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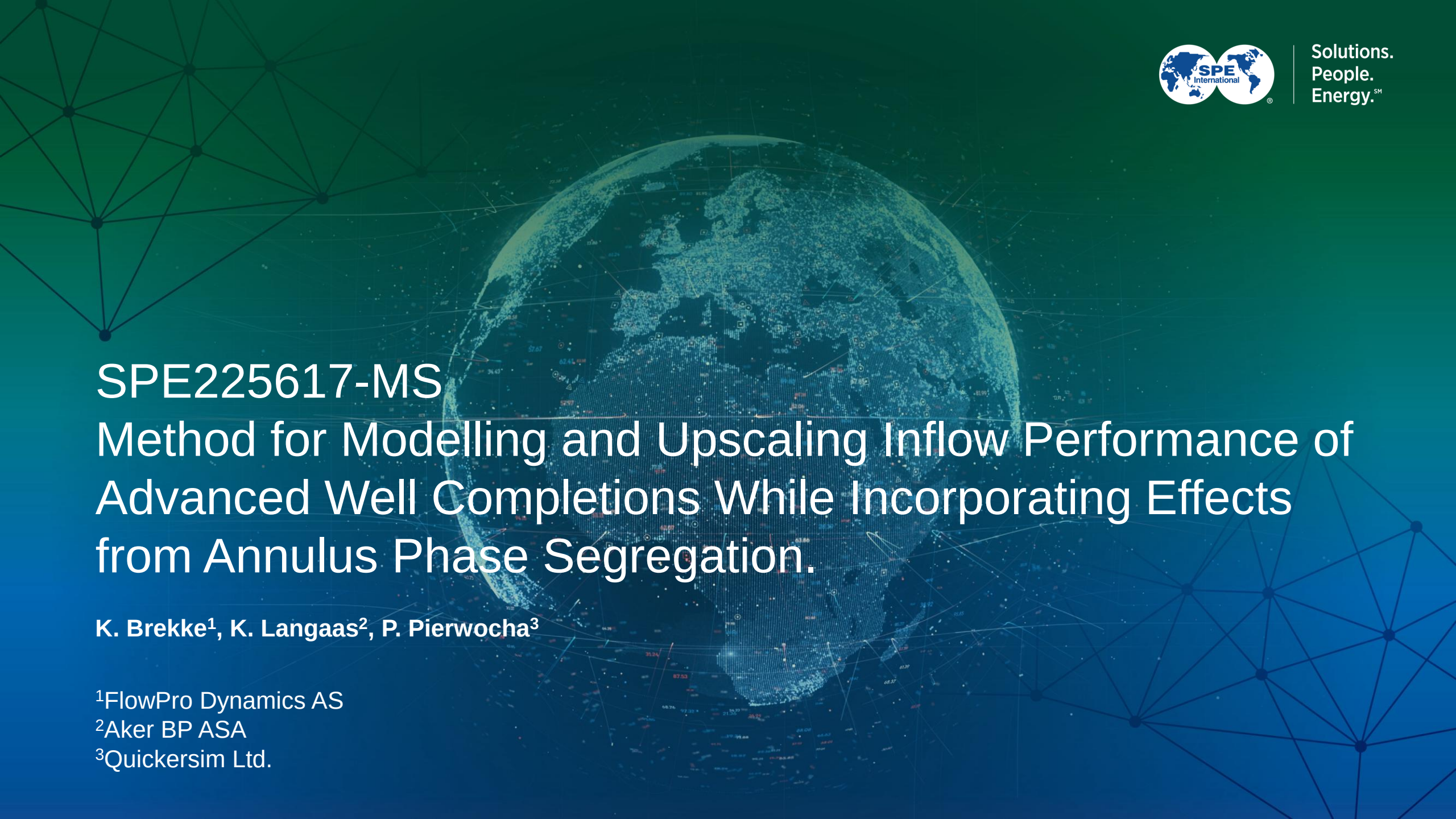

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SPE225617-MS
Method for Modelling and Upscaling Inflow Performance of Advanced Well Completions While Incorporating Effects from Annulus Phase Segregation.

K. Brekke[1], K. Langaas[2], P. Pierwocha[3]

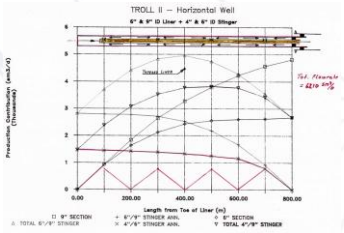
[1]FlowPro Dynamics AS
[2]Aker BP ASA
[3]Quickersim Ltd.

Outline

- Inflow Control Technology (ICT) modeling history (from personal archive)
- Description of a new ICT analysis and upscaling method
- Example reservoir modeling using the new work process
- Method validation (comparison with Ansys Fluent)

ICT Modeling History

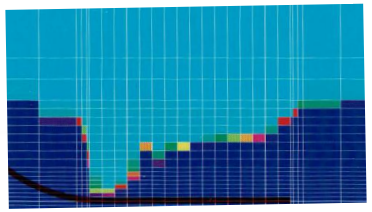
1991
First ICD hand calculations on Troll West (Norsk Hydro)



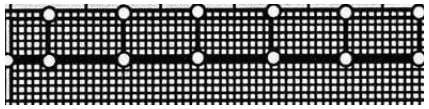
1992
First ICD patent and prototype developed for Troll West

First steady state ICD network simulations

1993
First coupled reservoir and detailed wellbore simulations



1994-1996
Theory for neTOOL type wellbore modeling being developed



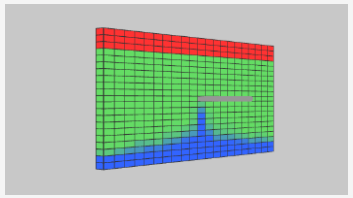
2019-2024
Autonomous valve technology emerging

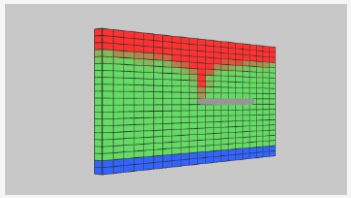
Implementation of wellbore network models in reservoir simulators.

Insight - CFD based ICT analysis and upscaling software

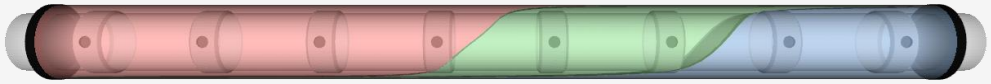
Motivation for New Work Process

- Simulate all ICT (inflow control technology) physically correct.



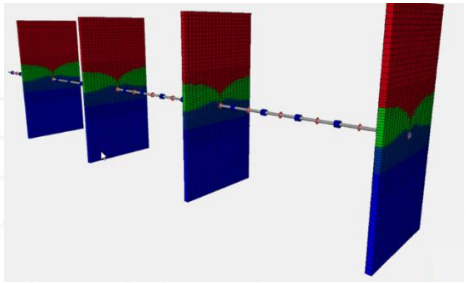


Water and gas influx



Annulus phase segregation

- Efficiently include ICT performance in dynamic reservoir simulations.

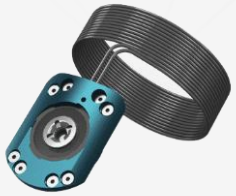


Reservoir and well simulation

Inflow Control Technology

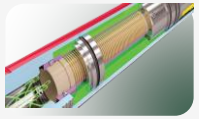
ICD

AICV



AICD (RCP)

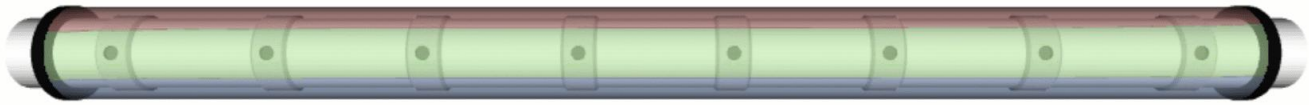
ICV



DAR / D-AICD

New Work Process - Main Features

- Captures the physics of annulus phase segregation and valve interaction.
- Custom CFD – 3 million times faster than Industry standard CFD for a typical zone.
- Integrates upscaled zone inflow performance in reservoir simulators through the RCP equation or VFP tables.
- Design of multi zone inflow control completions.
  - Type of ICT
  - Number and size of valves
  - Distribution of valves

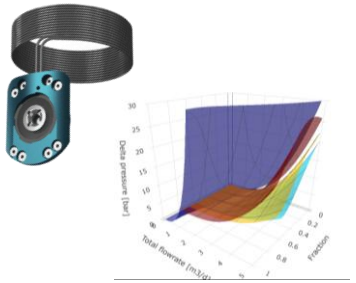


New Method and Procedure

Lower Completion Design

1

Single Valve Performance

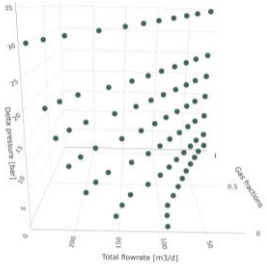


2

Define Zone Geometry and ICT Setup

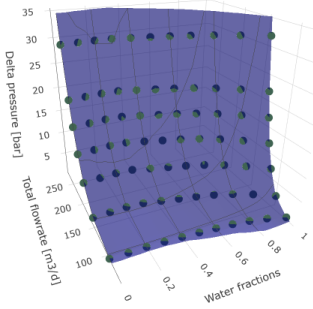
3

Multiple Runs of Zone Inflow Simulations



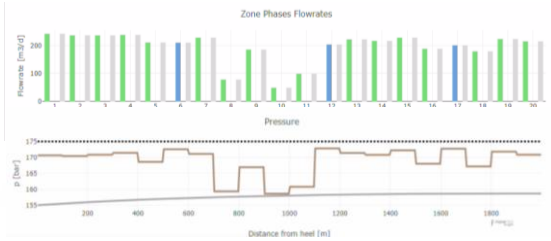
4

Upscale Zone Inflow Performance



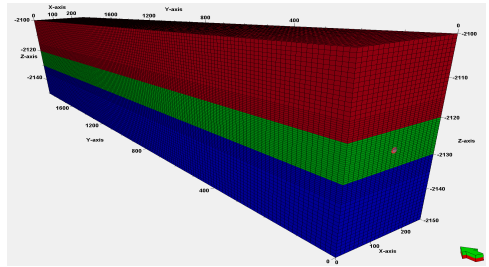
5

Screen and Optimize with Multi Zone Well Model



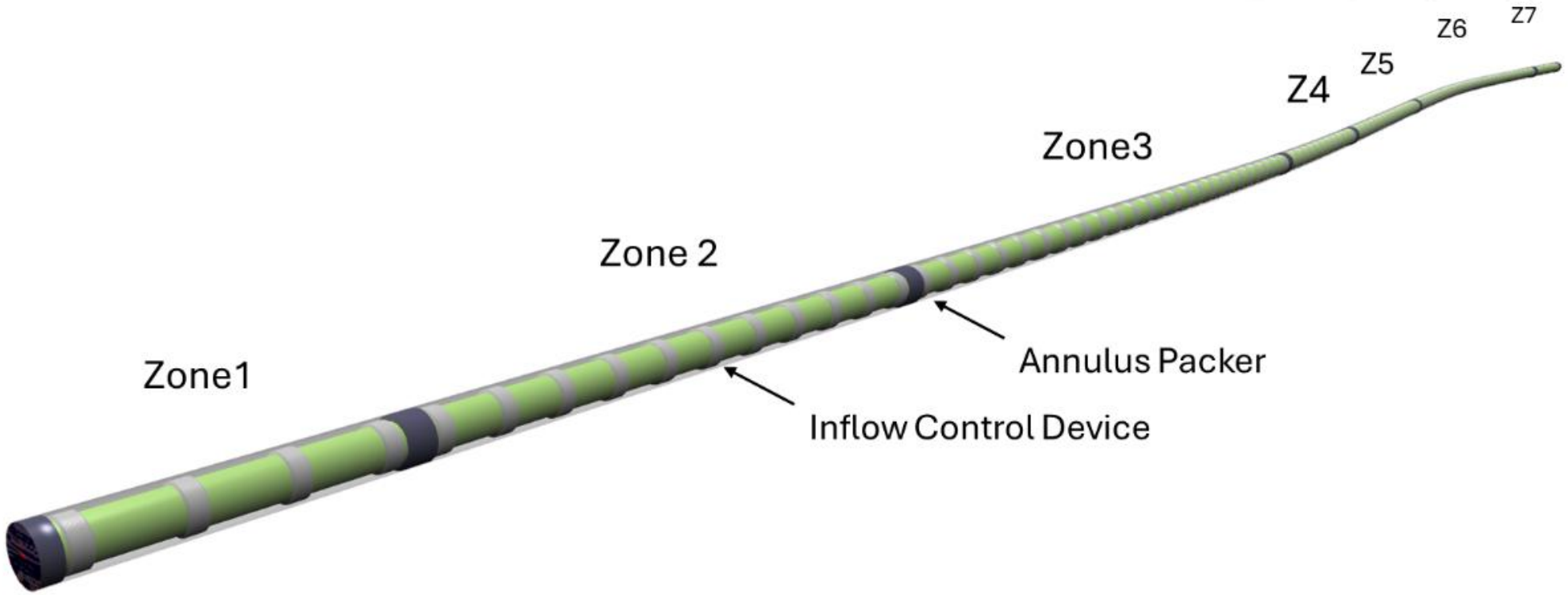
Optional - 6

Dynamic Reservoir / Well Simulations



7

1) Define Lower Completion Design



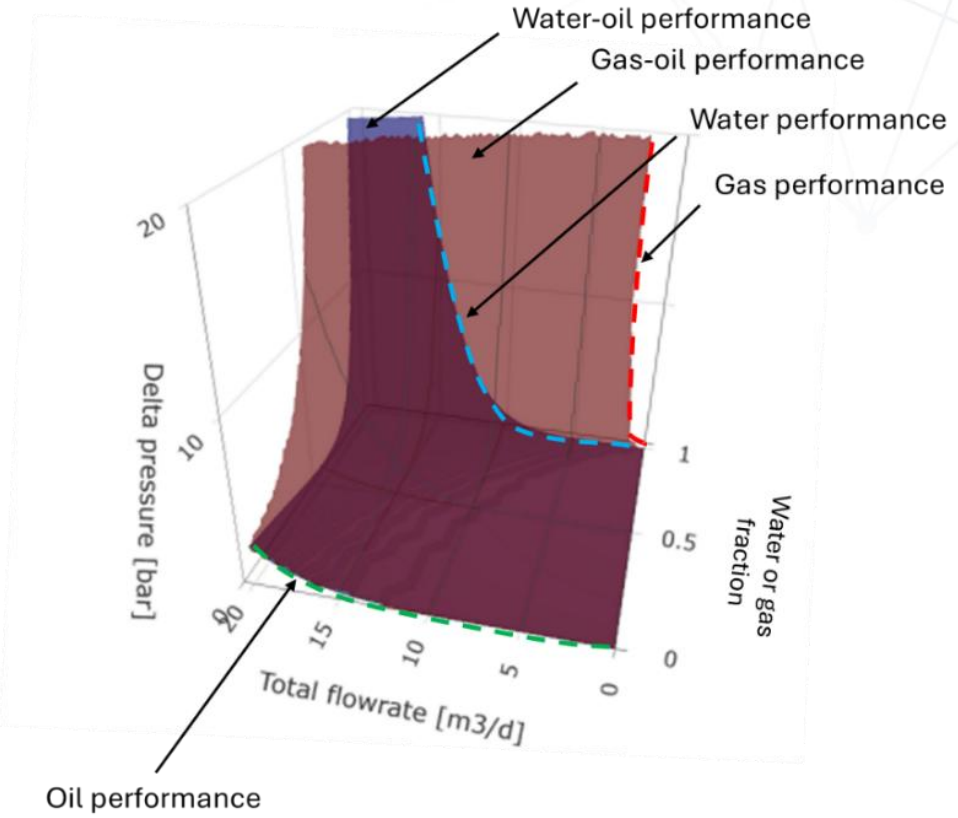
2) Define Single Valve Flow Performance

- Valve model 1 - The orifice equation used for static inflow control devices – ICD
- Valve model 2 – The RCP function for AICDs and AICVs

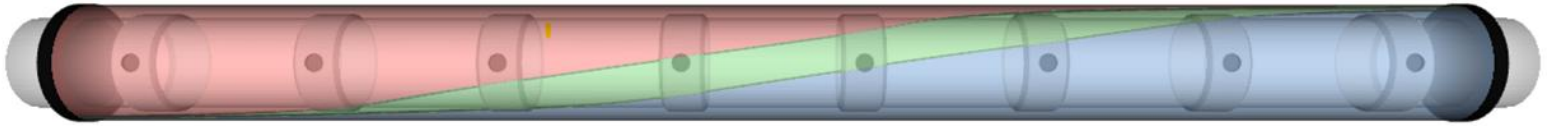
$$\Delta p = \left(\frac{\rho_{\text{mix}}}{\rho_{\text{cal}}}\right)^{z} \left(\frac{\mu_{\text{cal}}}{\mu_{\text{mix}}}\right)^{y} \rho_{\text{mix}}\, aAICD \left(\frac{q}{q_{\text{cal}}}\right)^{x}$$

- Valve model 3 – The trinary valve model used for density activated AICDs and ICVs

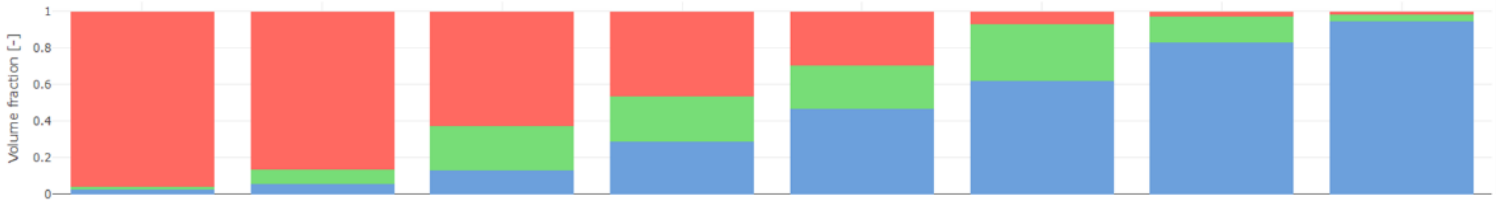
Single valve AICV performance



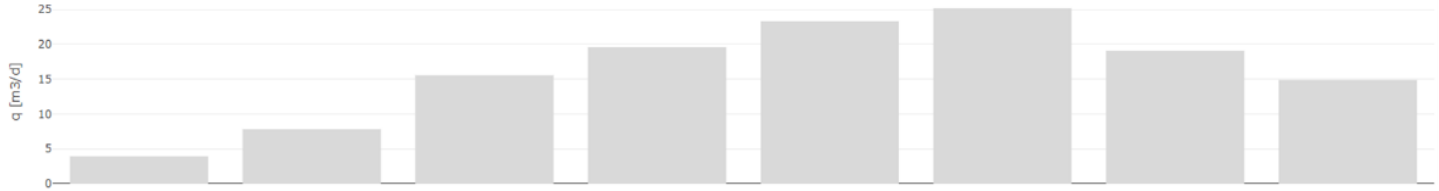
3) Define and Simulate Zone – (example AICV)



Phase distribution in annulus

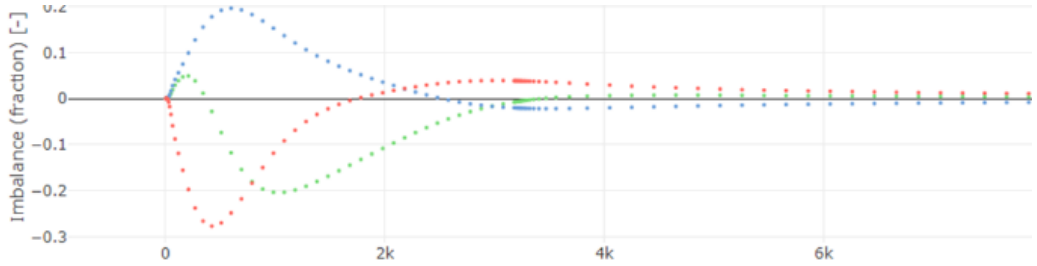


Phase fractions in valves



Total flowrate through valves

Phase specific completion zone mass accumulation

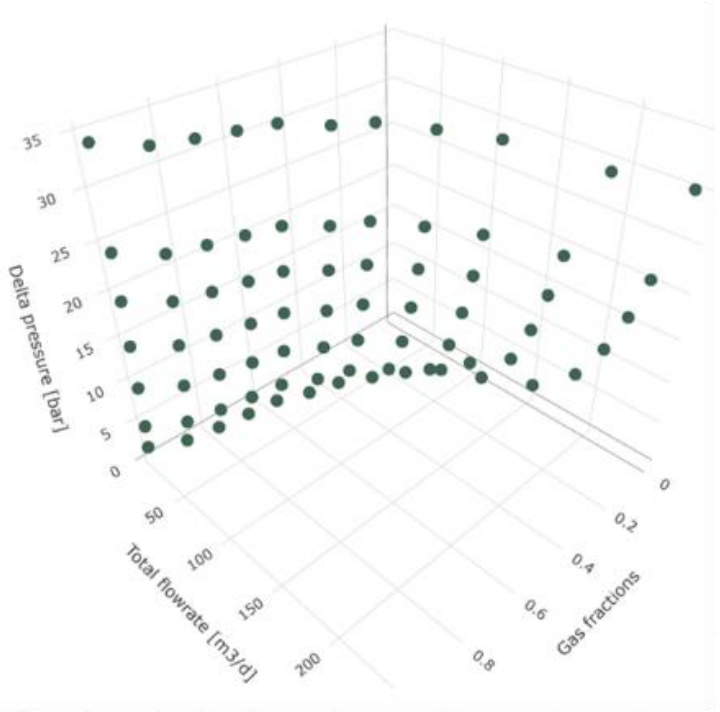


Transient and stabilized flow

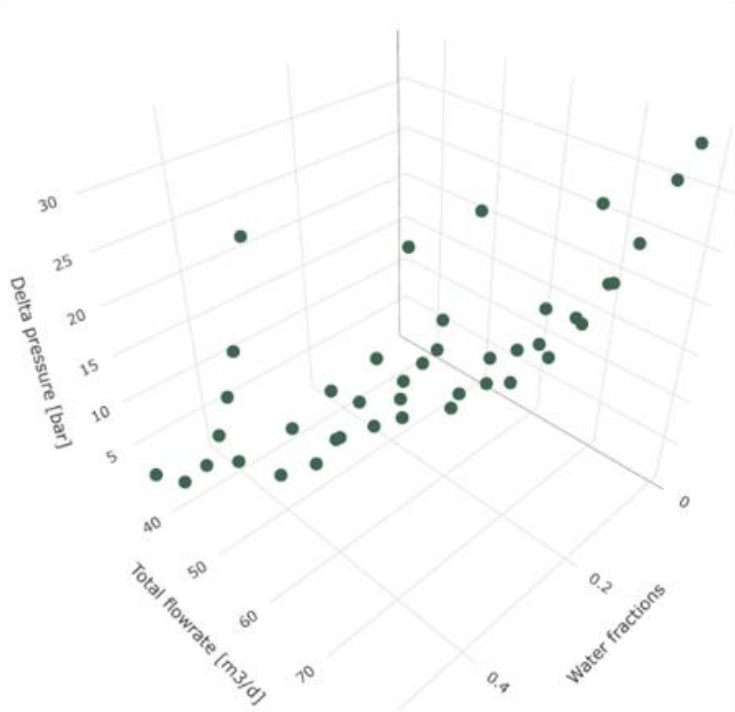
4) Multi-run result - 100 m zone with 8 AICVs.

Pressure loss vs. phase fractions and total volumetric flowrate.

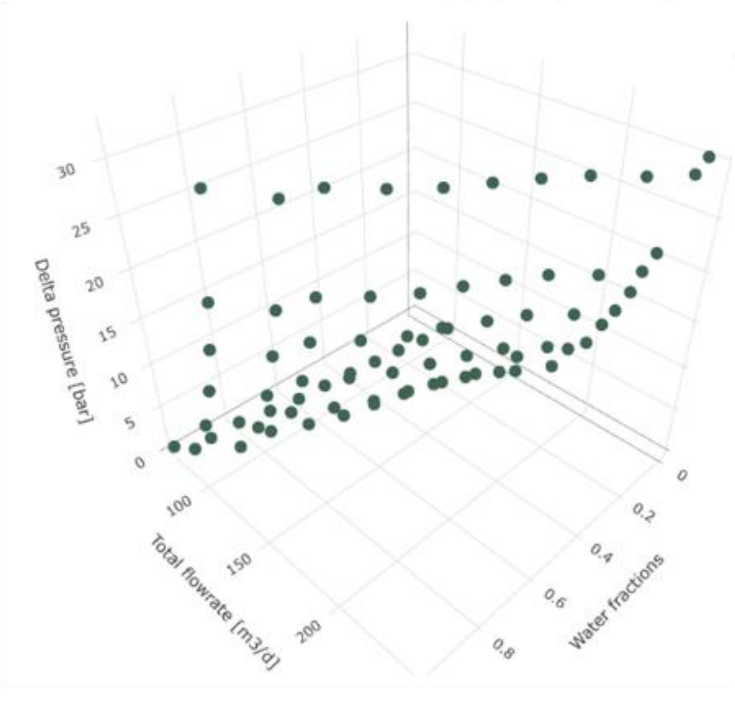
Gas-oil performance



Gas(50%)-water-oil performance

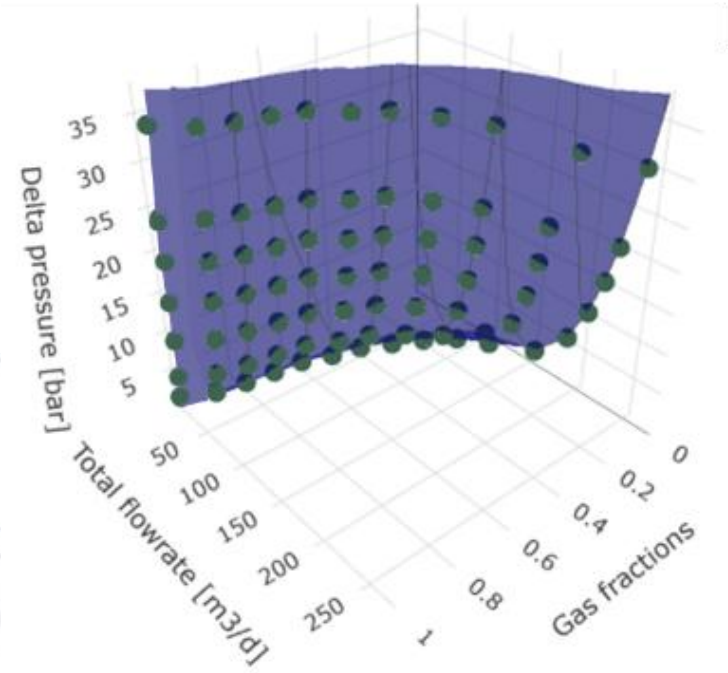


Water-oil performance

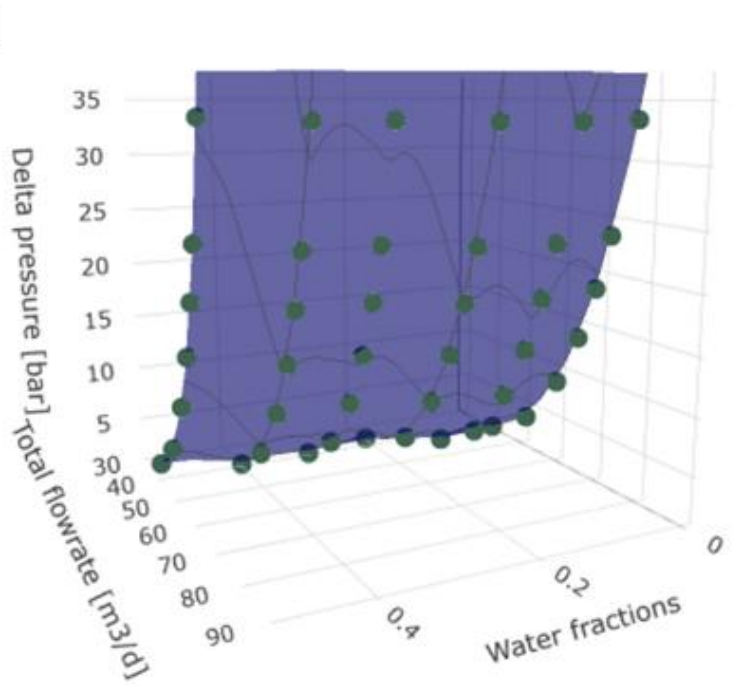


5) Upscaled zonal ICT model (VFP table) matched to multi run results.

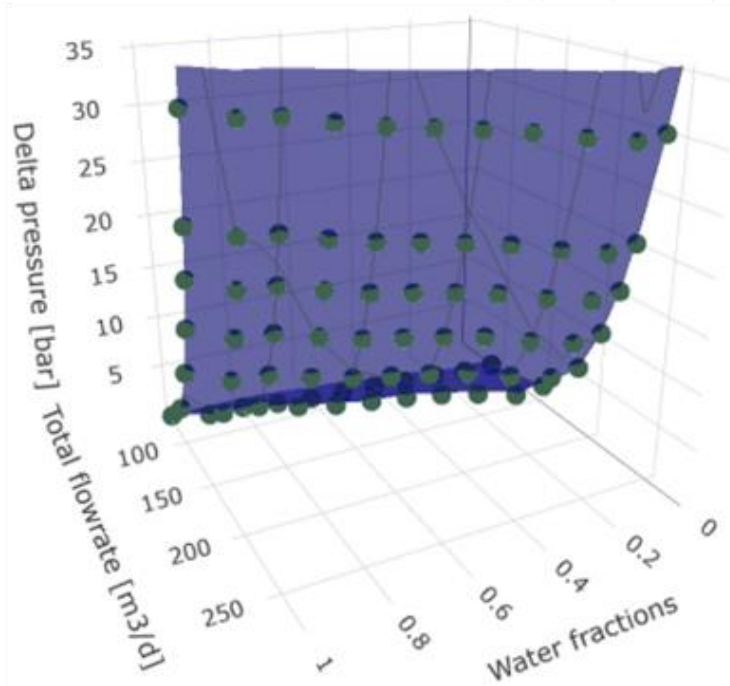
Gas-oil performance



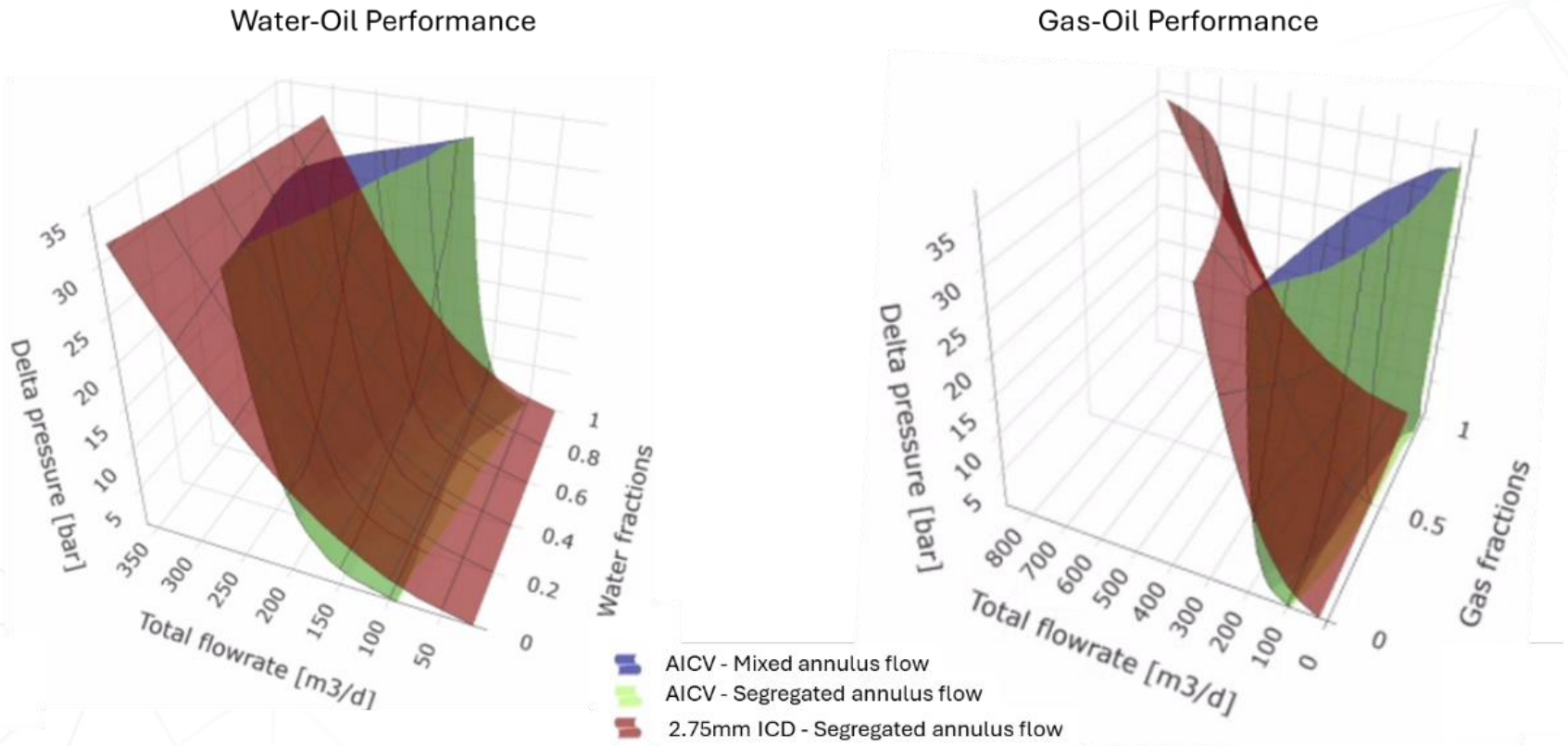
Gas(50%)-water-oil performance



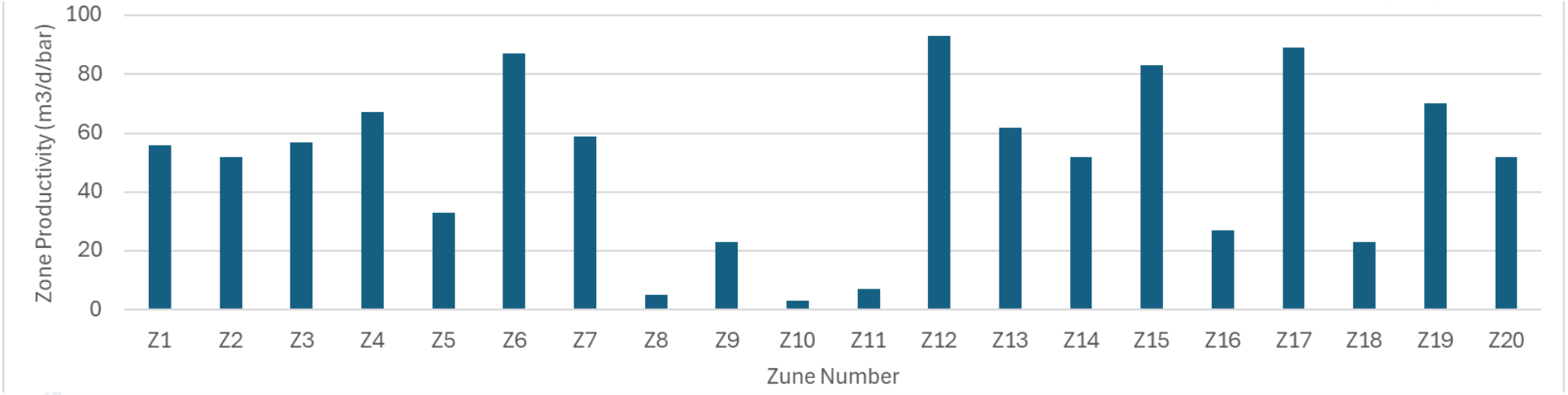
Water-oil performance



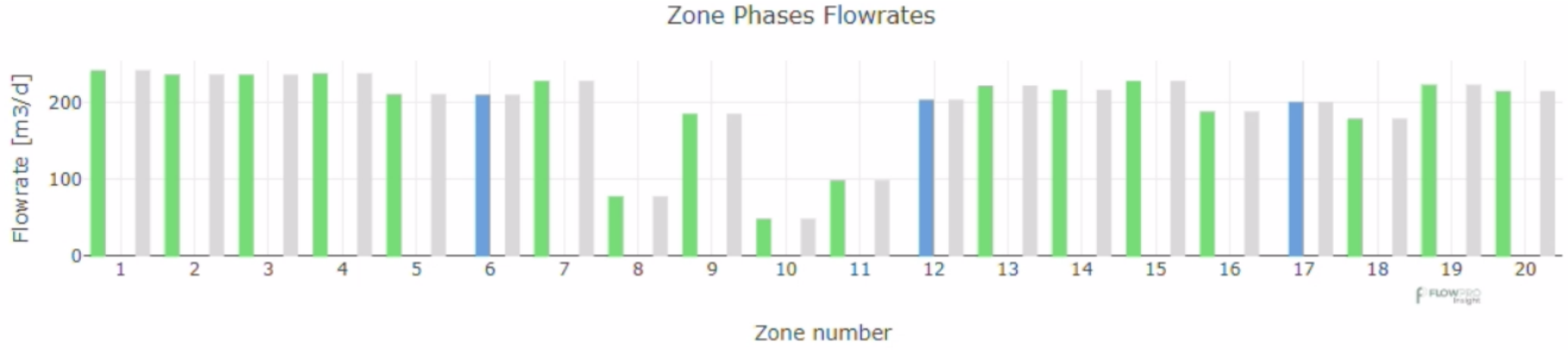
Comparison of Upscaled Zone ICT Models (VFP tables)



Optional 6) Screen and Optimize with Multi Zone Well Model



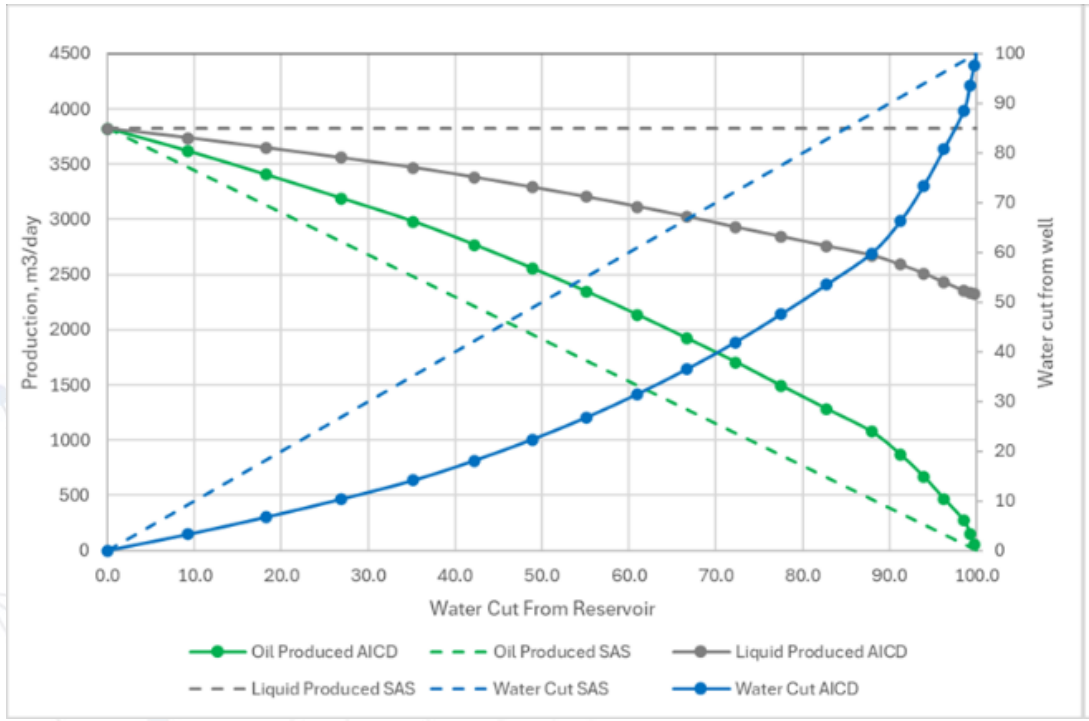
Zone productivities



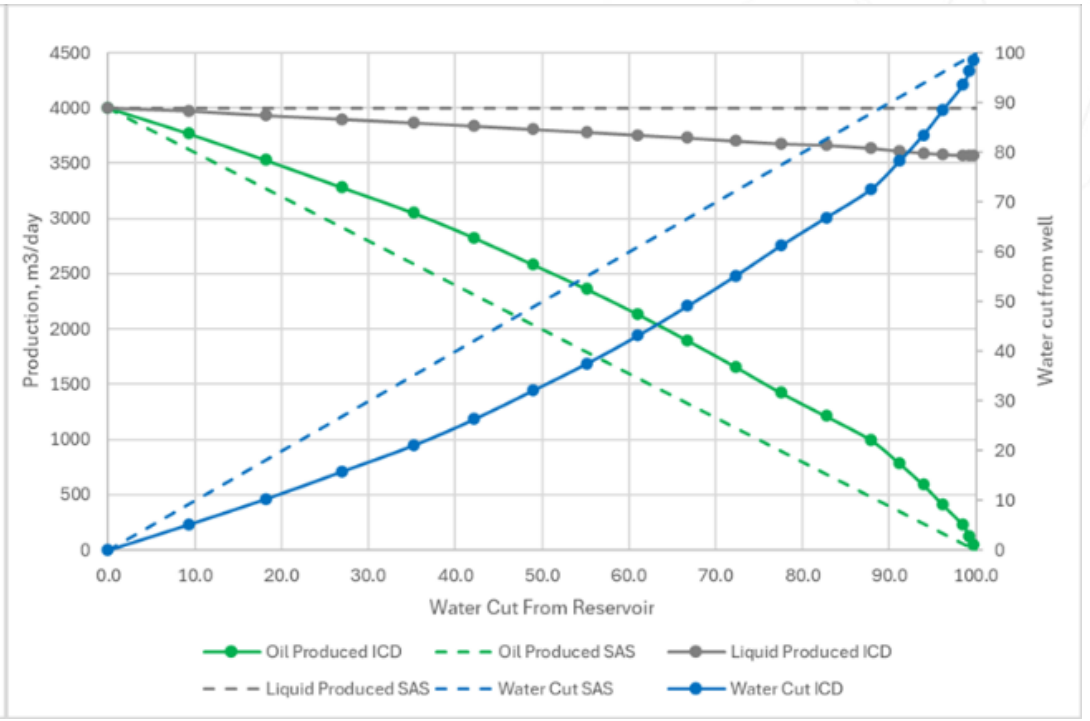
Zone Flowrates
AICV completion

Optional 6) Screen and Optimize with Multi Zone Well Model

AICV completion

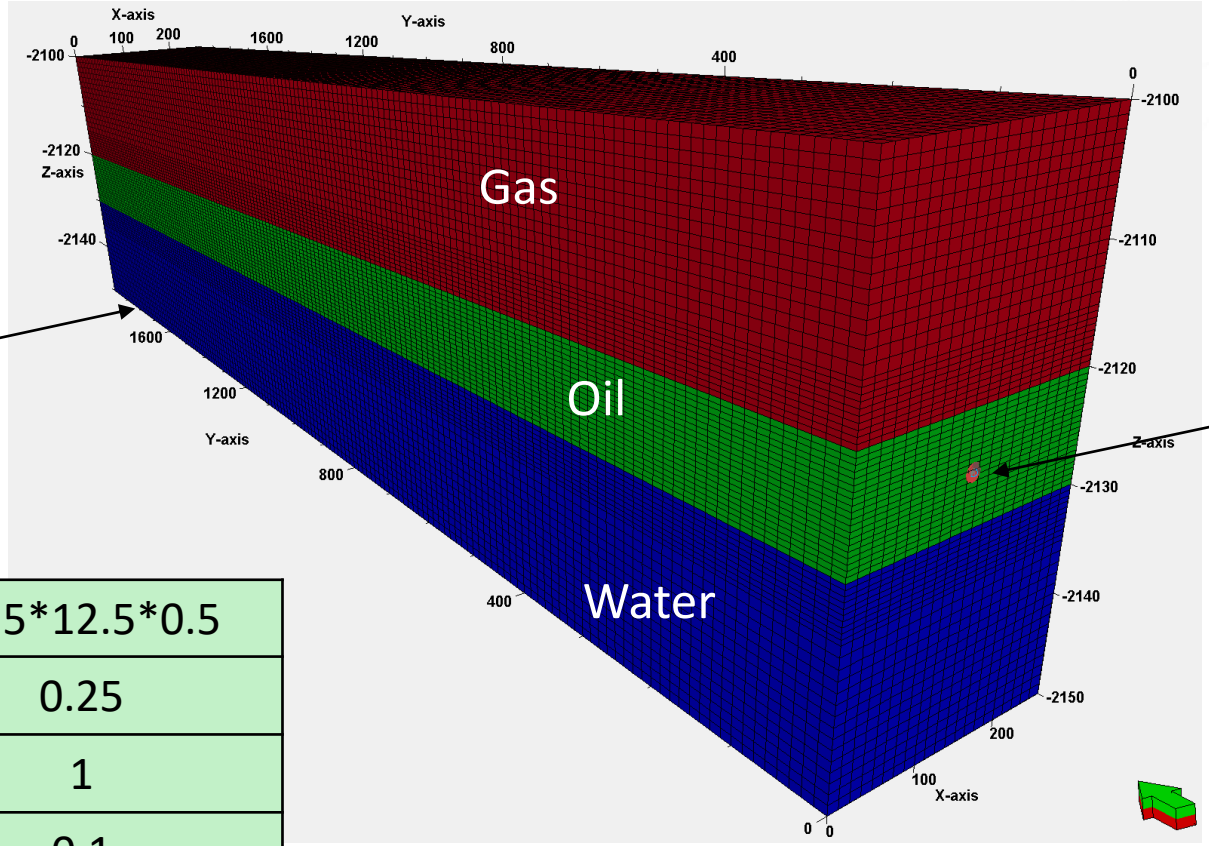


ICD completion



7) Reservoir modelling using the New work process

Bottom water drive MULTPV=1e6

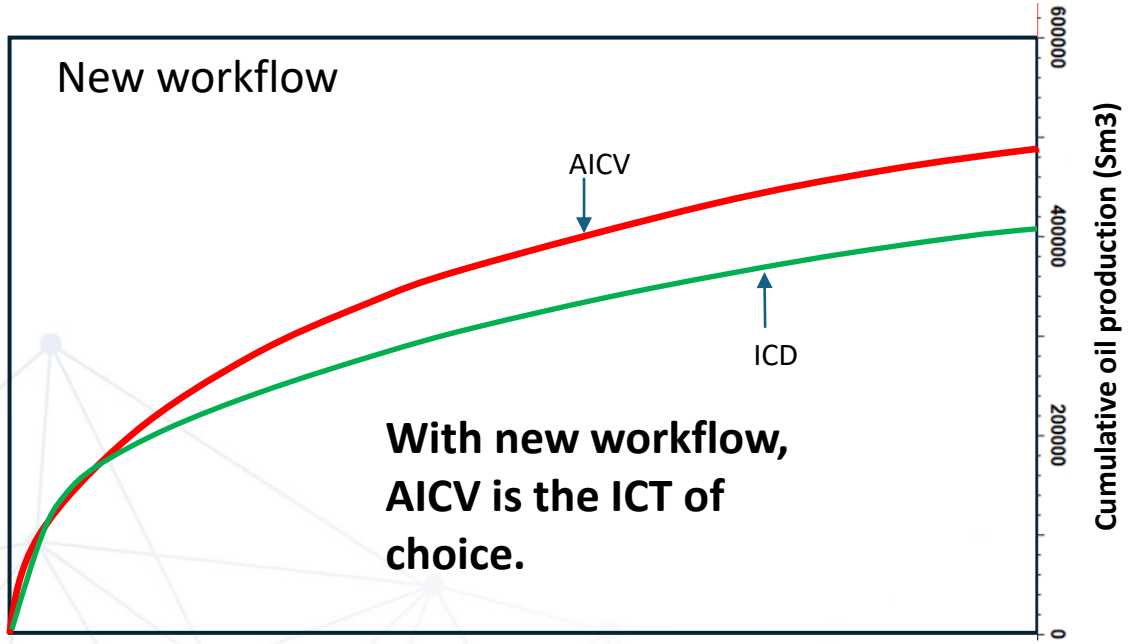


2000m horizontal well

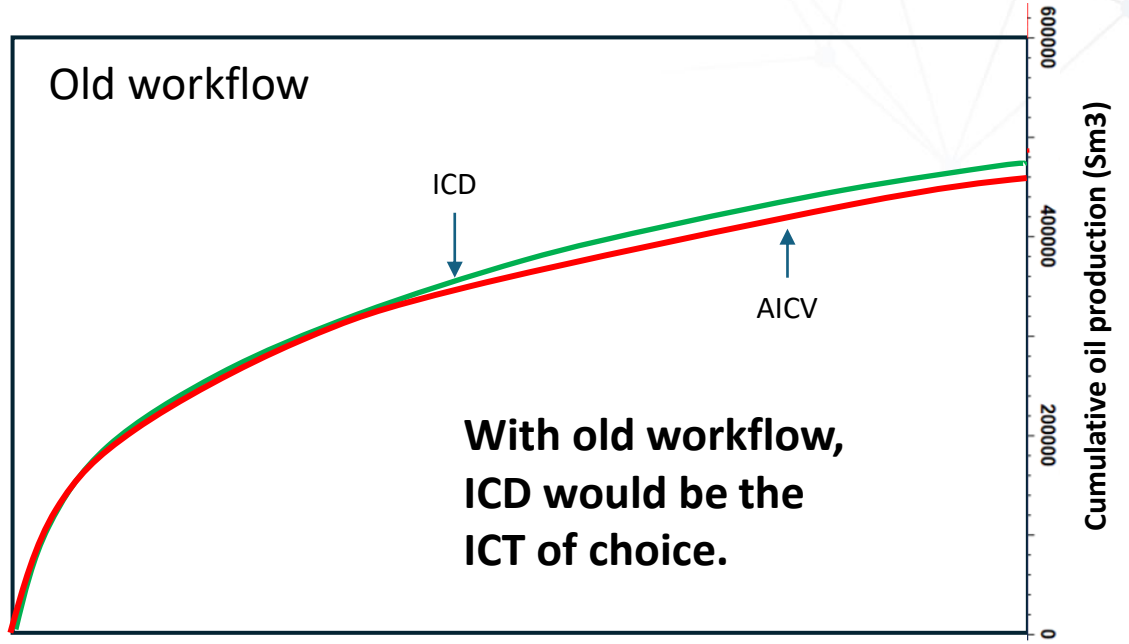
Grid (m)	12.5*12.5*0.5
Porosity (frac.)	0.25
Permeability hor. (D)	1
Permeability vert. (D)	0.1

AICV and ICD performance comparison

AICV outperforms ICD with segregated flow in annulus

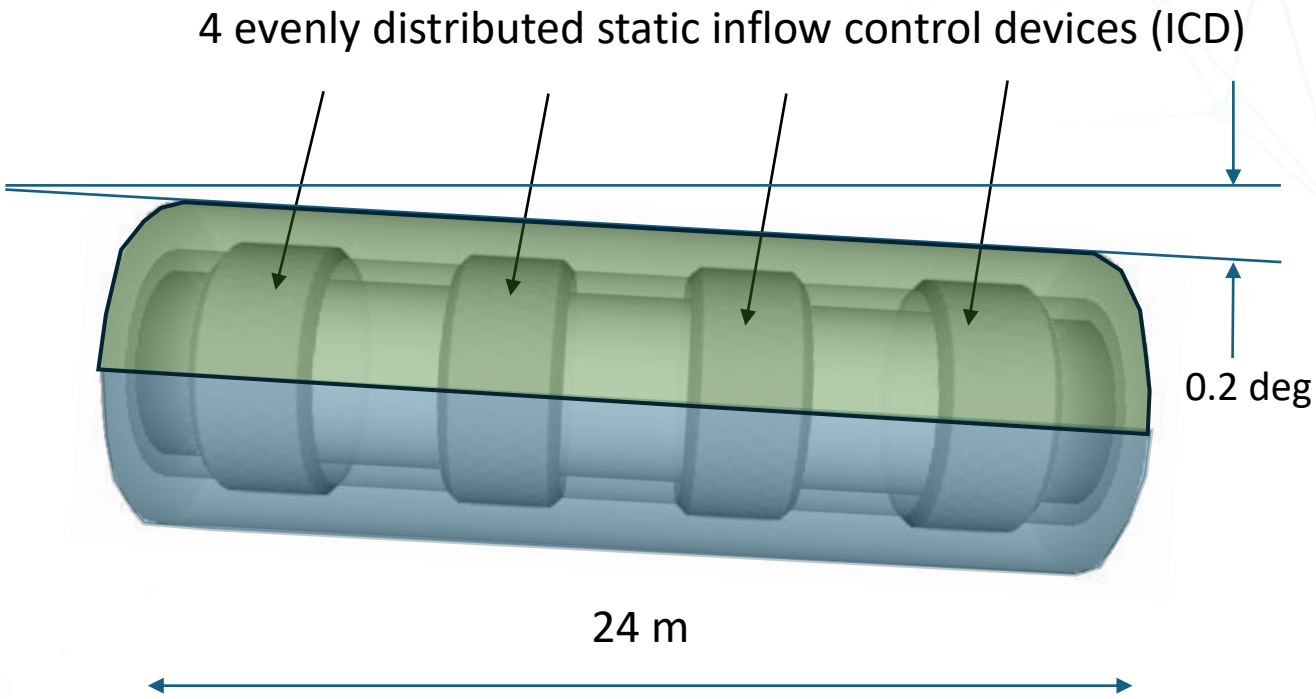


ICD outperforms AICV with mixed flow in annulus

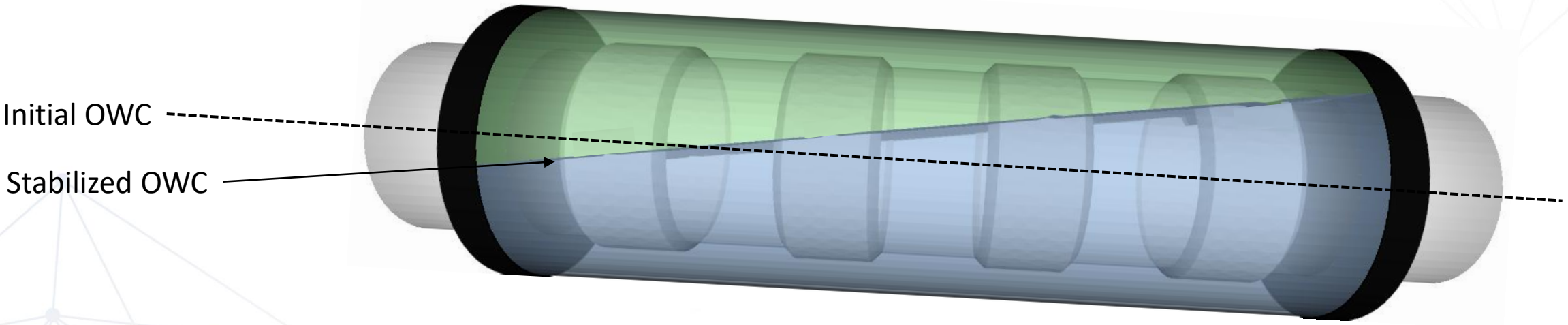


New Method vs. Ansys Fluent Validation Model

50% water and 50% oil
Flowrate from reservoir = 48 m3/d
(12 m3/d/valve)



New Method vs. Ansys Fluent Validation Model



Ansys Fluent Validation Model

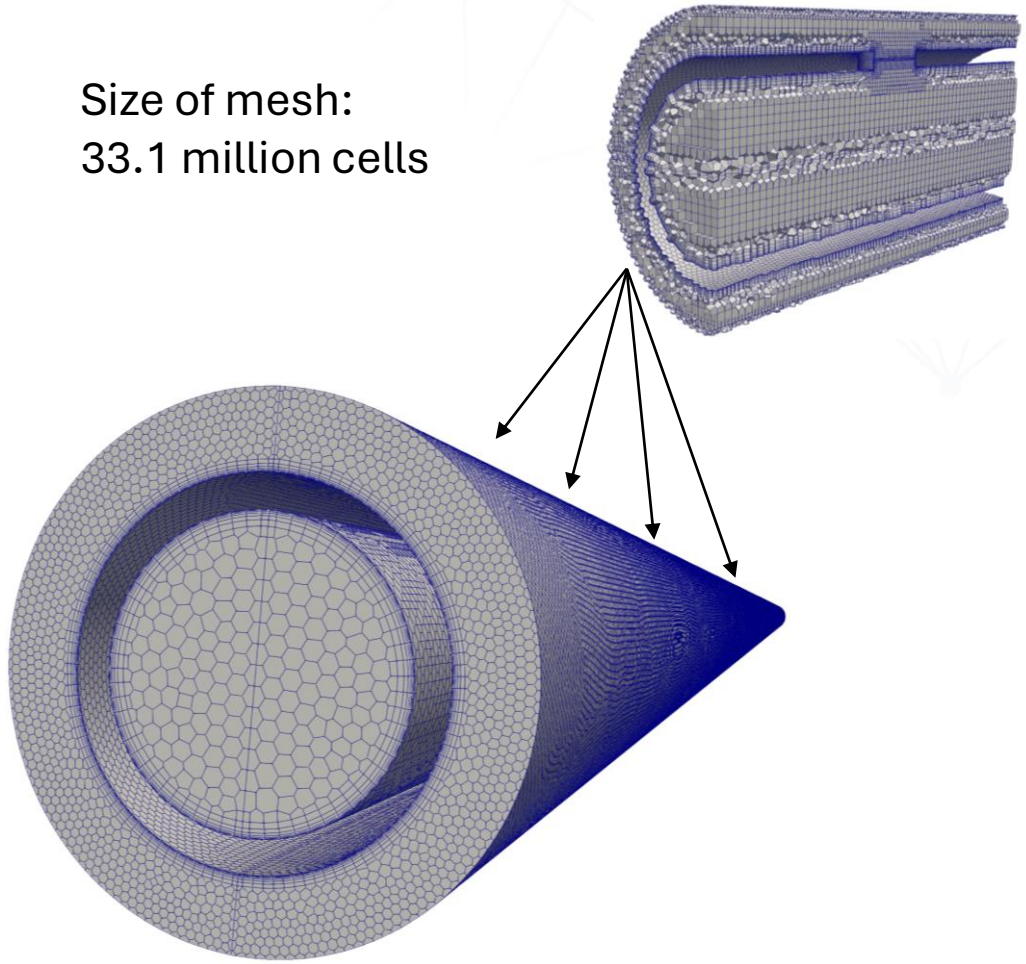
Fluids:

- Oil - density: 700 kg/m3 - viscosity: 0.5 cP
- Water - density: 1000 kg/m3 - viscosity": 0.4 cP

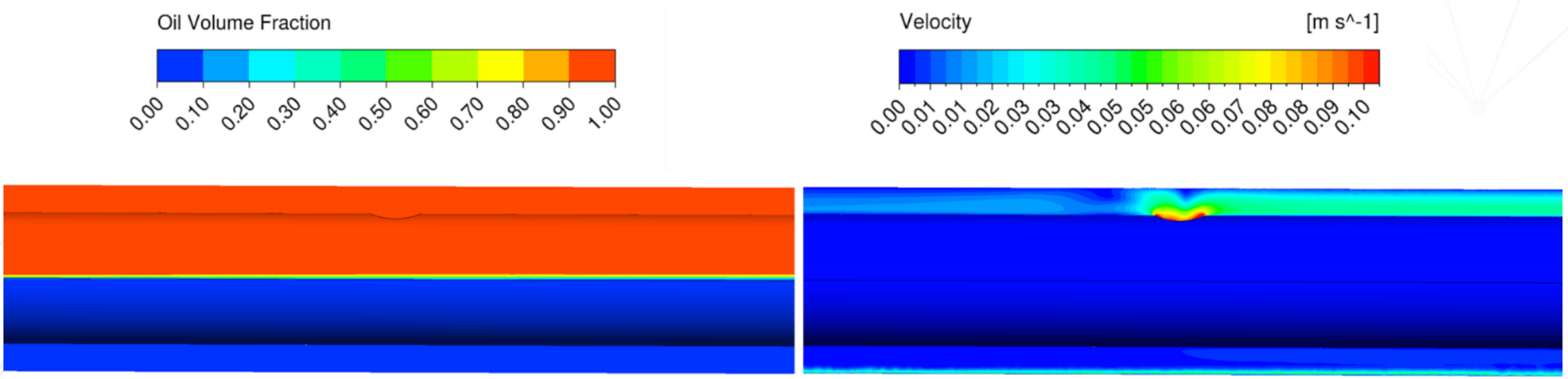
Geometry:

- Wellbore diameter: 8.5 in.
- Liner/screen OD: 6 in.
- Liner/screen OD: 4.92 in.

Size of mesh:
33.1 million cells

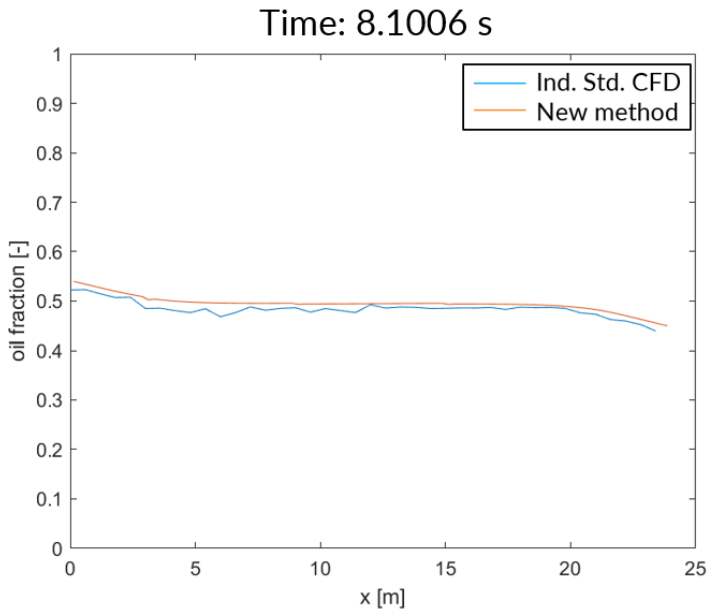


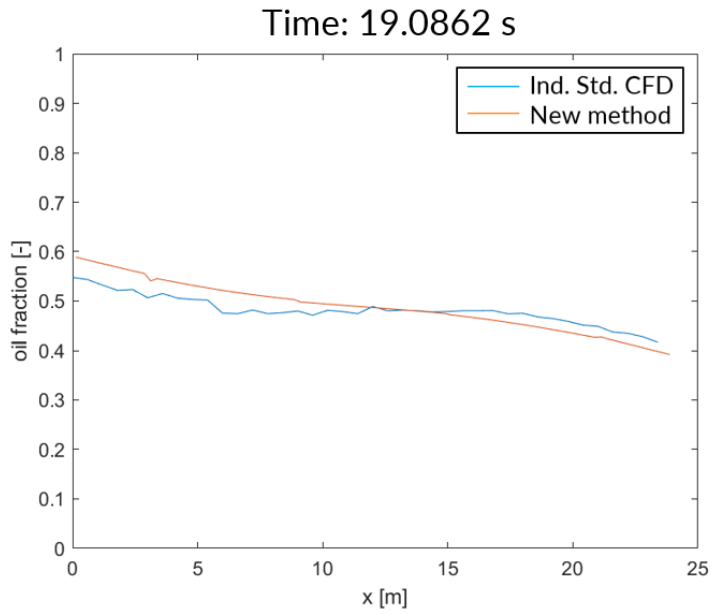
Ansys Fluent CFD model
Annulus oil saturation and velocity field

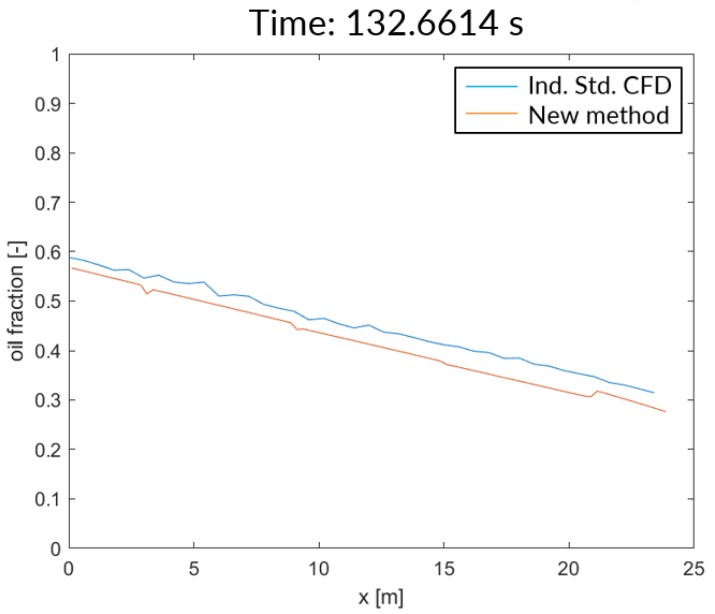


New Method vs. Ansys Fluent Validation Model

- The oil saturation showed a maximum relative error of 4.93% and an average error of 3.49%.
- For the simulated zone, the new method is 3.1 million times faster than industry standard CFD.







Main Conclusion

Use of new vs. old workflow will have impact on:

- The type of ICT equipment to be used
- The design of ICT solution (number and size of devices)

Conclusions

- A CPU time efficient, CFD-based simulation method is successfully developed.
- The approach improves the accuracy of inflow performance predictions significantly.
- An upscaling procedure is developed to efficiently include ICT well performance in standard reservoir simulators through standard RCP functions or VFP tables.
- This study concludes that sustained mixed flow in the annulus of long horizontal wells with ICT is very unlikely under typical operating conditions.
- Verification against industry-standard CFD tools confirms new method has high accuracy.
- New method drastically reduces computational time by several orders of magnitude, making it suitable for field-scale implementation.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