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Shaping the future.

Brage Statfjord Revitalization

Subsurface Workflow during an Infill Well Project

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Agenda

- Introduction to Brage Statfjord

- Basis for new wells
- Static model

- Case Study: uncertainty handling during the lifetime of the project
  - Identify phase
  - Select phase

- Conclusion

Introduction to Brage Statfjord

- On production since September 1993, Statfjord has contributed over 50% of the total Brage production (3 other reservoirs)
- Concept: **Sand-Box** → connected reservoir

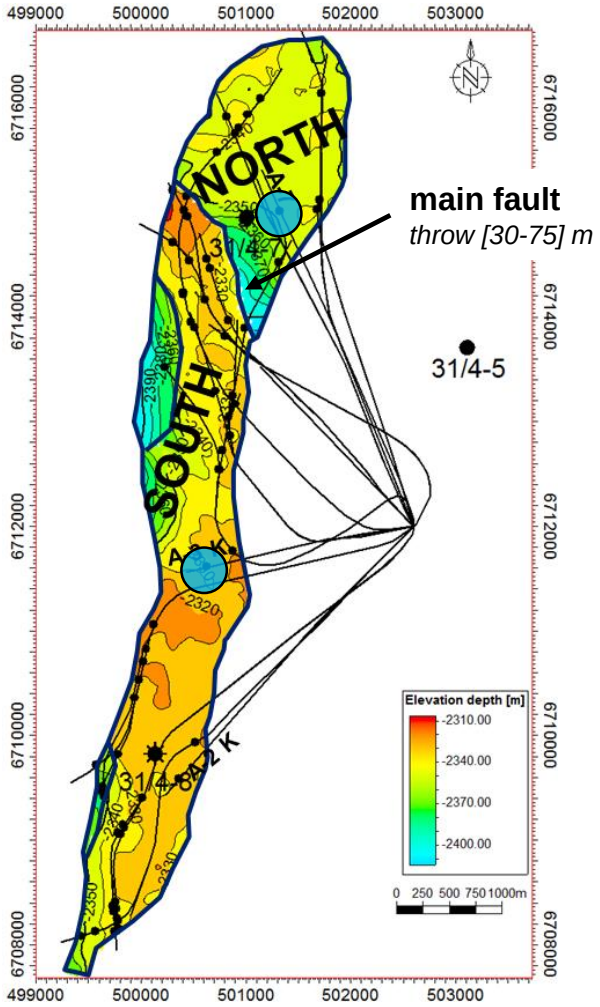
Sand

Depositional environment: braided river system
Facies: Amalgamated sand channels, eroded overbank shales, local calcites
Good properties: Darcy sands, Phi ~ 0.25

Box

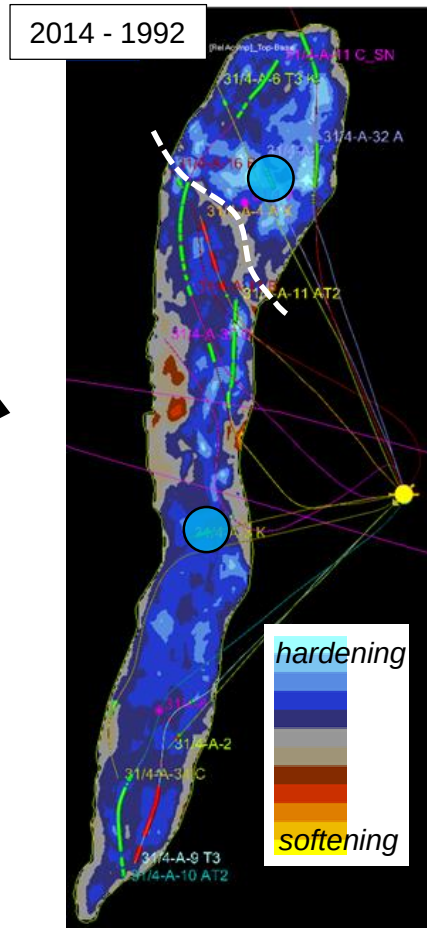
Bounded horst ~ 8x1 km² with 2 segments in communication
2 smaller downthrown blocks in South
Thickness: 75-110 m

- Dead oil with common initial FWL and limited bottom aquifer: 60m oil column in South, less in North
- STOIIP ~ 53 MSm3 / RF >=55%
- 13 historical producers: mostly long horizontal, near reservoir top (now 5 active in South)
- 2 main historical injectors: slanted perforated around and below the initial FWL (now 1 active in South)



Basis for a Well Project in South

- Natural production decline: need for infill targets
- Based on STOIIP estimates and historical production:
  - RF: 65% N vs 55% S → Potential in South
  - Backed-up by 4D seismic signal
- Explanations:
  - ratio of (injected water) / (pore volume)
  - well density
- Contingency for South injector failure

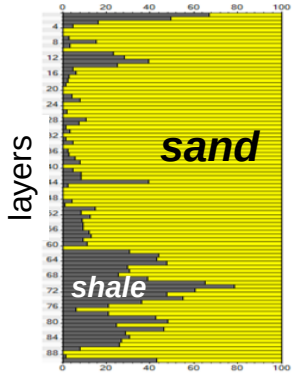


4D map: change in AI

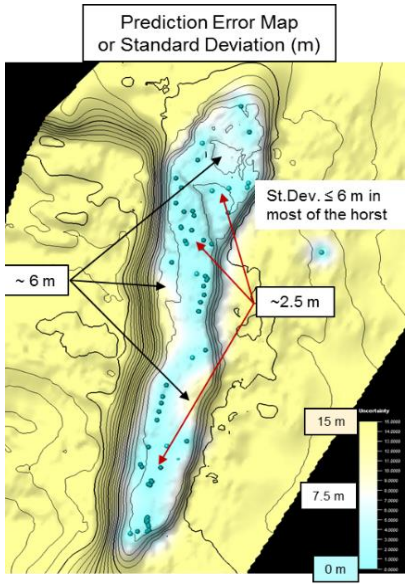
Static Model (Pre Well Project)

	observations / starting point	chosen option
Properties	logs from previous model	*keep all except* new Sw logs (n,m - Archie) → 3 J-functions for initialization → 1 kept after early HM
Properties	High sand proportion No well-well shale correlation Calcite nodules 2-4 % of GRV	Facies: Sand / Shale (SIS) with VSP K/Phi: Gaussian sim. (shale inactive) NTG
Grid	High marker control Depth conversion (top surf.) - Error map - U: +/-3% in GRV (200 real.) Bounding faults U: +/-3% in GRV	Use most likely top surface Isochore down 50*50*1 m^3 / no upscaling

single static realisation: base case



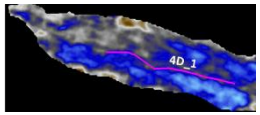
Vertical Sand Proportion (VSP)



Identify Phase – Prove Feasibility

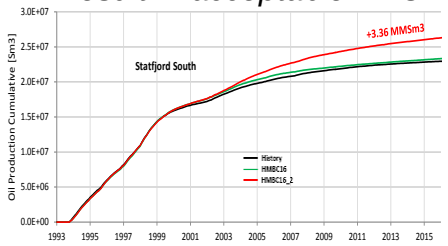
Manual **HM** (focus: South and oil prod.)
- sensible parameters: Kv/Kh, Rel perm
- need to include vertical baffle

control from SCAL data



also seen in 4D seismic

result: 2 acceptable HMs

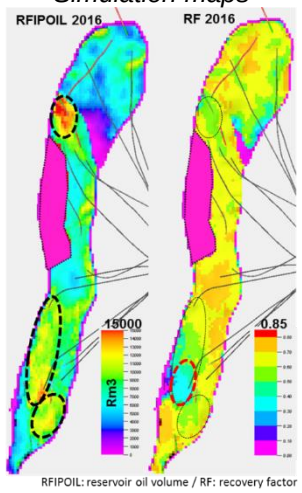


Well **Concept**
- volume balance in South tank
- avoid closing current producers

	Pres [Bar]	
Liquid [Sm3/D]	≈ 200	230
A-4 K	3480	4500
A-9 T3	3564	4000
A-10 AT2	3895	4250
A-16 B	3331	4150
A-34 C	3409	3900
Total Production	17679	20800
Total Injection	14500	14500
+1 producer		4250
+1 injector		10000
Total Production		25050
Total Injection		24500

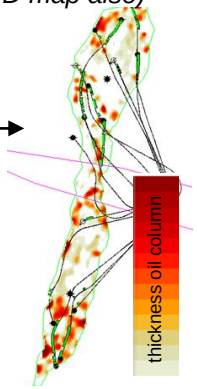
Well-Pair:
1 producer
1 injector

Simulation maps



Well **Locations**
- same strategy as hist. wells: 2D prob.
- limited number of tested configurations
- use 2D maps for producer

Seismic attic oil map
(4D map also)

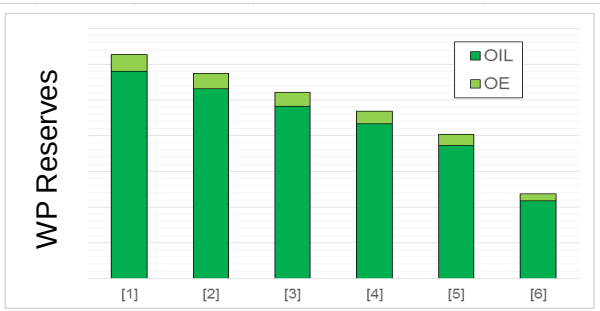


iterations

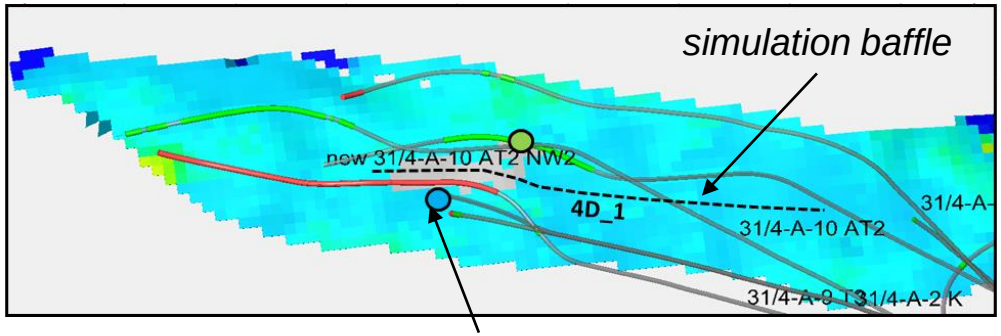
Drilling & Well Dept.

Identify Phase – Prove Feasibility

- Reserves estimate: field delta oil production - 6 cases
  - 2 HMs
  - Different prediction settings in the “Do Nothing” case (reservoir pressure)



Well-Pair



injector close to old producer, convenient slot (well cost)

Project approved

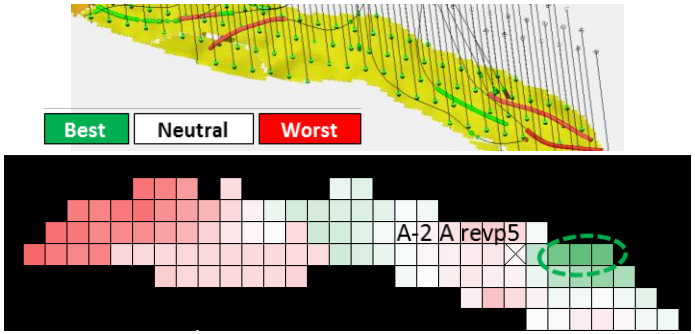
Select Phase – Optimize

- Part 1: still using the base case static model and the 2 HMs

Compare Well-Pair with other **concepts** (>10)
- [1-2] new wells
- use active wells for injection or short sidetracked prod.
- economic screening

⇒ *Well-Pair ranks best Producer before injector*

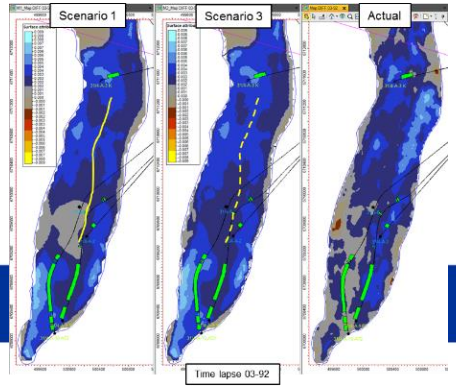
Injector location
- tested every 250 m



⇒ *Move injector ~ 500 m South*

checked on 4 realisations (2HMs, 1/0 baffle)

Simulation baffle tested against synthetic 4D seismic



⇒ *Baffle "confirmed" and mapped with 3D seismic*

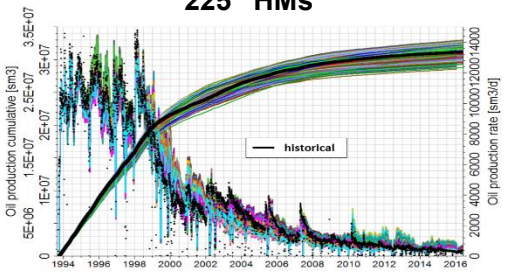
Select Phase – Uncertainty

- Part 2: more static realisations

Petrophysical update (unpredicted)
- core data is now stress corrected
- K/Phi correlation clarified

- Variograms (facies, props.)
- seeds
→ small range in STOIIP

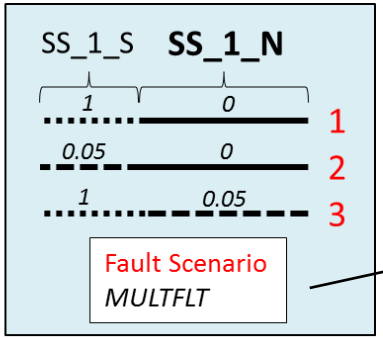
225 "HMs"



Workflow – "discrete" variables

- 25 static realizations..... a: [1-25]
- 3 "dynamic sets"..... b: [1-3]
  1 → HMBC16 / 2 → intermediate / 3 → HMBC16_2
- 3 fault scenarios..... c: [1-3]

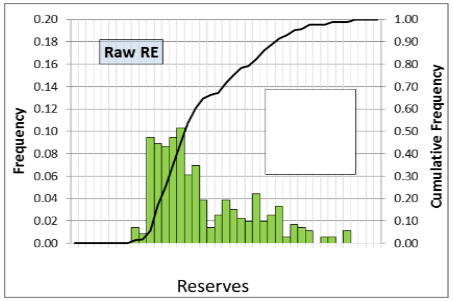
case name: **XXX_a_b_c** *(all combinations)*

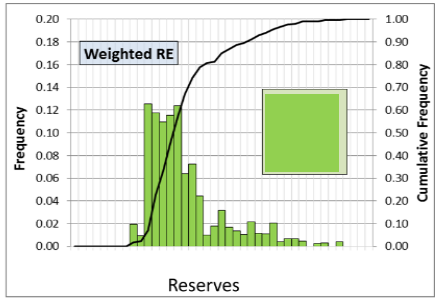


4D baffle geometries

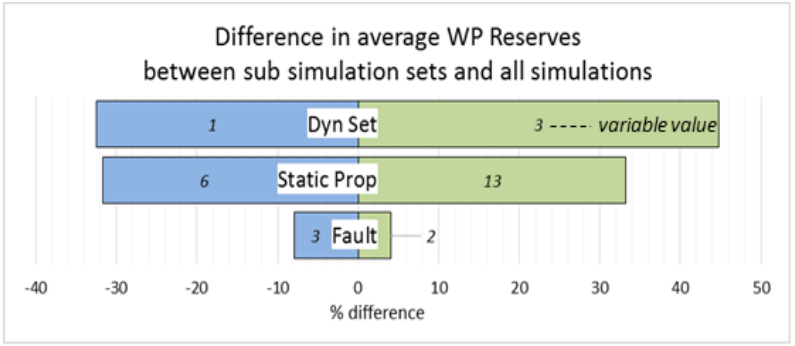
From previous phase:
Kv/Kh
Rel. perm

Reserves Estimate
- cases assumed a priori equiprobable
- for each case - HM mark (criteria, OF)
- screening or "weighting"



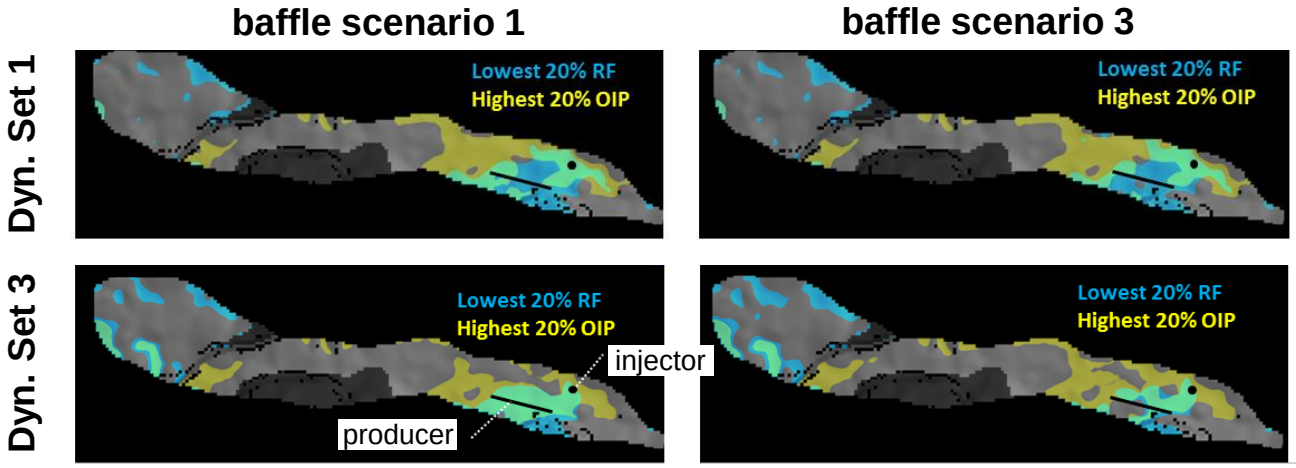


Select Phase – Posterior Analysis



Impact of input variables

Maps: posterior justification for the WP location



Project approved: wells to be drilled in 2017

Conclusion

- How is the uncertainty on the well-pair evaluation evolving during the project ?
  - confidence is building up after each milestone (decision)
  - complexity and number of parameters is increasing

- The exercise of looking back at the full project workflow is performed too rarely

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Acknowledgements to Petech colleagues and our license partners:

pointresources

REPSOL

VNG Norge

Faroe

Questions ?