. JX Nippon Oil and Gas Exploration (BIGST) Sdn. Bhd. 2. PETRONAS Carigali Sdn. Bhd.

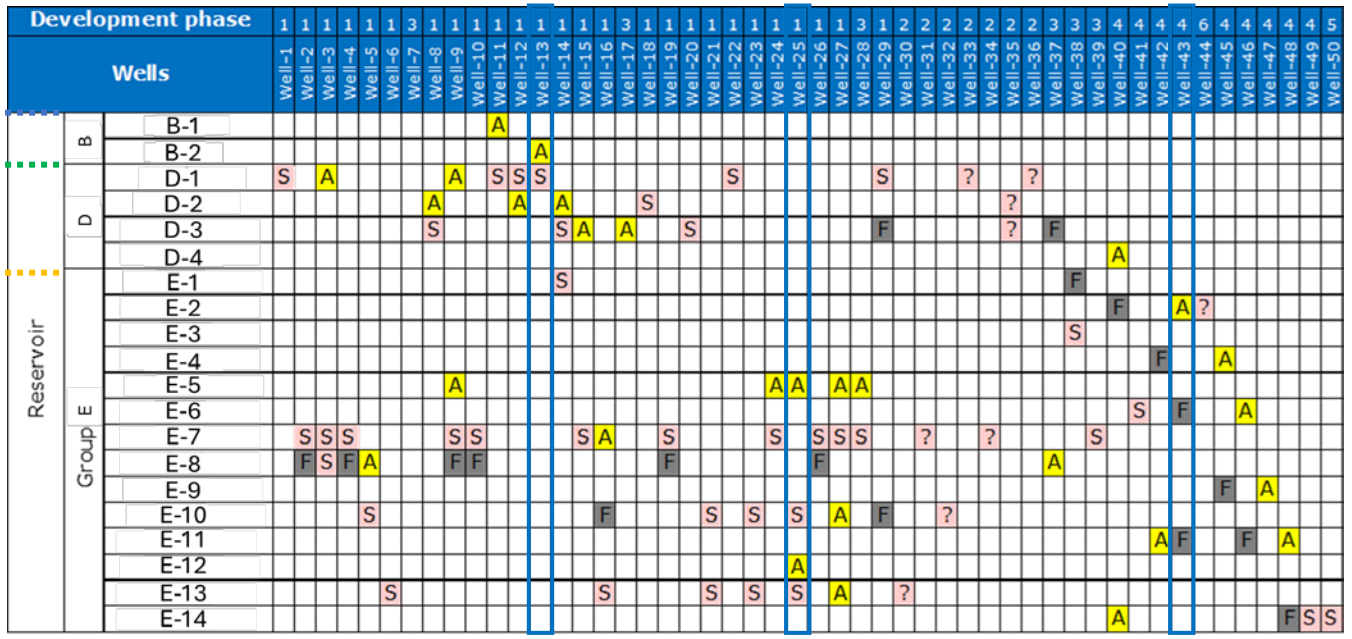
Introduction

Our challenges



NOTE) General schematic image to explain well result of Field 'J',
not reflecting actual reservoir distribution pattern or well alignment

Well completion status in Field 'J', Malay Basin



S: **Successfully** completed / produced as per plan

?: Produced (plan unknown)

A: Completed / Produced but not planned (**Additional** unit)

F: Planned but **Failed** to complete / produce

- Highly heterogeneous / channelized multiple-stacking reservoirs in Malay Basin
- Difficult to predict "sweet spots" before (or even after) development
- Low well success: often **fail to hit sands, fail to produce**
- Crucial to establish a development plan which incorporates risks of well failure
- **Key solution: Using multiple (i.e. probabilistic) models efficiently & realistically**

Methodology

Integrated uncertainty analysis workflow

Challenges

Static

Very high uncertainty of reservoir distribution patterns

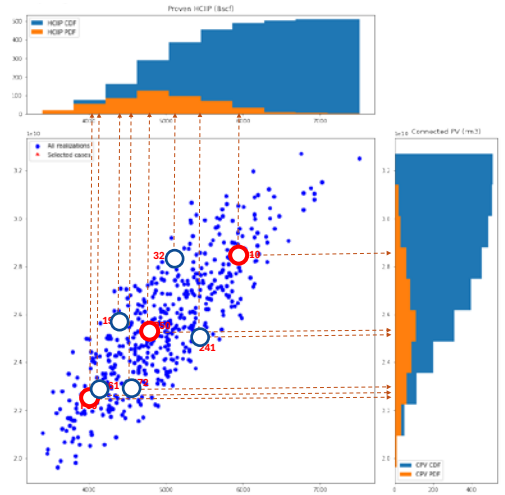
Dynamic

Time consumption of simulation with variable parameters

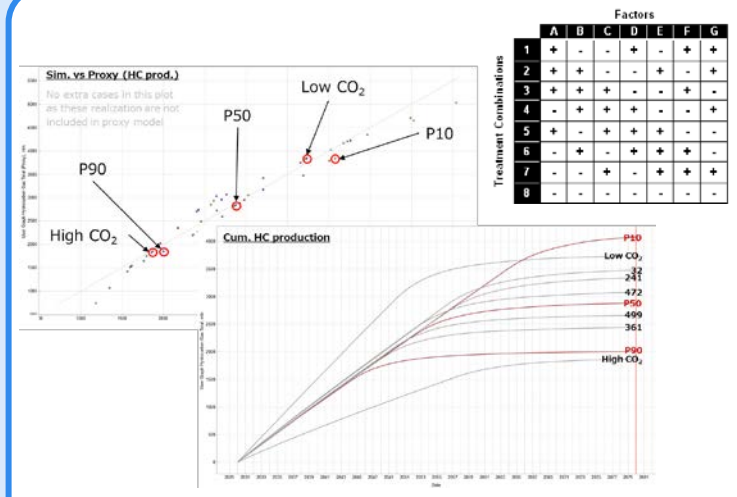
Development planning

Reality of development plan and possibility of well failure

Solutions

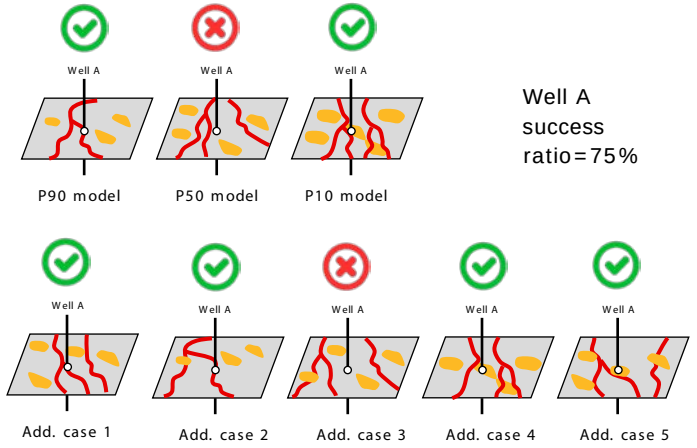


Multi-Scenario & Multi-Realization



Experimental design & proxy modeling

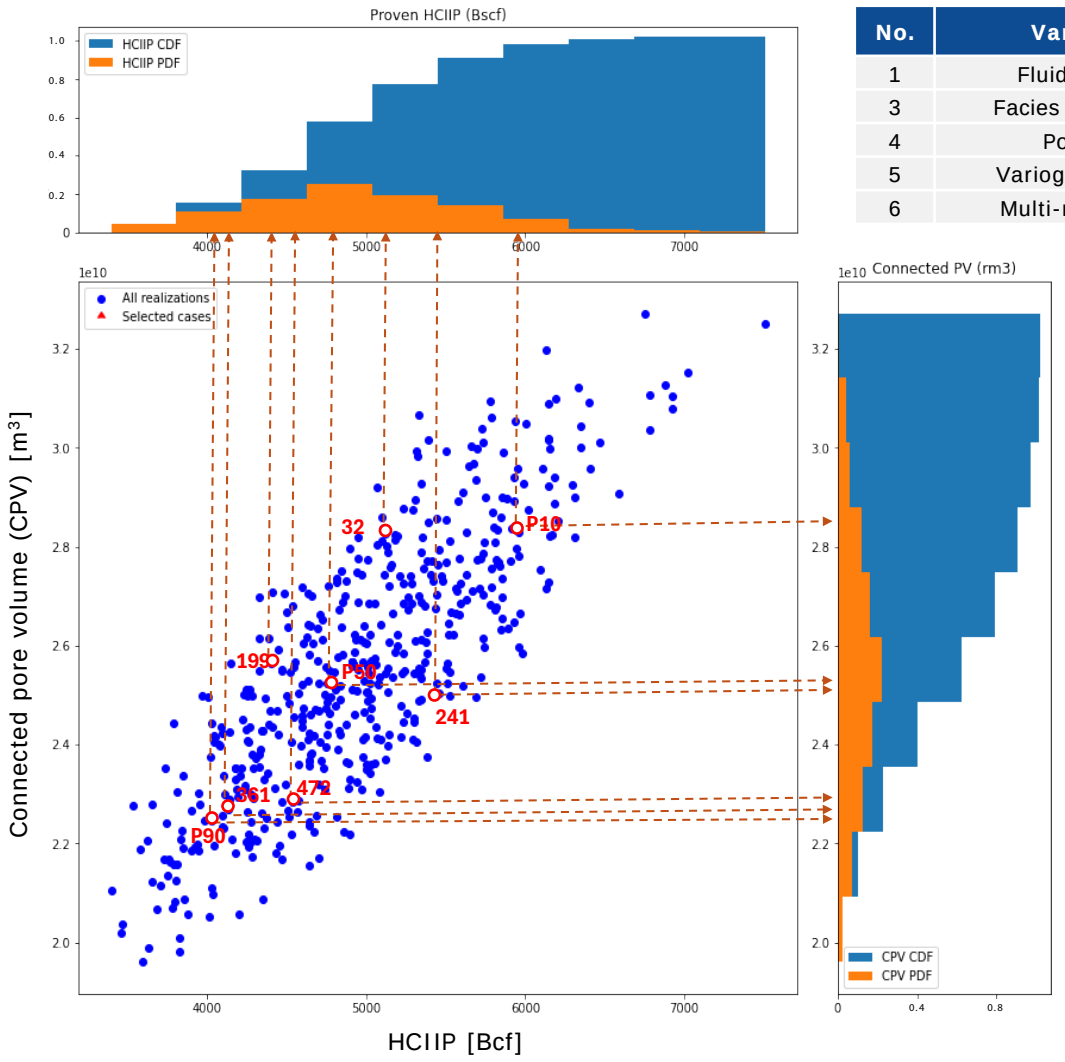
(Makishima et al., 2007)



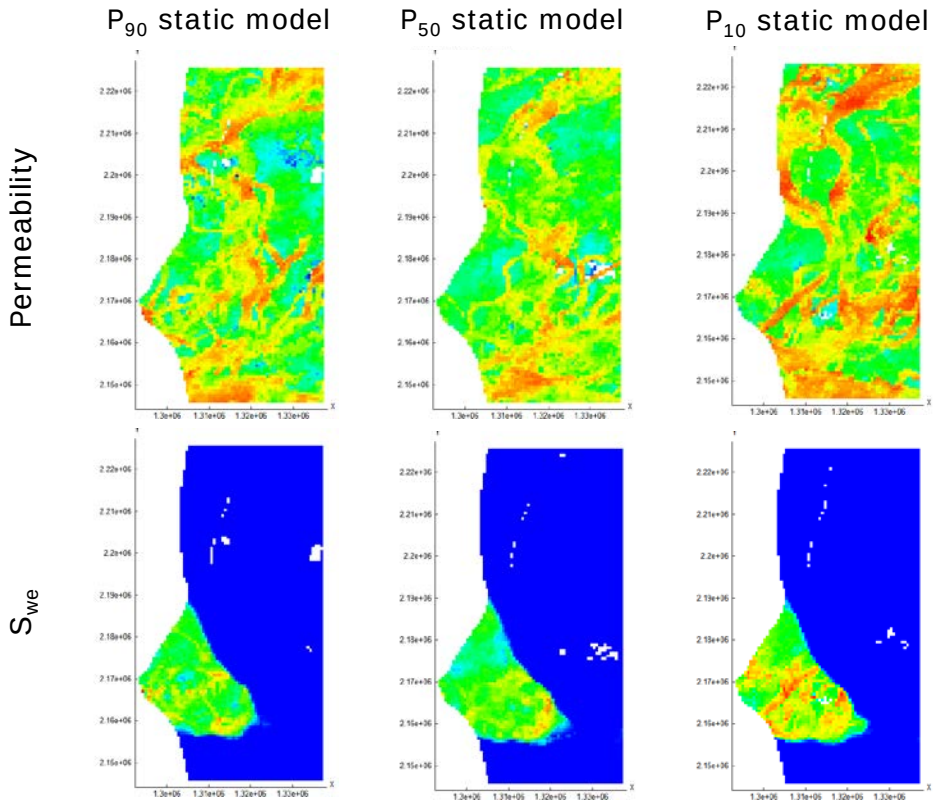
Well planning with multi-models & Reality check by analogy

Result

1) Uncertainty evaluation in static modelling: Multi-Scenario and Multi-Realization



No.	Variables
1	Fluid contact
3	Facies proportion
4	Porosity
5	Variogram range
6	Multi-realization



- Representative static model (P_{90}, P_{50}, P_{10}) were chosen via Multi-Scenario & Multi-Realization approach, focusing on both static (HCIIP) and dynamic (CPV from streamline simulation) indexes
- Additional 5 static models were chosen to cover the uncertainty ranges

Result

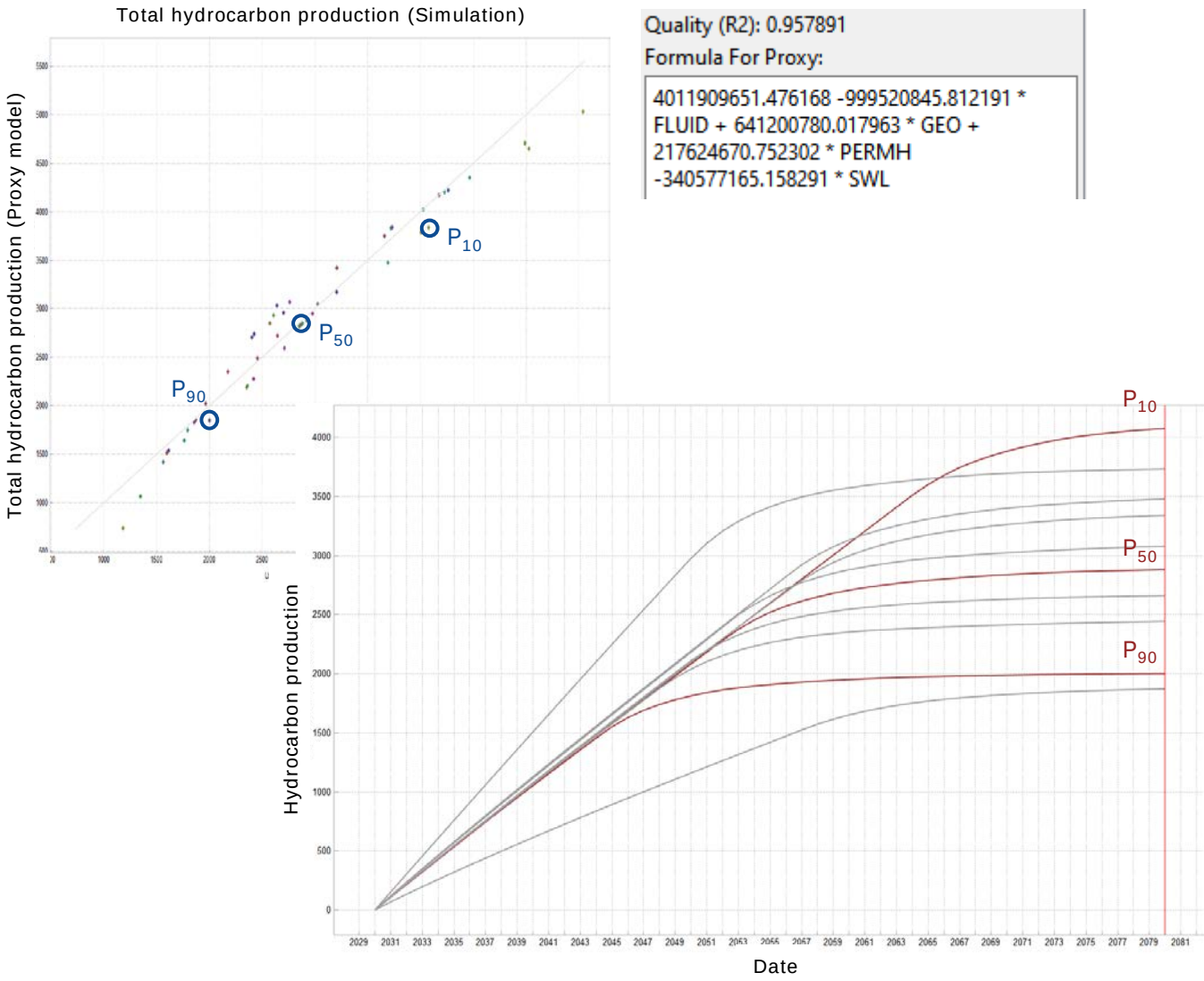
2) Probabilistic dynamic modelling using experimental design

No.	Parameters	Low	Base	High
1	**Static model**	P_{90} model	P_{50} model	P_{10} model
2	**Fluid model**	Lean-High CO_2	Base-Base CO_2	Rich-Low CO_2
3	**Swir**	+20%	RQI / Swir coeff.	-20%
4	**Permeability**	X 0.5	X 1	X 2

1) Screening dynamic parameters by sensitivity analysis

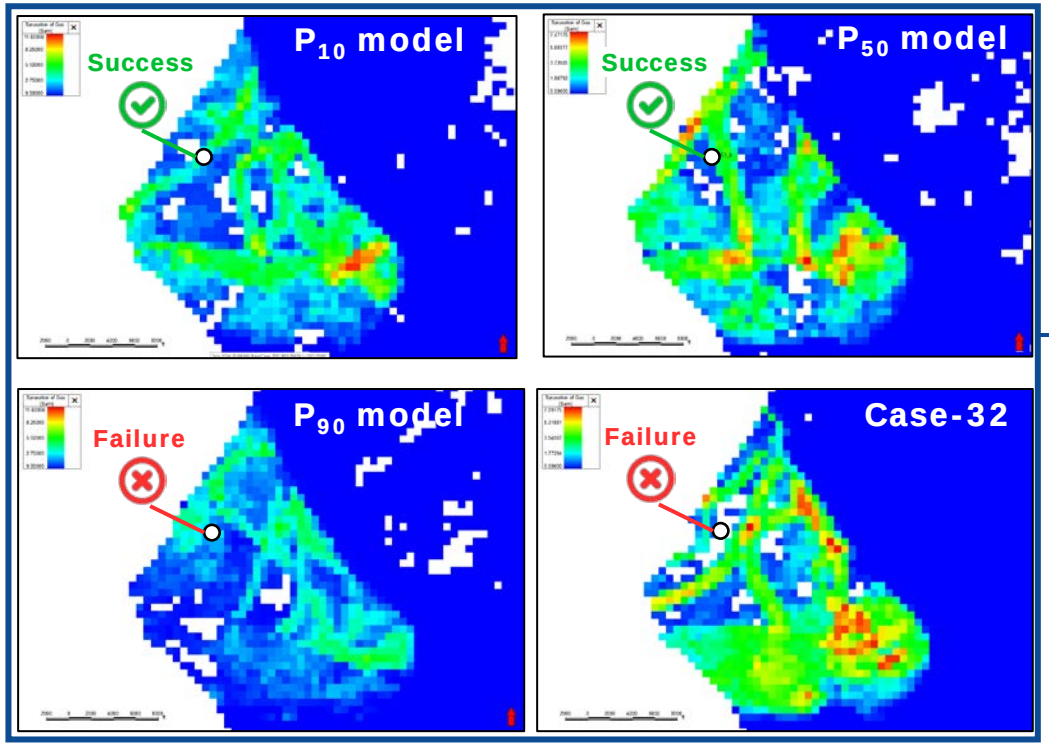
2) Select test cases by using experimental design (Plackett-Burmann)
Compress number of simulation runs: 3^5 (243)→12

3) Predict P_{10} , P_{50} , P_{90} values of HC recoverable and select equivalent dynamic models by Monte-Carlo simulations using the proxy model



Result

3) Well planning and well success ratio



Sufficient number of wells were proposed based on geological interest, and then dropped if they does NOT meet the following criteria;

1) Total production is more than 1.00 Bcf, AND

2) 1) is observed more than **50%** chance (>4 models among total 8 models)

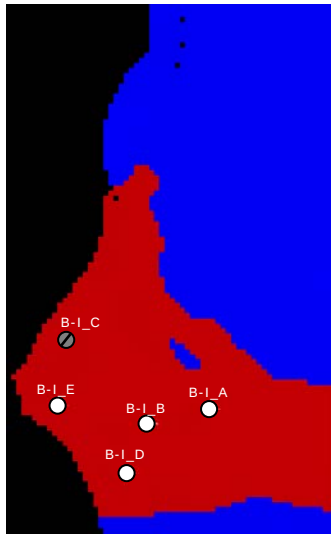
Res.	Well	WGPT [BSCF]								No. of DPs	Note	Success ratio	
		P50 model	P10 model	P90 model	Case 32	Case 472	Case 361	Case 241	Case 499			Well	Res.
B-I	B-I_A	0.00	0.00	0.00	12.28	0.00	7.96	15.22	3.89	4	-	50%	68%
	B-I_B	15.53	38.25	3.49	15.38	50.09	47.37	1.64	9.51		Re-access to exp well	100%	
	B-I_C	0.00	0.00	8.84	0.00	0.00	0.00	0.00	0.00		Dropped	13%	
	B-I_D	0.00	111.22	47.92	73.29	9.03	1.86	125.97	21.84		-	88%	
	B-I_E	59.58	7.51	15.74	0.00	28.56	29.94	15.78	31.94		-	88%	
B-II	B-II_A	22.33	0.00	44.69	18.28	33.35	14.20	56.89	44.60	5	Re-access to exp well	88%	67%
	B-II_B	40.94	67.01	0.00	60.93	0.00	40.52	57.60	50.19		Re-access to exp well	75%	
	B-II_C	10.74	25.67	0.00	4.42	2.94	0.00	0.00	5.41		-	63%	
	B-II_D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.51		Dropped	13%	
	B-II_E	18.88	50.93	1.29	87.00	101.61	22.84	34.67	8.28		-	100%	
	B-II_F	37.96	39.85	0.00	0.00	20.03	40.46	9.11	0.01		-	63%	
D-I	D-I_A	33.49	99.96	17.21	115.25	64.96	78.19	104.91	72.63	9	-	100%	100%
	D-I_B	95.24	135.04	62.70	92.61	27.65	66.66	103.73	39.98		-	100%	
	D-I_C	58.21	64.29	67.14	46.22	59.26	58.62	38.32	55.28		Re-access to exp well	100%	
	D-I_D	83.25	122.47	102.72	124.92	120.67	68.39	102.50	110.60		Re-access to exp well	100%	
	D-I_E	61.00	150.04	75.09	91.86	70.34	76.72	99.54	105.06		-	100%	
	D-I_F	57.36	184.96	105.65	150.46	108.66	132.20	121.77	114.85		-	100%	
	D-I_G	62.16	85.70	52.06	64.74	61.23	105.82	112.76	94.64		-	100%	
	D-I_H	129.96	110.49	42.89	61.31	55.54	100.25	106.68	124.96		-	100%	
	D-I_I	-	-	-	-	-	-	-	-		Accelerator	-	
E-I	E-I_A	0.00	0.00	0.65	33.60	18.07	20.23	0.00	13.13	-	Dropped	50%	43%
	E-I_B	0.00	4.88	0.00	0.27	0.00	0.00	0.00	0.05		Dropped	13%	
	E-I_C	5.28	0.00	0.00	0.00	5.88	0.03	48.19	0.00		Dropped	38%	
	E-I_D	46.26	0.00	12.66	8.48	0.06	0.04	0.00	4.11		Dropped	50%	
	E-I_E	18.56	31.02	1.72	0.00	1.75	0.00	0.00	24.72		Dropped	63%	
E-II	E-II_A	3.07	42.56	2.61	44.92	17.33	11.49	7.96	35.92	5	Re-access to exp well	100%	75%
	E-II_B	15.35	11.51	33.66	14.84	8.17	16.77	2.45	0.00		Re-access to exp well	88%	
	E-II_C	9.96	8.68	0.10	0.00	0.06	2.52	4.44	3.19		-	63%	
	E-II_D	0.63	10.85	0.00	0.00	2.98	9.77	7.22	0.00		-	50%	
	E-II_E	17.22	9.78	0.00	3.27	24.25	2.22	40.65	0.00		-	75%	
E-III	E-III_A	11.07	19.76	0.00	8.57	33.76	0.00	72.03	32.73	9	-	75%	83%
	E-III_B	17.01	39.03	1.32	12.46	1.44	0.06	26.36	11.27		-	88%	
	E-III_C	33.81	16.90	7.52	7.15	24.65	2.53	19.71	7.25		Re-access to exp well	100%	
	E-III_D	3.14	32.05	0.00	43.84	24.56	3.04	22.60	54.02		Re-access to exp well	88%	
	E-III_E	41.12	49.95	50.45	4.97	11.09	27.90	12.03	27.72		Re-access to exp well	100%	
	E-III_F	49.19	37.77	25.25	35.89	52.77	53.86	35.41	24.12		-	100%	
	E-III_G	0.00	4.31	0.35	22.10	21.22	0.00	0.00	14.11		Dropped	50%*	
	E-III_H	4.33	7.99	0.37	0.00	2.32	0.00	0.00	17.91		-	50%	
	E-III_I	4.77	33.24	11.28	11.05	36.03	46.85	2.67	7.32		-	100%	
	E-III_J	-	-	-	-	-	-	-	-		Accelerator	-	
Summary	Total	1067.39	1653.66	795.42	1270.36	1100.29	1089.30	1408.84	1205.71	32		-	-
	Average	35.56	53.34	34.52	45.36	35.49	40.34	48.58	38.89	-		76%	-

*Success rate is on-border (50%) but dropped due to low production in all 8 realizations

Result

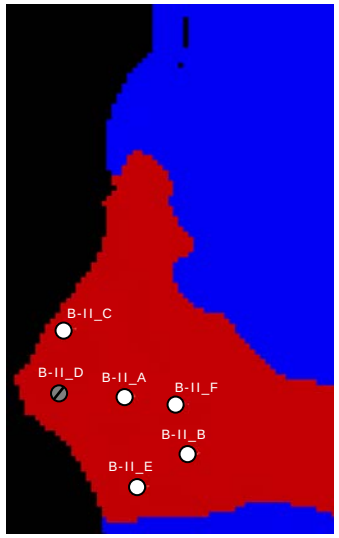
4) Well planning with risk anticipation

B-I



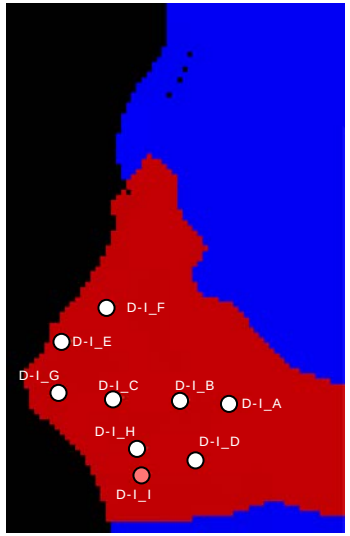
4 wells

B-II



5 wells

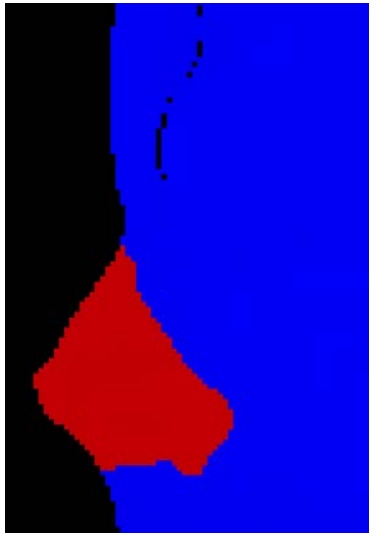
D-I



9 wells

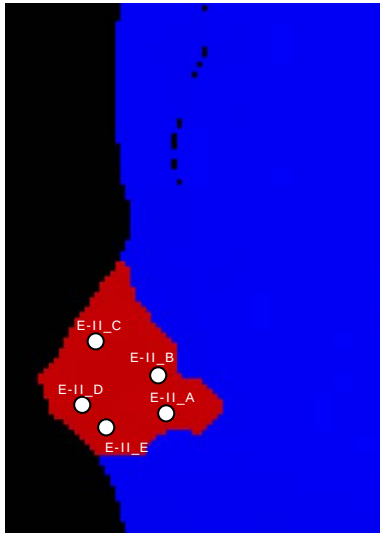
(To be commingled in the final plan)

E-I



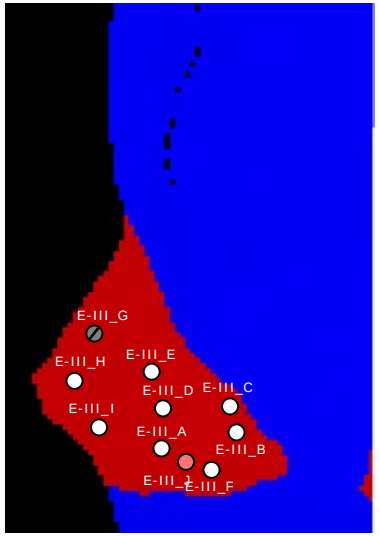
Back-up reservoir

E-II



5 wells

E-III



9 wells

(To be commingled in the final plan)

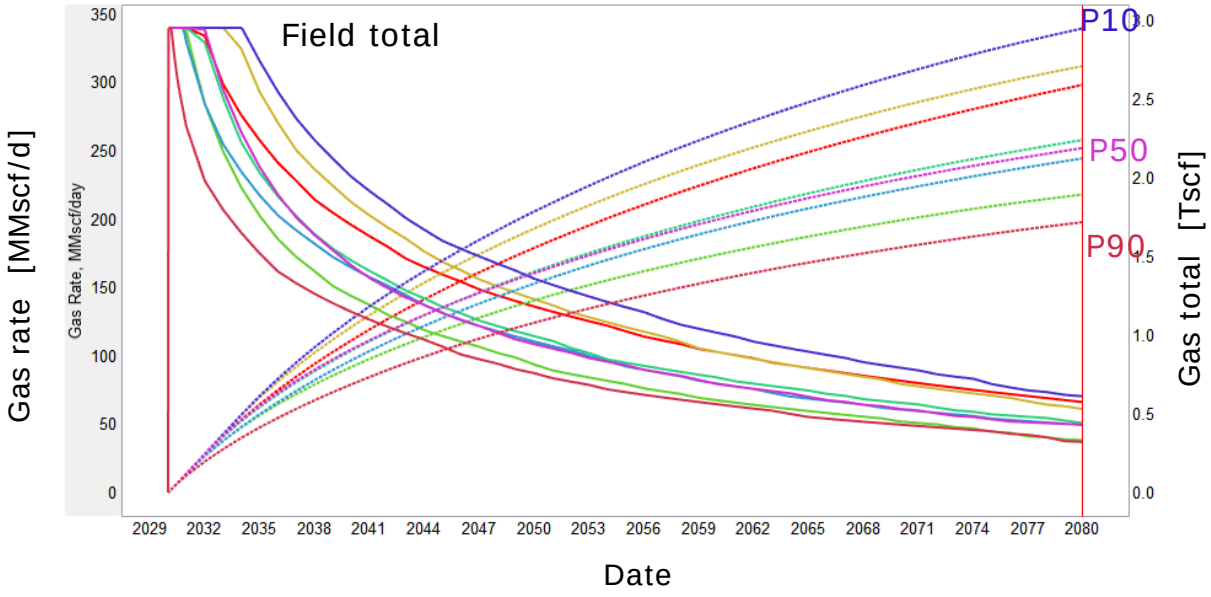
○ : Proposed well

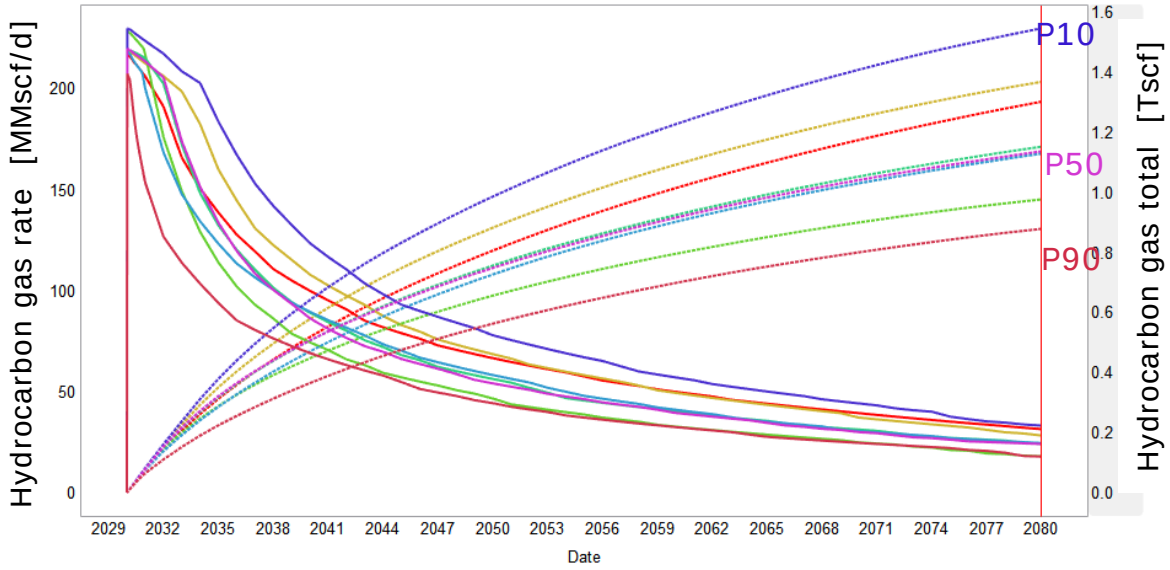
◍ : Dropped wells due to low success ratio

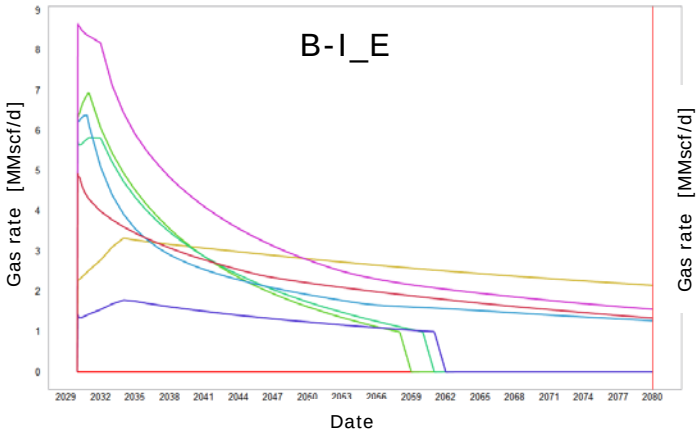
● : Accelerator

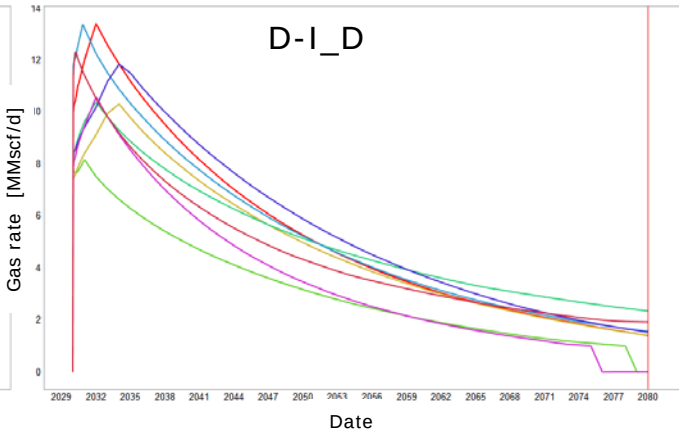
Result

5) Production profiles and uncertainties









- Estimated production profile with range of uncertainty
- Evaluated uncertainty in production performance of each well

Result

Validation of well success ratio and number of wells with analogy

Reservoirs	Success ratio		Number of wells			
	Analogy [A]	FDP	Analogy (Success only) [B]	Analogy (with back-up) [= B / A]	FDP	
					Per reservoir	To be commingled in the final plan
B-I	-	68%	-	-	4	5
B-II	-	67%	-	-	5	
D-I	100%	100%	7 - 17	7 – 17	9	9
E-I	65% (48 – 88%)	43%	1 – 3	2 - 5	(Back-up res.)	9
E-II		75%	1 – 4	2 - 6	5	
E-III		83%	3 – 7	4 - 11	9	

- Approximated success ratio and number of wells from GIIP of each reservoir, using analogy of nearby fields
- **Number of wells in FDP supported by analogy in nearby fields, in consideration of well-failure risk**

Conclusions

Development plan of Field ‘B’ in Malay Basin was established by a holistic approach in consideration of well-failure risk, composed of followings;

- Multi-Scenario and Multi-Realization of static models, capturing high uncertainty of reservoir distribution
- Proxy modeling with experimental design, reducing time consumption of multiple dynamic modeling and simulations
- Consistent well success ratio validated by actual results in nearby fields