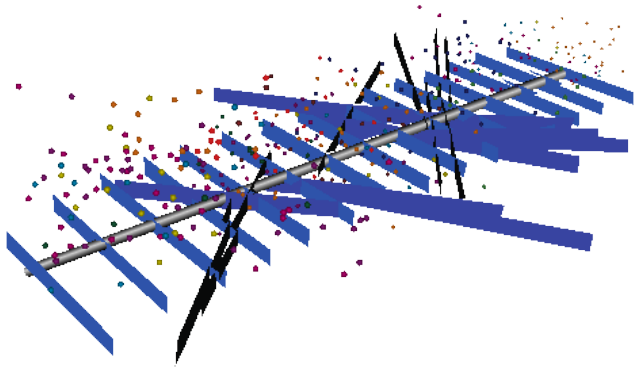


KAPPA

UR Add-on pack

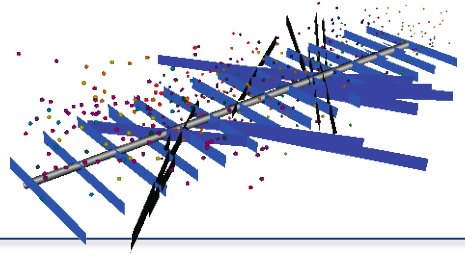
KURC / Add-on pack

KURC – KAPPA Unconventional Resources Consortium

- KURC-1: 2012 – 2015
- KURC-2: 2016 – …
- KURC options are exclusive to members for 3 years since their release
- KURC members get access to any Add-on features

UR Add-on pack

- New developments + selected KURC-1/2 features post-exclusivity period
- Specific license privilege in Saphir, Topaze and Rubis
- Non-digressive, per stand-alone license
- Available since KW v5.20.01 (2018)



Add-on pack features

KAPPA

- Fast numerical models for SRV & Trilinear geometries
- DFN analytical model with conjugate fractures
- Numerical single-well DFN model
- Numerical model with composite zones
- Load and display of microseismic data
- Simulation of Klinkenberg effect
- Fickian diffusion
- Water flowback with static Initialization
- Clarkson DDA Linear Flow plot
- Flowing Material Balance plot
- Statistical EUR

New in KW v5.30 (2020):

- Anomalous diffusion model
- Multi-zone fractional model
- Refrac for a MFHW
- DFN Upscaling
- Loading properties of fracs

KURC-1/2 exclusive features

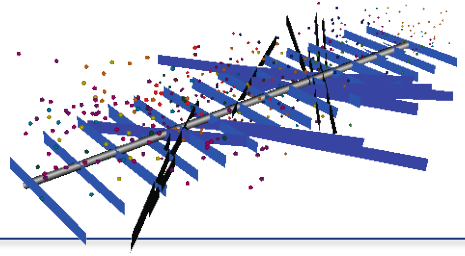
Features contractually exclusive to KURC members until mid-2020:

KURC-1

- Load from Fracturing Software
- Confined PVT
- Multiple KrPc

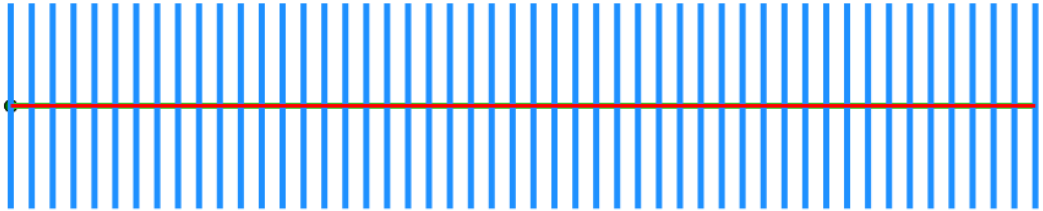
KURC-2

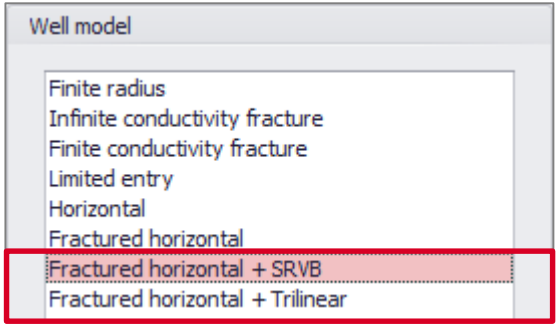
- Stochastic DFN realizations
- Interference with DFN: Fast Marching Method
- Stimulated zones around the fractures



Fast numerical models

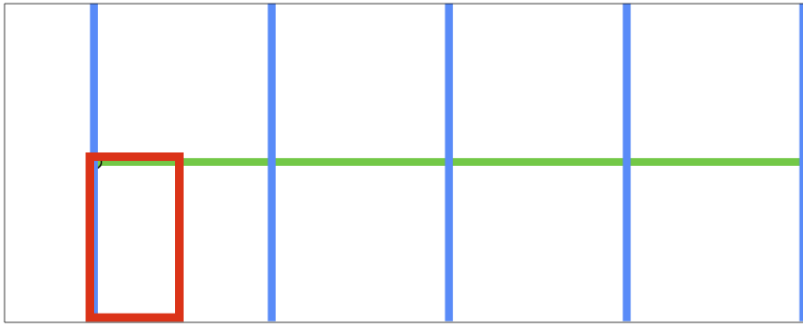
Very useful in the case of complex PVT and a simple but very long MFHW to tune the fracture properties prior to running the full numerical model



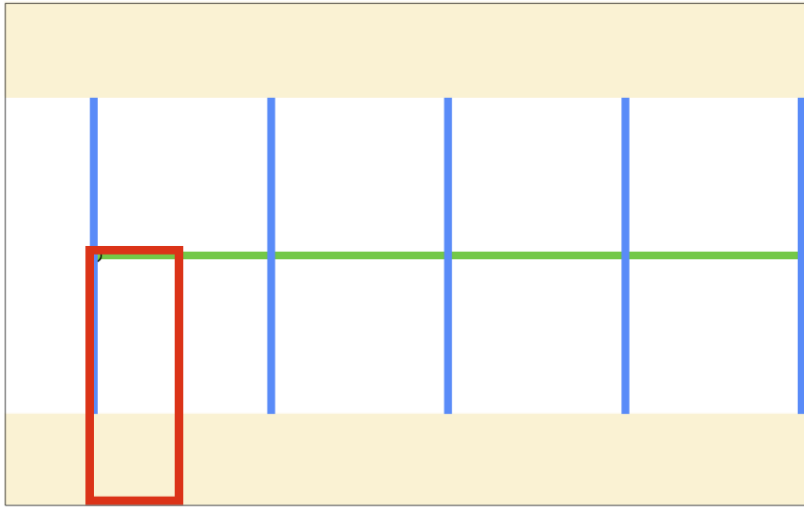


Can be initiated from an analytical model via the Dashboard

Stimulated Reservoir Volume bounded (SRVB)



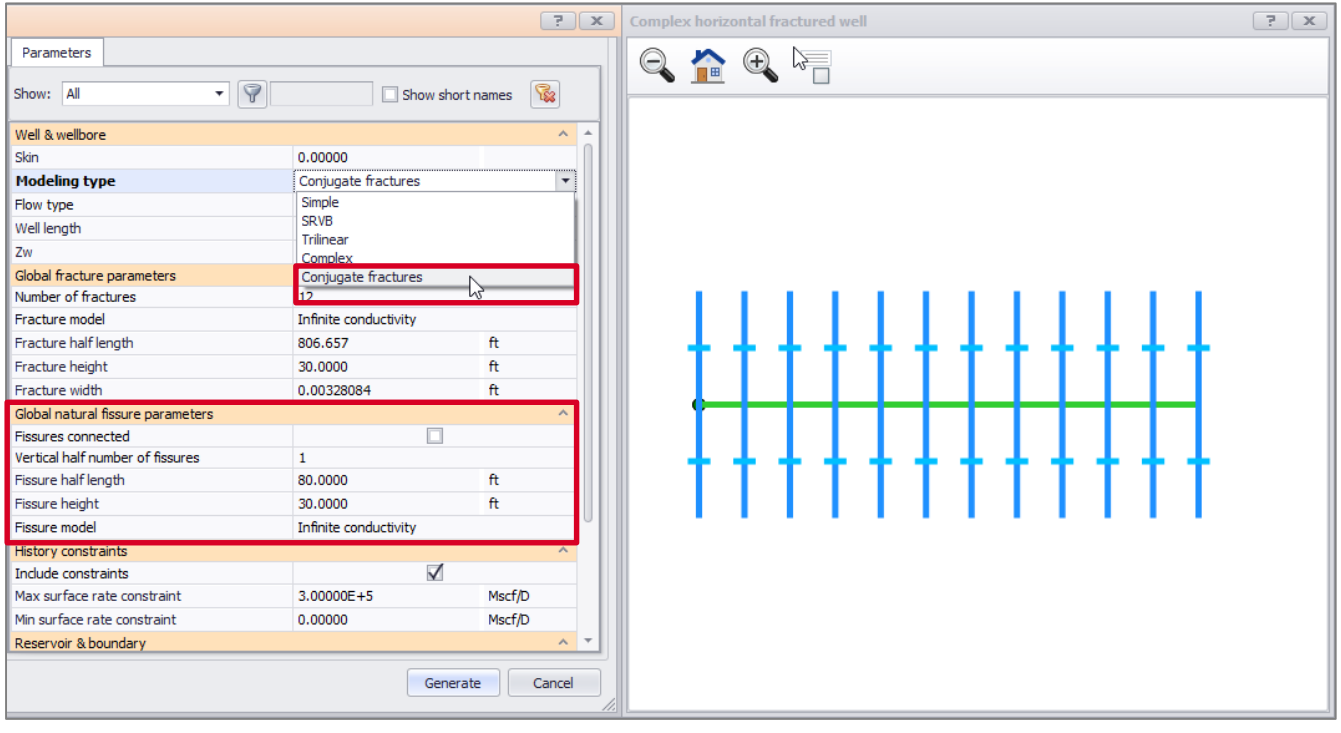
Trilinear

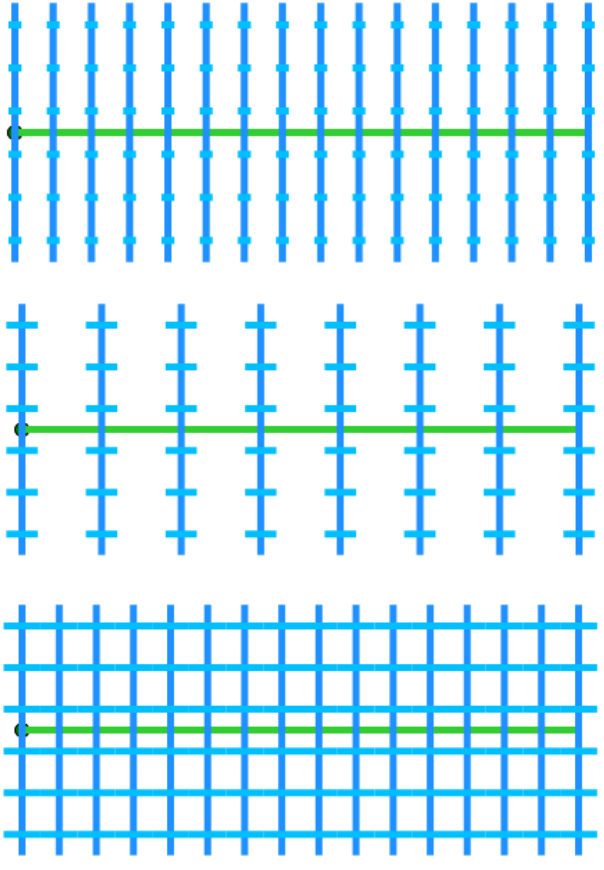


Efficient Proxies for Numerical Simulation of Unconventional Resources, Artus et al., 1896873-MS URTEC Conference Paper (2014)

DFN analytical model

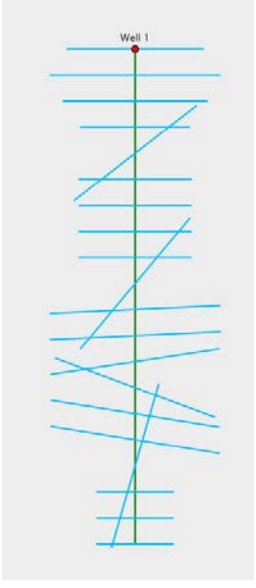
- Conjugate fractures: # fissures and geometry

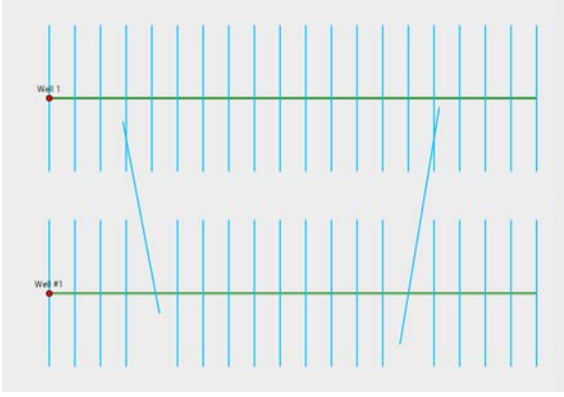


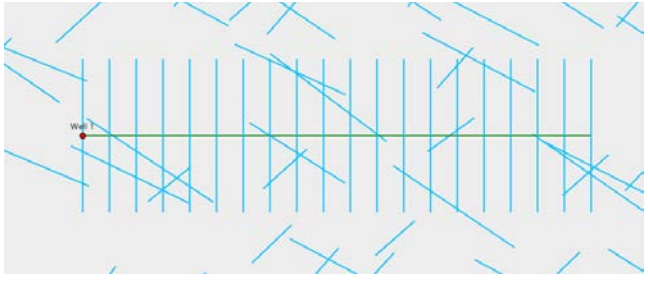


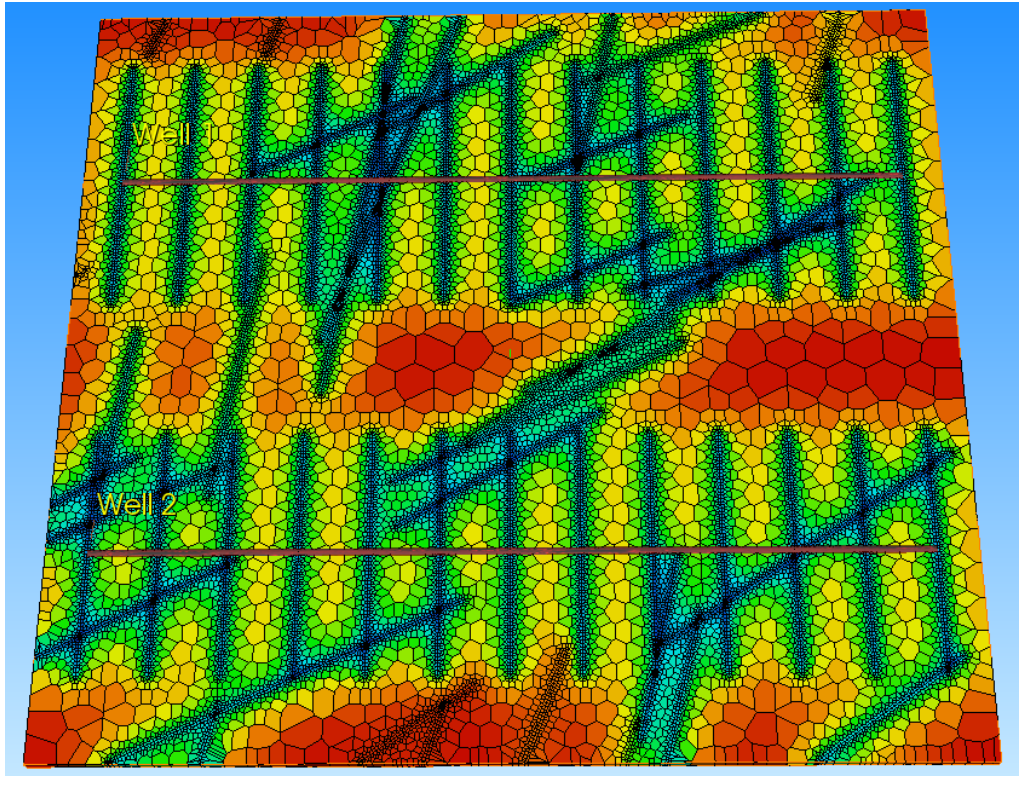
Numerical DFN

DFN and well fractures have distinct properties, including relative permeabilities and $k(p)$.



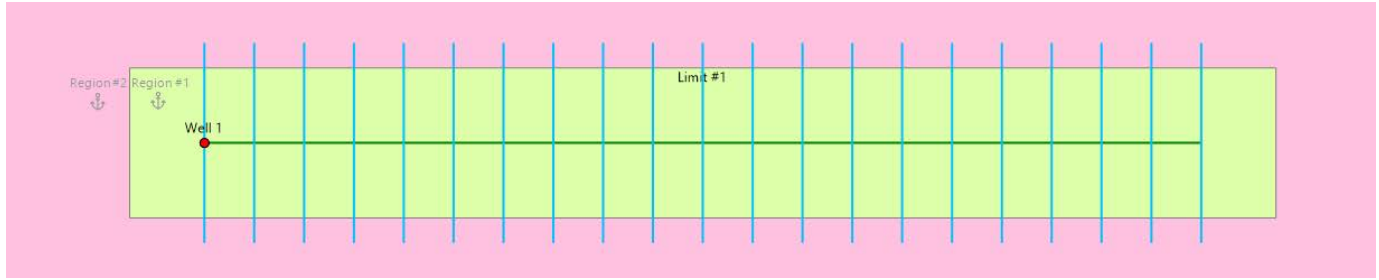




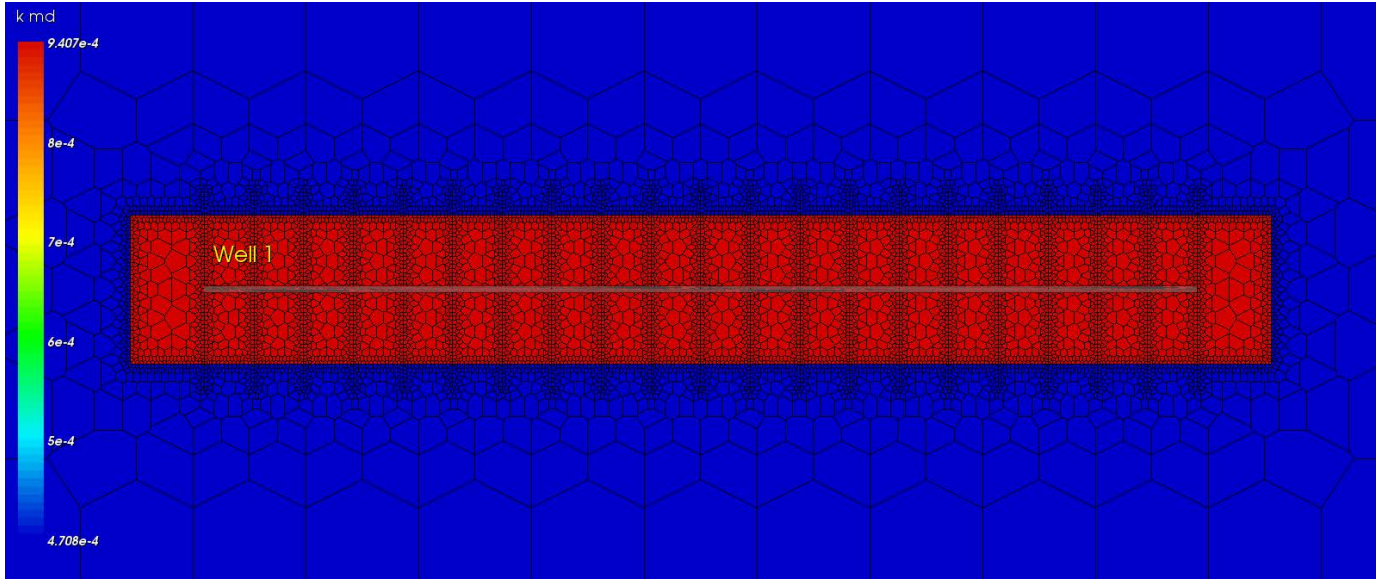


Composite zones

Composite limits are now allowed to cross fractures to simulate enhanced area close to the well



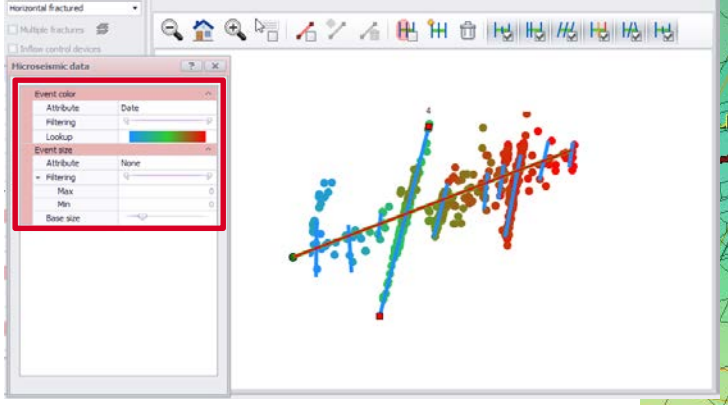
Region #1	
Reservoir type	Homogeneous
M	1.00000
D	1.00000
Net-to-gross	1.00000
Region #2	
Reservoir type	Homogeneous
M	Homogeneous / Dual porosity pseudo steady state
D	
Net-to-gross	1.00000

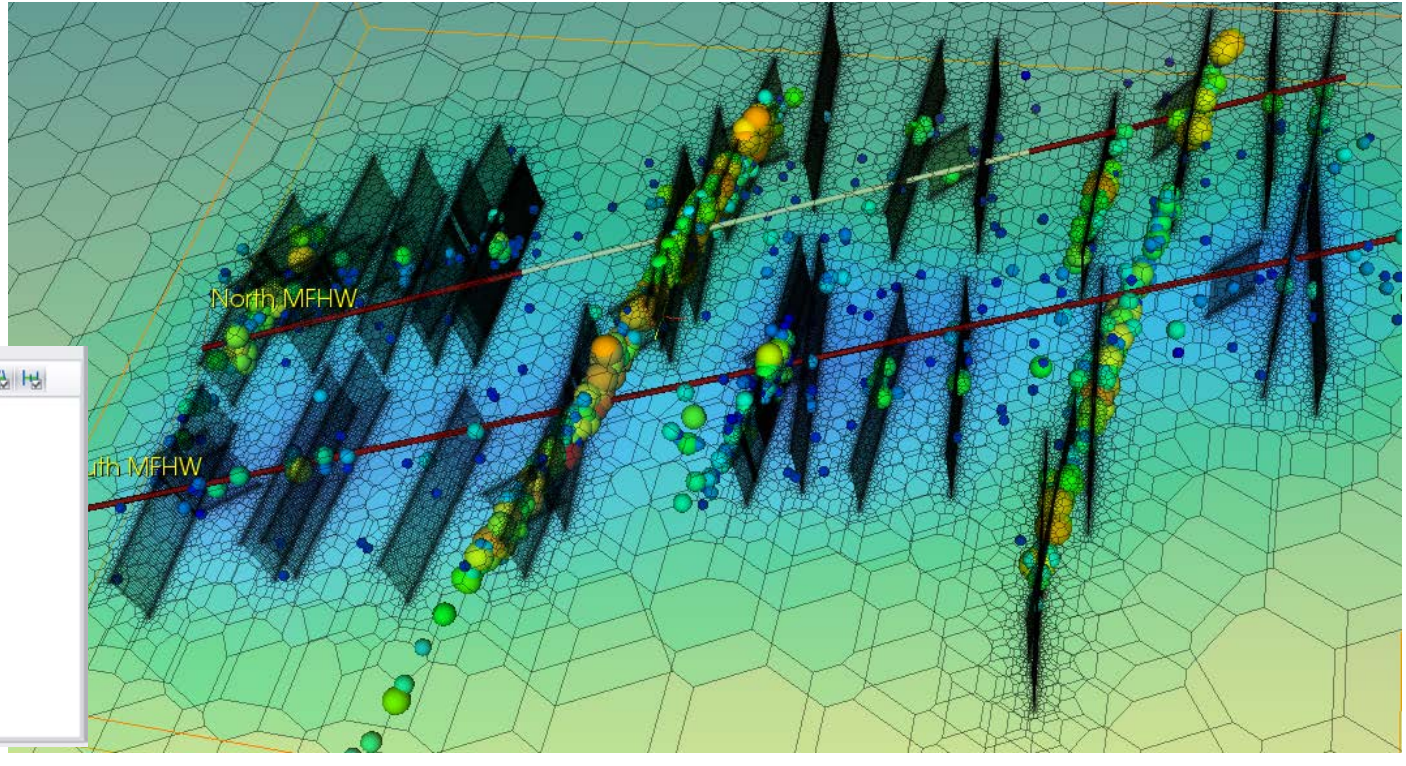


Microseismics

Load and display of microseismic events to constrain the MFHW configuration

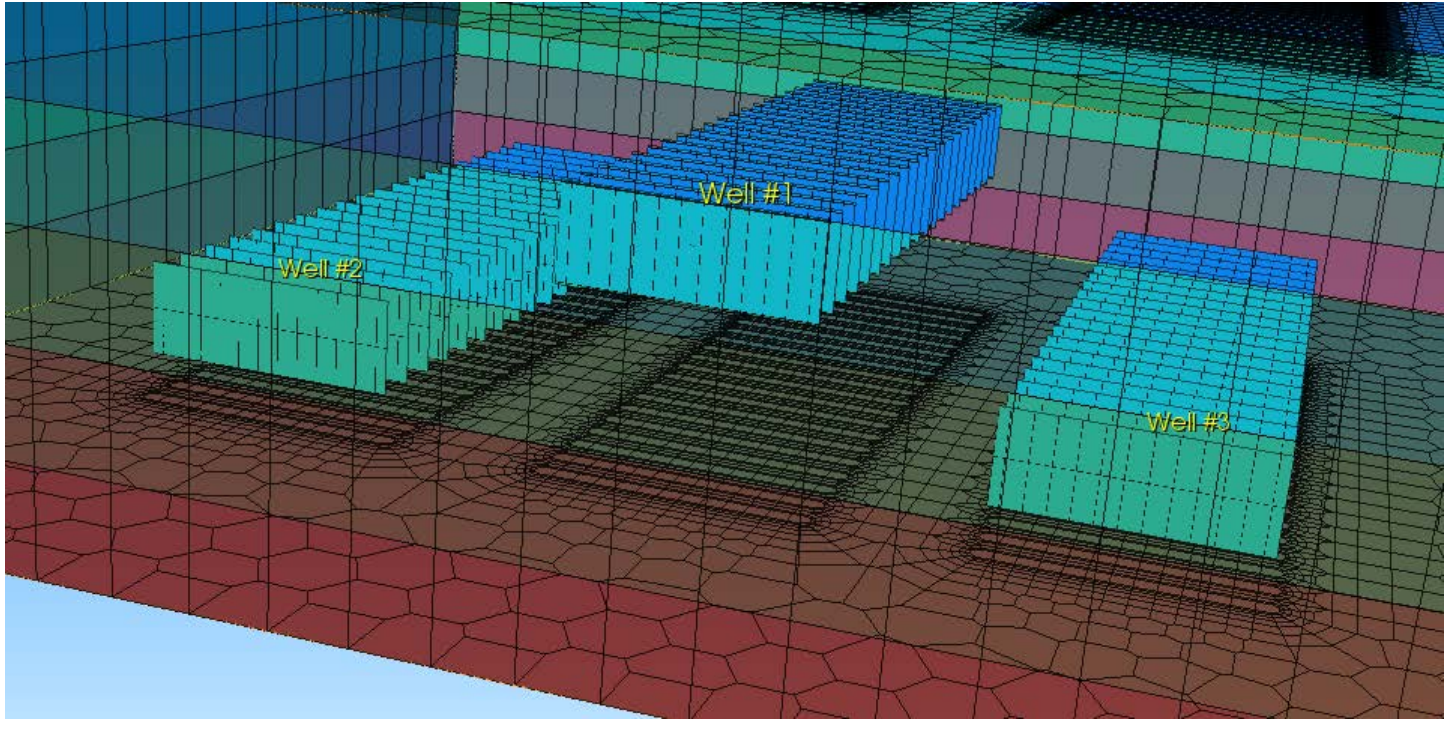
Visualizing attributes:
date, amplitude, stage index





Accelerated initialization

Large models with multiple MFHWs are initialized using specific faster procedures



Klinkenberg effect

For gas observed permeability can be higher than the true/absolute permeability of the rock due to slippage

Available in the numerical model:

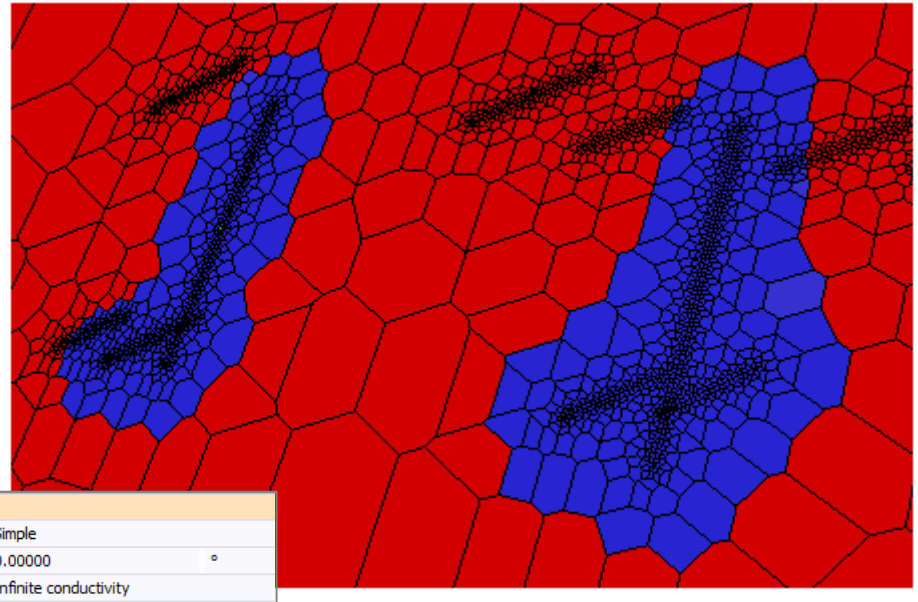
- PVT is set to dry gas
- Real PVT are used
- Reservoir type: homogeneous

Well 1		
Zw	15.0000	ft
Perforation length	30.0000	ft
Well length	30.0000	ft
Rate dependent skin	☐	
Skin	0.00000	
Wellbore model	None	
Bottomhole MD	6000.00	ft
Include constraints	☐	
Reservoir		
Initial pressure	7246.55	psia
Reservoir type	Homogeneous	
Transmissibility	1000.000	md.ft
Permeability	33.3333	md
Thickness	30.0000	ft
Porosity	0.1	
Klinkenberg	☑	
Klinkenberg b	200.000	psia
Net-to-gross	1.00000	
kz/kr	1.00000	

Water flowback

To model the post fracture treatment water flowback:

- The user inputs the total injected water volume
- The injected volume is divided between the connected hydraulic and natural fractures (accounts for Kr end points)
- The local pressure increase is not modeled



Available in the numerical model:

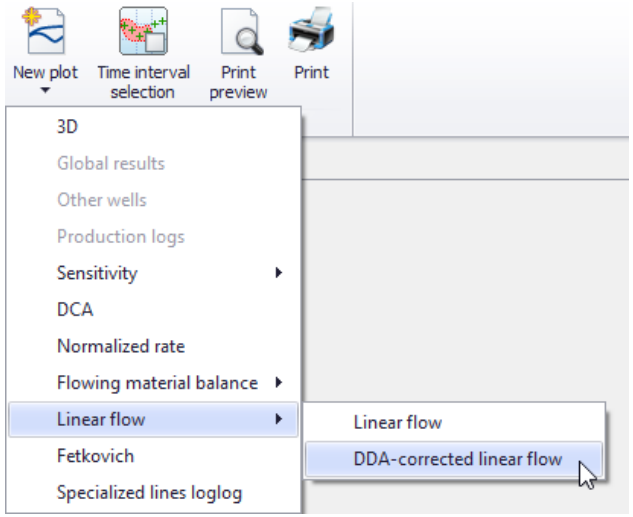
- Multiphase PVT includes water
- Real PVT are used
- Well is set to MFHW

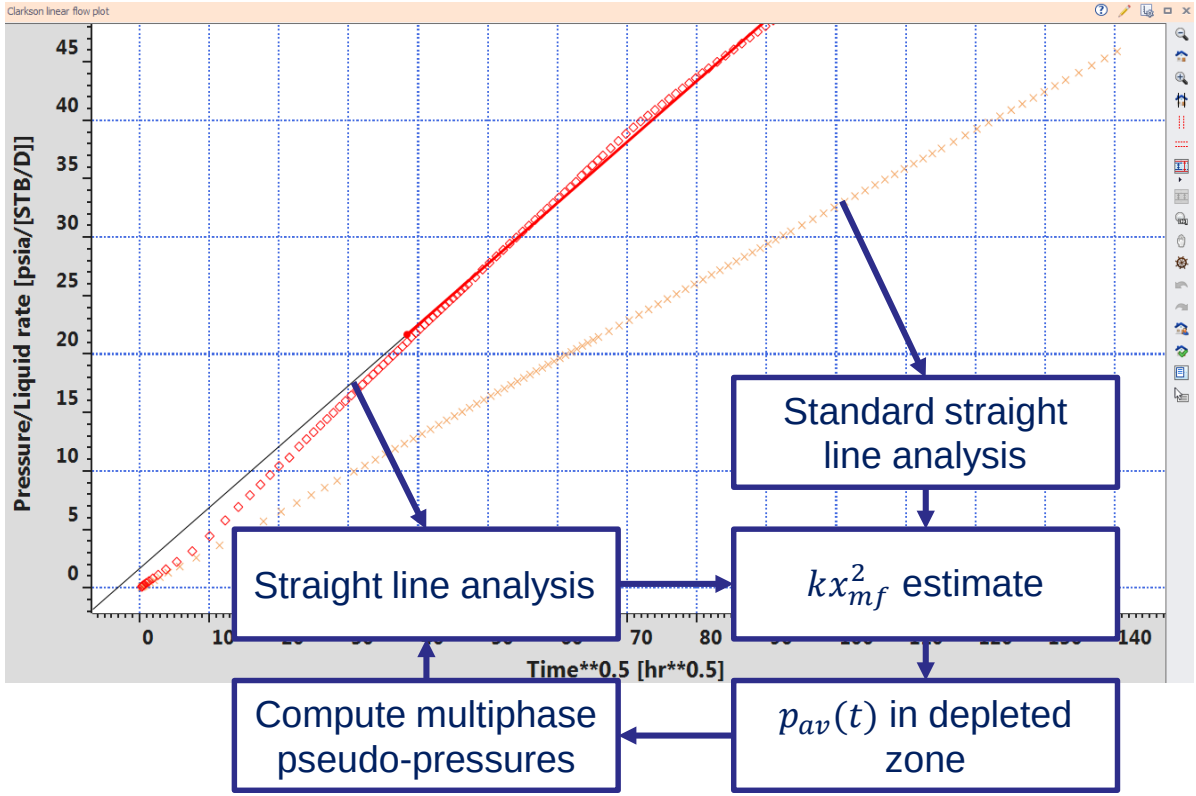
Well 1		
Modeling type	Simple	
Drain angle	0.00000	°
Fracture model	Infinite conductivity	
Number of fractures	15	
Fracture half length	300.000	ft
Fracture height	30.0000	ft
Fracture mid-point height	15.0000	ft
Width	0.00328084	ft
Fracture angle	90.0000	°
Zw	15.0000	ft
Well length	1000.00	ft
Stimulated zones around fractures	☐	
Include injected water	☑	
Injected water	5000.00	MMSTB
Rate dependent skin	☐	

Clarkson DDA Linear Flow plot

Linear flow analysis modified using pseudo-p from Dynamic Drainage Area concept

Multiphase extraction





Rate-transient analysis of liquid-rich tight/shale reservoirs using the dynamic drainage area concept: Examples from North American Reservoirs, Qanbari and Clarkson, Journal of Natural Gas Science and Engineering 35 (2016)

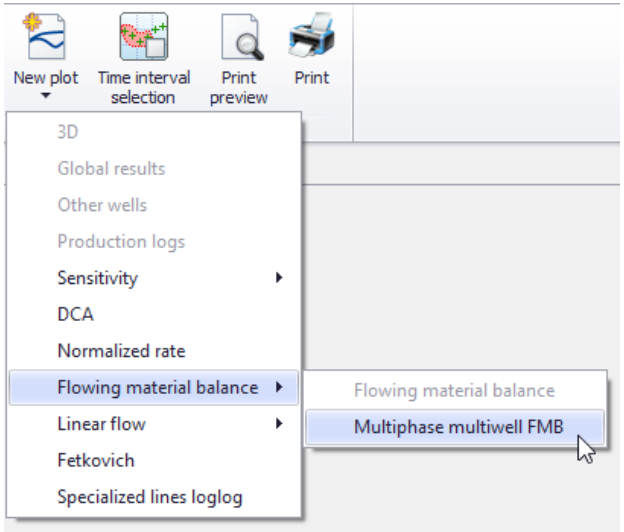
Multiphase/multiwell FMB Plot

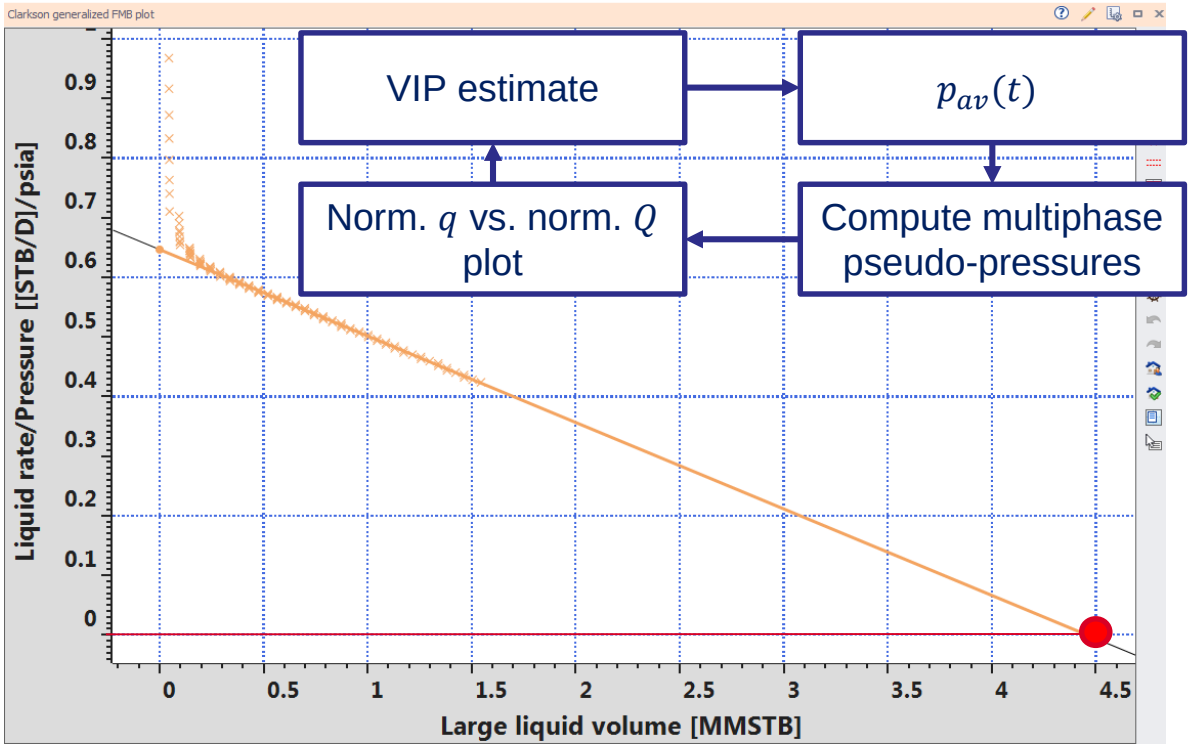
General Flowing Material Balance equation modified using pseudo-p and p_{av} from MB calculations

$$\frac{q_o}{\Delta p_{pw}} = \frac{1}{b} - \frac{1}{bN}\left(\frac{\Delta p_{pav} N}{\Delta p_{pw}}\right)$$

Multiphase extraction

except: Dry gas + Water, Wet gas + Water, EoS + Water





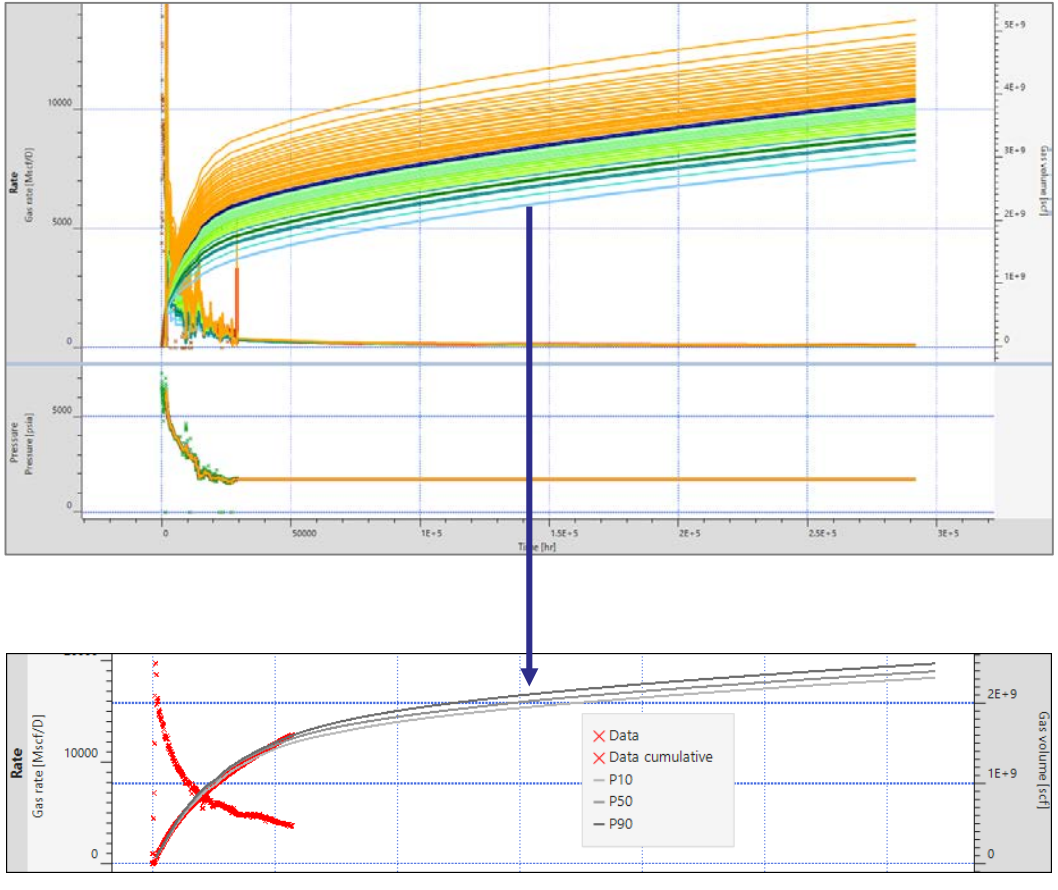
Multi-Well, Multi-Phase flowing Material Balance Shahamat and Clarkson, SPE 185052 (2017)

Statistical EUR

- → Single forecast
- → Monte Carlo + Improve for uncertainty estimate
- → **Monte Carlo + Model Mining**: replacing the CPU expensive nonlinear regression step by a data mining proxy

Model Mining is activated when:

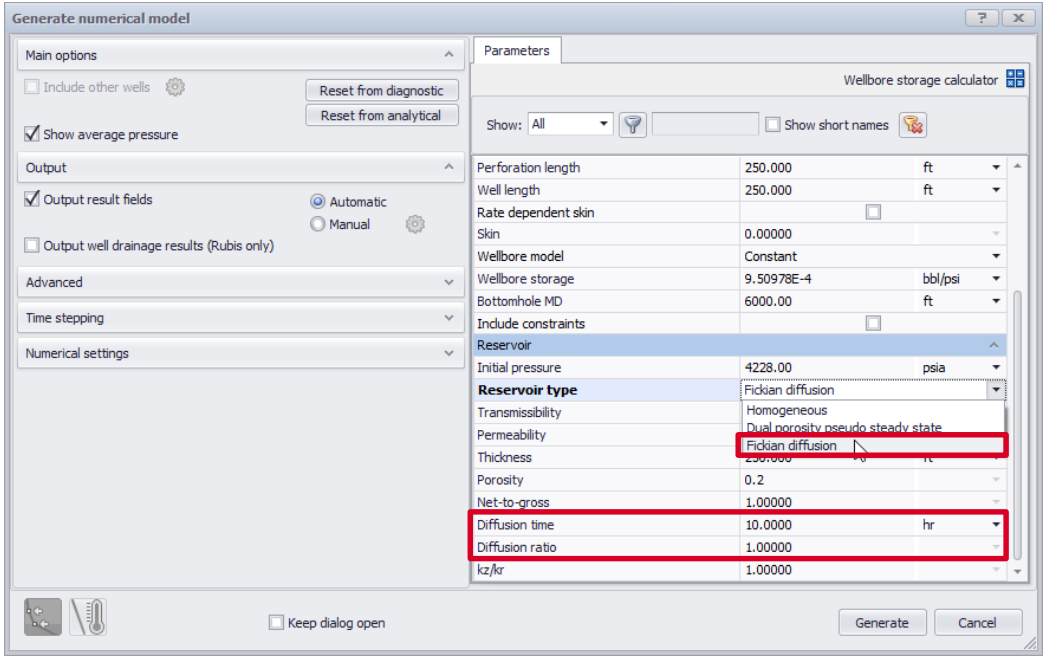
- Model forecast in done
- There are multiple Monte Carlo sensitivity runs on the forecast
- The sensitivity runs ‘bracket’ historical Q_{cum}



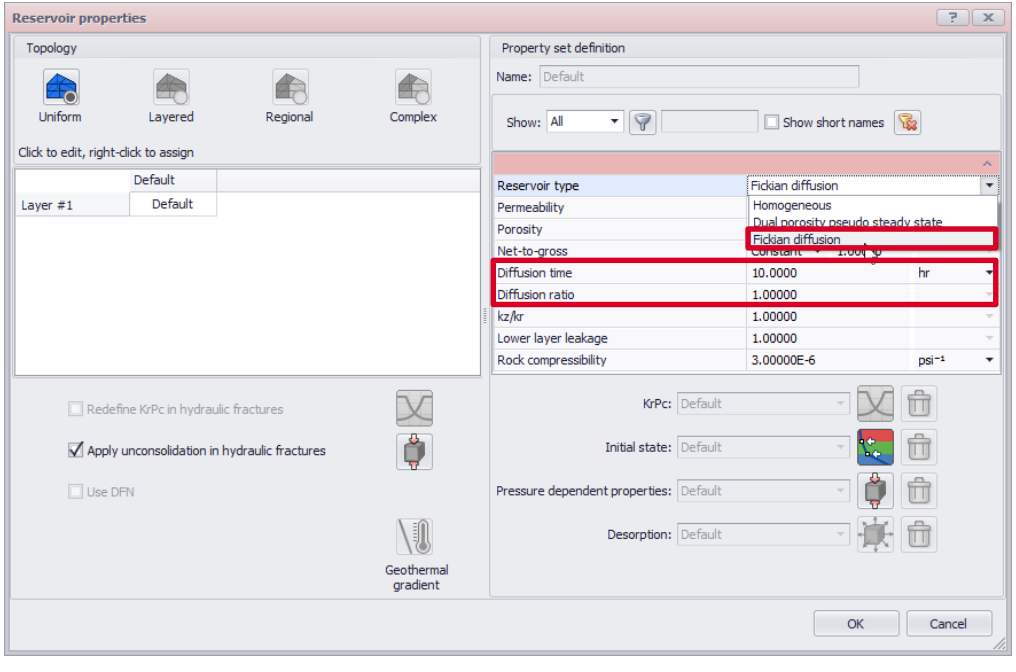
Fickian diffusion

PVT includes gas & Real PVT are used

Available under ‘Reservoir type’



or ‘Reservoir properties’



DFN Upscaling

New in v5.30

KAPPA

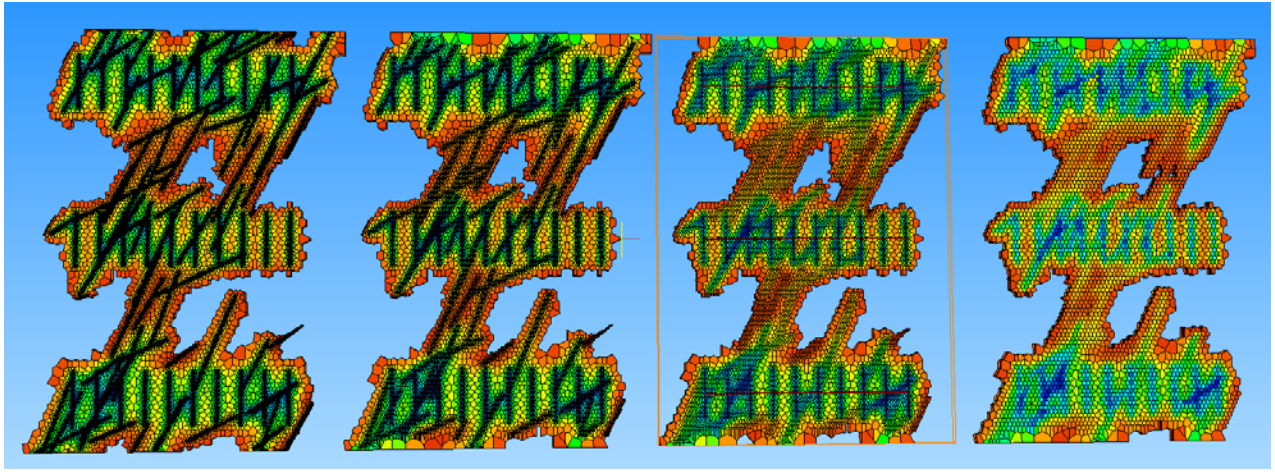
DFN upscaling reduces the refinement of the grid (and gridblock count), correctly accounting for the matrix-to-fracture flow and interaction

- DFN added in Map 

- Upscaling parameters are available in Grid 

- Min gridblock size changes from ‘DFN resolution’ to ‘DFN coarse resolution’

DFN upscaling	☑	
DFN resolution	4.00000	ft
DFN coarse resolution	50.0000	ft

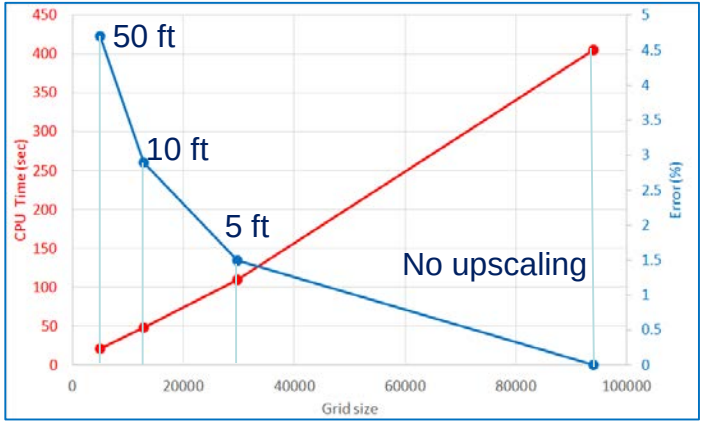


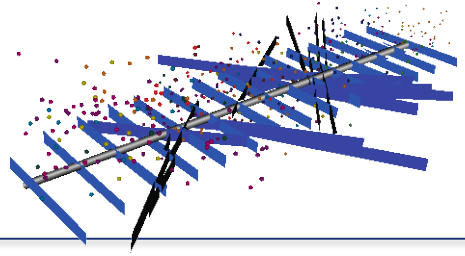
No upscaling
~94,000 cells

5 ft upscaling
~30,000 cells

10 ft
~13,000 cells

50 ft
~5,000 cells





Refrac

New in v5.30

KAPPA

The option allows opening some MFHW fractures at a later time

- Well is set as a MFHW
- Fractures are Finite conductivity

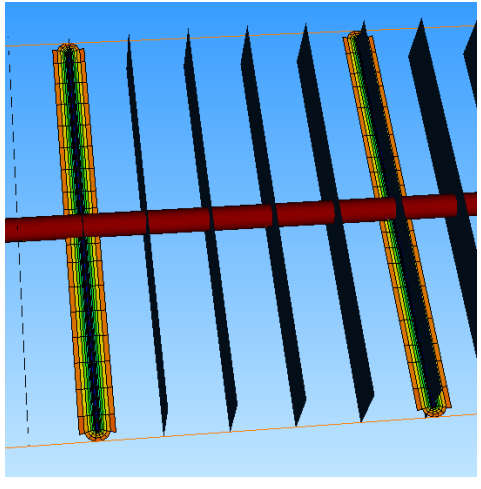
(a) **Regular** refrac pattern:

Refrac	☑	
Refrac elapsed time	18.0000	Month → T
Number of fractures at t0	12	→ a
Refrac ratio	4	→ b
Infill	☐	

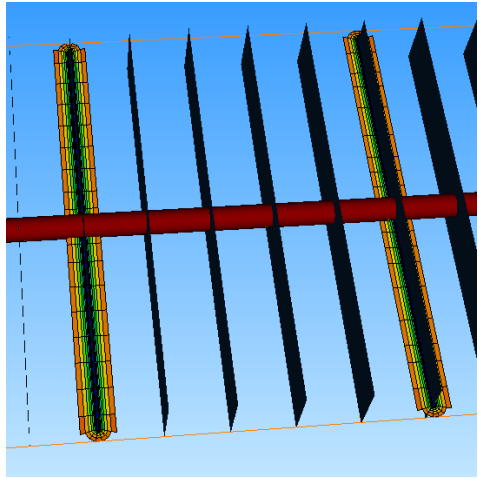
(b) **Irregular** refrac pattern:

- Complex MFHW + indiv.properties 
- Each fracture has its own refrac time T

Before refrac (time = 0): $N_f = a$



After refrac (time = T): $N_f = a + b\,(a - 1)$



(c) **Infill** option:

- All fractures start with matrix properties and switch to high conductivity at refrac elapsed time T

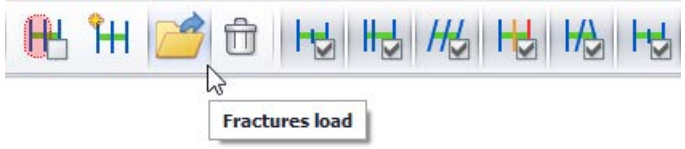
Loading properties of fracs

New in v5.30

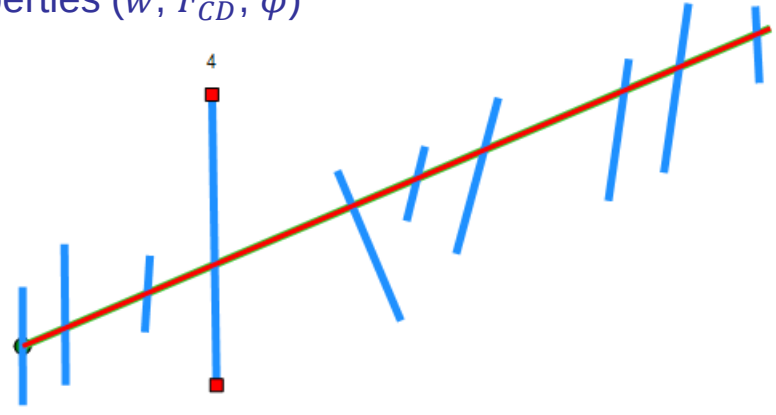
KAPPA

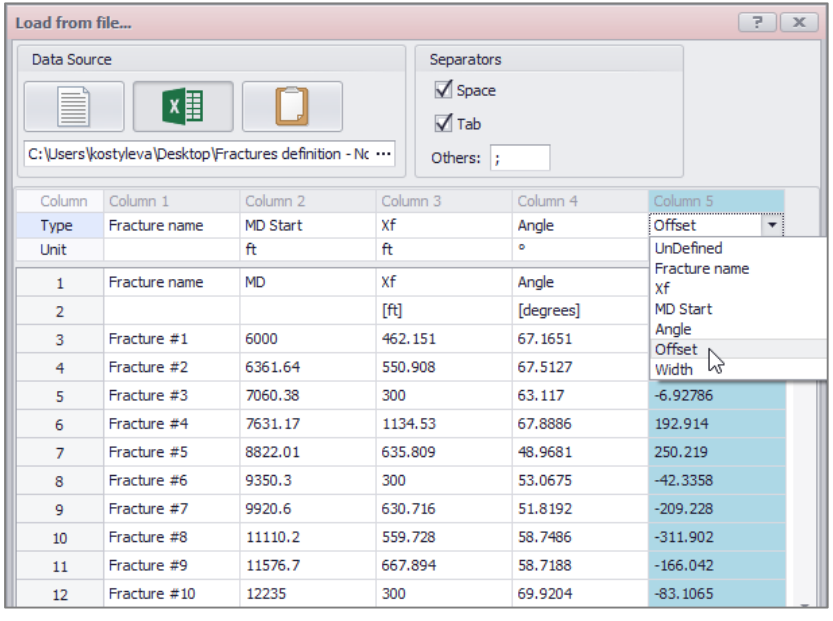
The option allows loading individual fracture properties for a complex MFHW from a file

- MFHW well modeling type should be set as ‘Complex’
- ‘Load’ button is available in the well dialog
- Tick the options prior to loading a file:
  - Half-length
  - Fracture position (MD)
  - Angle to the wellbore
  - Individual properties (w, F_{CD}, ϕ)
  - Offset



Geometry and properties - Fracture #4		
Measured depth	7631.17	ft
Fracture half length	1134.53	ft
Fracture angle	67.8886	°
Fracture offset	192.914	ft
Fracture height	400.000	ft
Fracture conductivity	150.000	md.ft
Fracture width	0.01	ft
Fracture porosity	0.1	



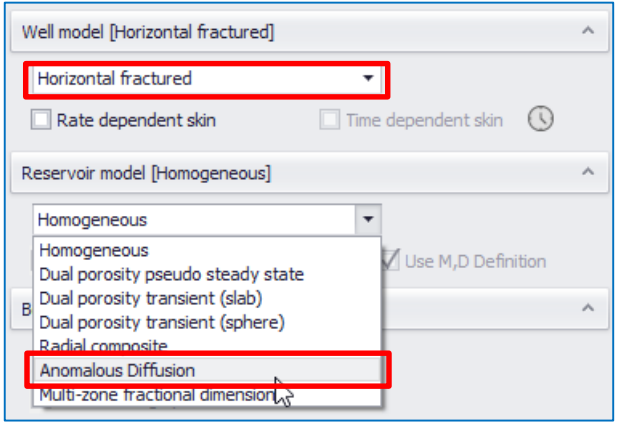


Anomalous Diffusion

New in v5.30

KAPPA

Anomalous Diffusion analytical model is made internal



- Well: Simple MFHW or Trilinear
- Single layer models only
- Matrix: homogeneous / double porosity
- Can include changing WBS, rate-/time-dependent skin

Well & wellbore	
Wellbore storage	0.01
Skin	0.00000
Modeling type	Trilinear
Flow type	Simple
Well length	SRVD
Zw	Trilinear
Number of fractures	Complex
	Conjugate fractures

Reservoir & boundary		
Initial pressure	5000.00	psia
Transmissibility	0.2	md.ft
Permeability	1.00000E-3	md
Thickness	200.000	ft
Porosity	0.1	
Primary diffusion exponent	**0.7**	
Secondary diffusion exponent	**0.3**	
Reservoir	Homogeneous	
kz/kr	1.00000	
Total compressibility	3.00000E-6	psi^{-1}

Additional parameters:

α_f and α_m

(also for outer zone in Trilinear)

Fractured-Well Performance Under Anomalous Diffusion, Raghavan and Chen, SPE-165584 (2013). Also SPE-191407, SPE-191484.

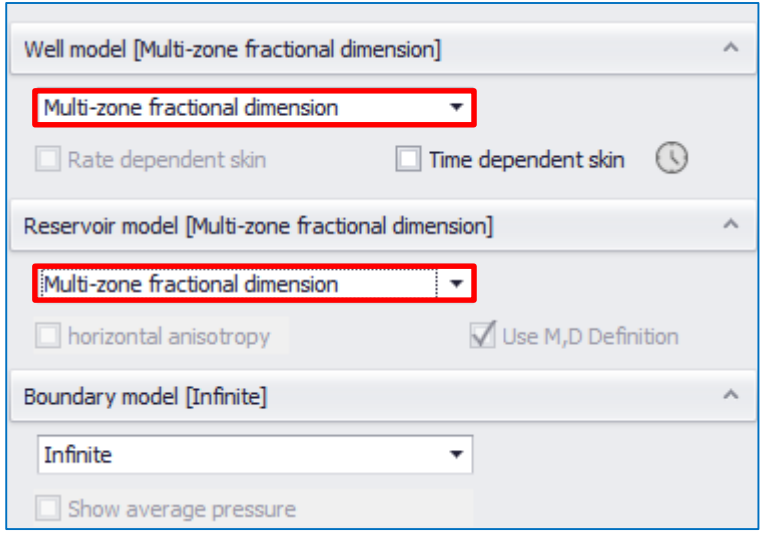
Multi-zone fractional dimension

New in v5.30

KAPPA

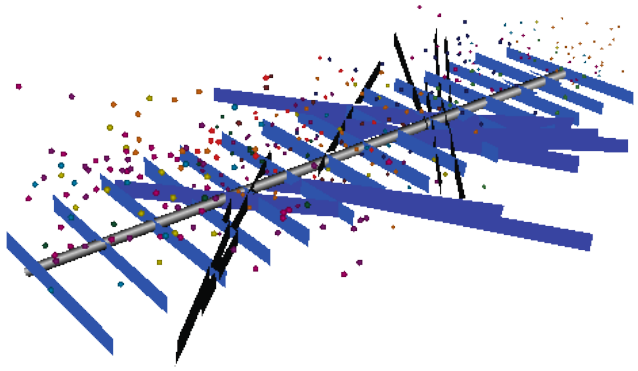
Multi-zone fractional dimension analytical model is made internal

Selected in Well or Reservoir model dialog (the two are synchronized)



- Boundary: infinite / circular / linear
- Compatible with multilayer geometry
- Compatible with time-dependent skin
- Not available with time-dependent well mode

Analytical Pressure and Rate Transient Models for Analysis of Complex Fracture Networks in Tight Reservoirs, J.A. Acuña, URTeC paper SPE-2429710 (2016). Also SPE-2667752, SPE-2896802, SPE-2876208.



KAPPA

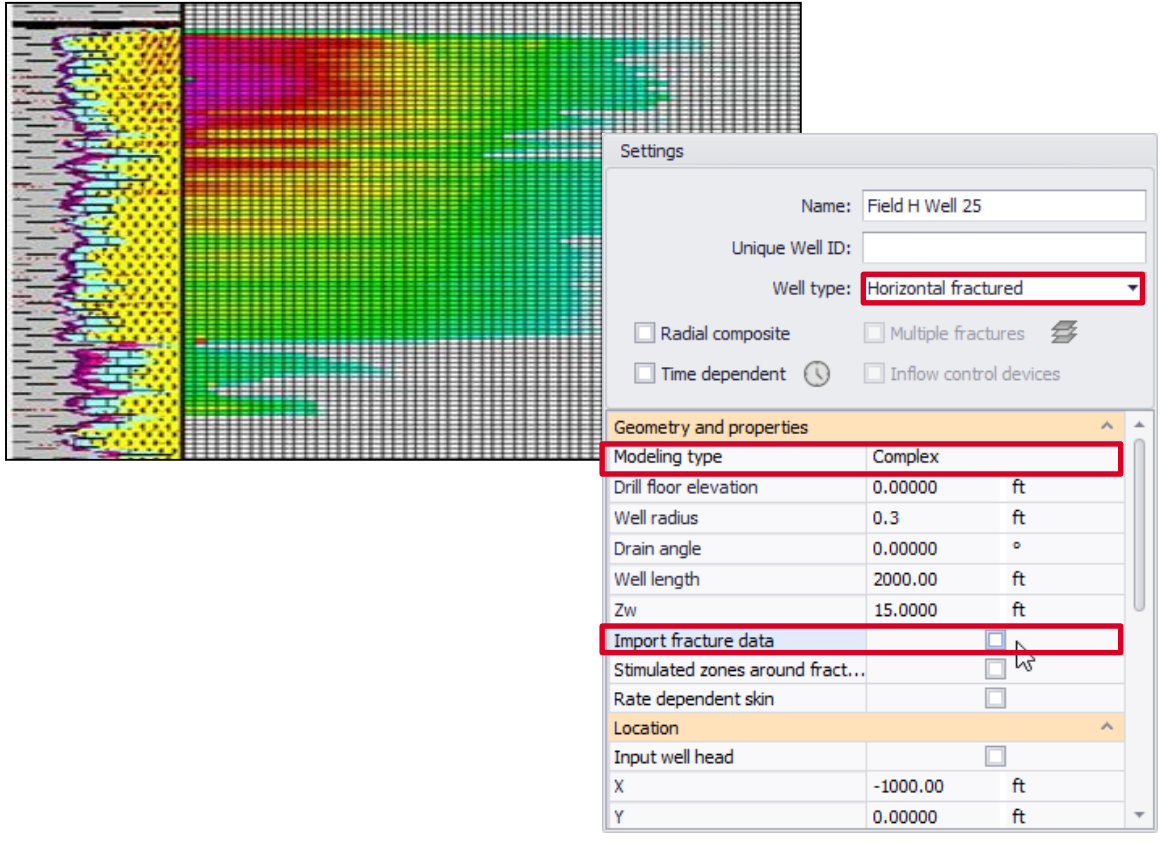
THANK YOU

kappaeng.com/ur

Load from fracturing software

KAPPA

Fracture properties can be non-uniform along the fracture plane



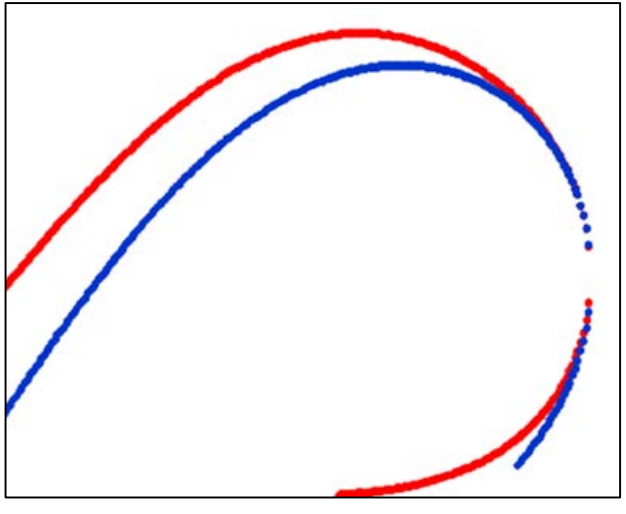
- Define a MFHW as ‘Complex’
- Activate ‘Import fracture data’
- Load properties from *.csv or *.xml:
  - Index, TVD and location at the well
  - (X,Z): w_f, k_f, F_{CD}, φ, β
- Define fracture MD and angles

Confined PVT

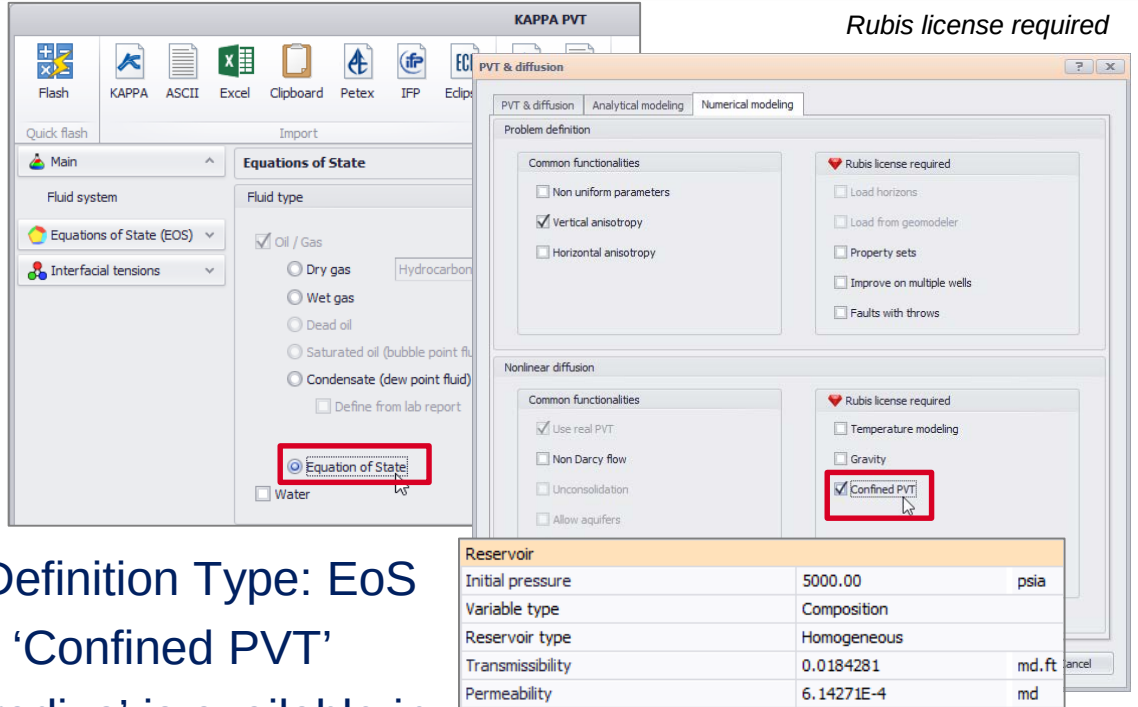
KURC-1

KAPPA

The size of the pores ~ the size of hydrocarbon molecules ('confined')
→ PVT is different from the phase behavior in a laboratory cell



Rubis license required



Reservoir		
Initial pressure	5000.00	psia
Variable type	Composition	
Reservoir type	Homogeneous	
Transmissibility	0.0184281	md.ft
Permeability	6.14271E-4	md
Thickness	30.0000	ft
Porosity	0.1	
Net-to-gross	1.00000	
kz/kr	1.00000	
Pore radius	**1.00000E-8**	m

- Fluid Definition Type: EoS
- Check 'Confined PVT'
- 'Pore radius' is available in Reservoir Properties

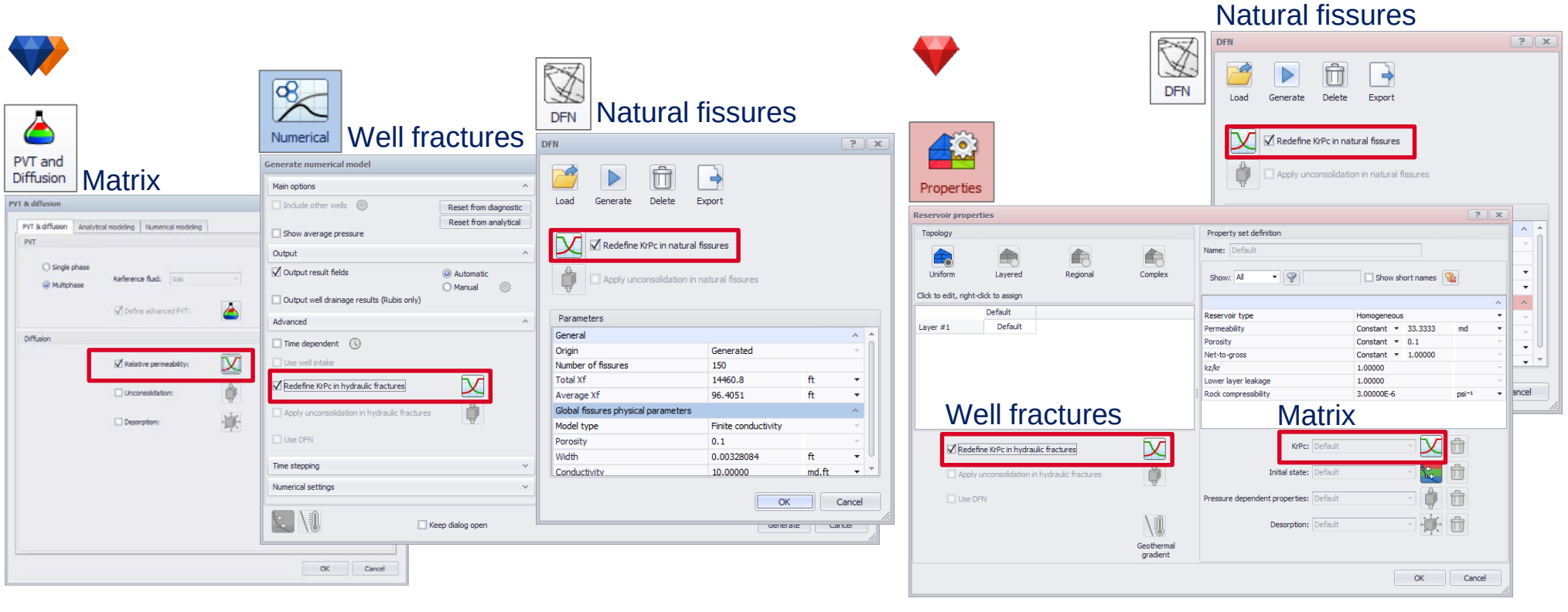
Multiple KrPc

KURC-1

KAPPA

Matrix, well fractures and natural fissures can have independent sets of KrPc

- Multiphase PVT is defined & real PVT are used



Stochastic DFN realizations

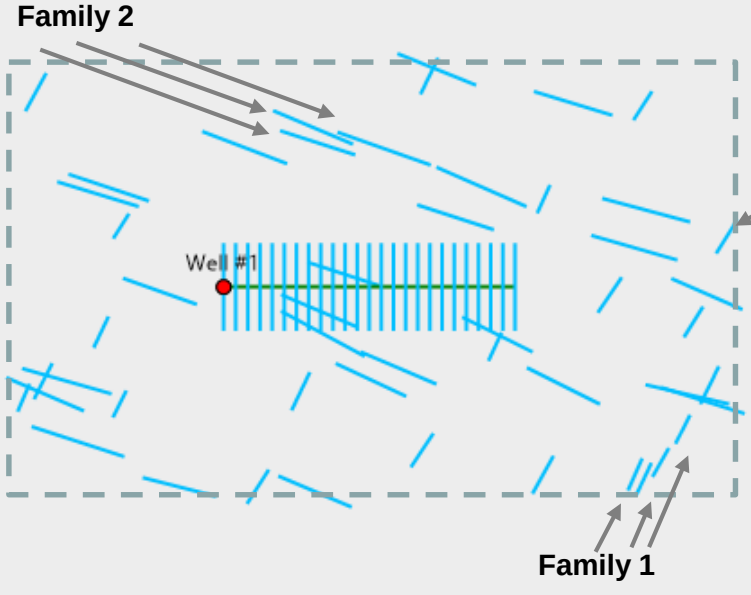
KURC-2

KAPPA

DFN

‘Map’ → ‘DFN’ → ‘Generate’

Location can be defined μ-seismic, if loaded



DFN geometry stochastic generation

Global settings

Fissures parameters		
Number of fissures	50	
Use microseismics events		
X minimum	-2500.00	ft
X maximum	**2500.00**	**ft**
Y minimum	-1500.00	ft
Y maximum	1500.00	ft
Impose random generator seed		

Fissure families

Family parameters		
Fraction	0.5	Fraction
Minimum fissure length	200.000	ft
Maximum fissure length	300.000	ft
Power	1.50000	
Strike angle	**30.0000**	°
K strike	400.000	

Family name

Family 1

Family 2

Add

Delete

Interference with DFN: FMM

KURC-2

KAPPA

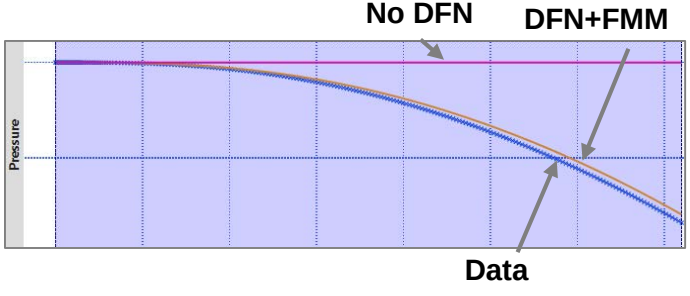
At least 2 wells must exist in the map

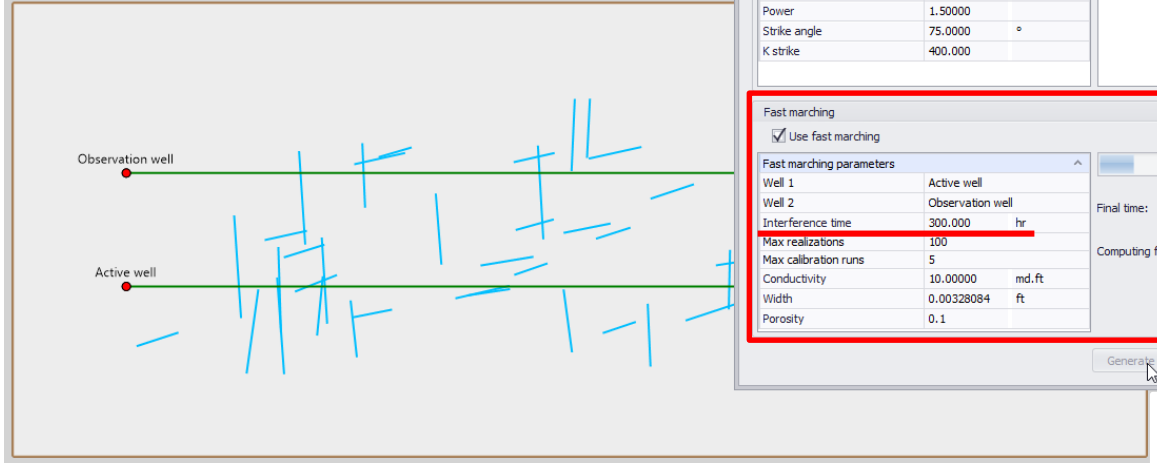
‘Map’ → ‘DFN’ → ‘Generate’

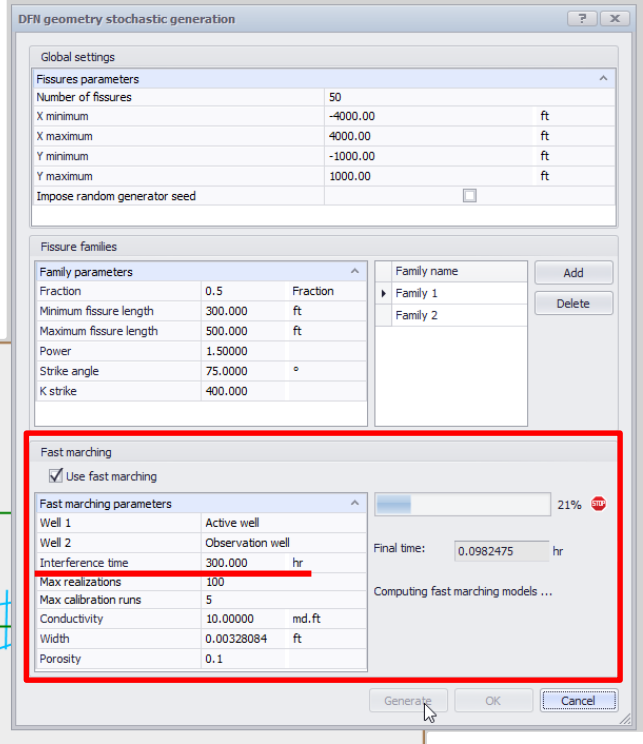
Interference time is an input to constrain the DFN

A number of realizations are run using Fast Marching (flow in fractures only) to pick one closest to the interference time

Then a full model is run in Analysis







Stimulated zones

KURC-2

KAPPA

Stimulated zones around fractures of a MFHW

- Available for both Simple and Complex well types
- Defined by radius of the zone, k and φ multipliers

Parameters

Show: All Show short names

Well 1		
Modeling type	Simple	
Drain angle	0.00000	°
Fracture model	Infinite conductivity	
Number of fractures	13	
Fracture half length	360.000	ft
Fracture height	30.0000	ft
Fracture mid-point height	15.0000	ft
Width	0.00328084	ft
Fracture angle	90.0000	°
Zw	15.0000	ft
Well length	2000.00	ft
Stimulated zones around fractures	☑	
Stimulation radius	50.0000	ft
Permeability multiplier	4.00000	
Porosity multiplier	1.00000	
Rate dependent skin	☐	
Wellbore model	None	
Bottomhole MD	6000.00	ft

These parameters can be regressed upon in 'Improve'

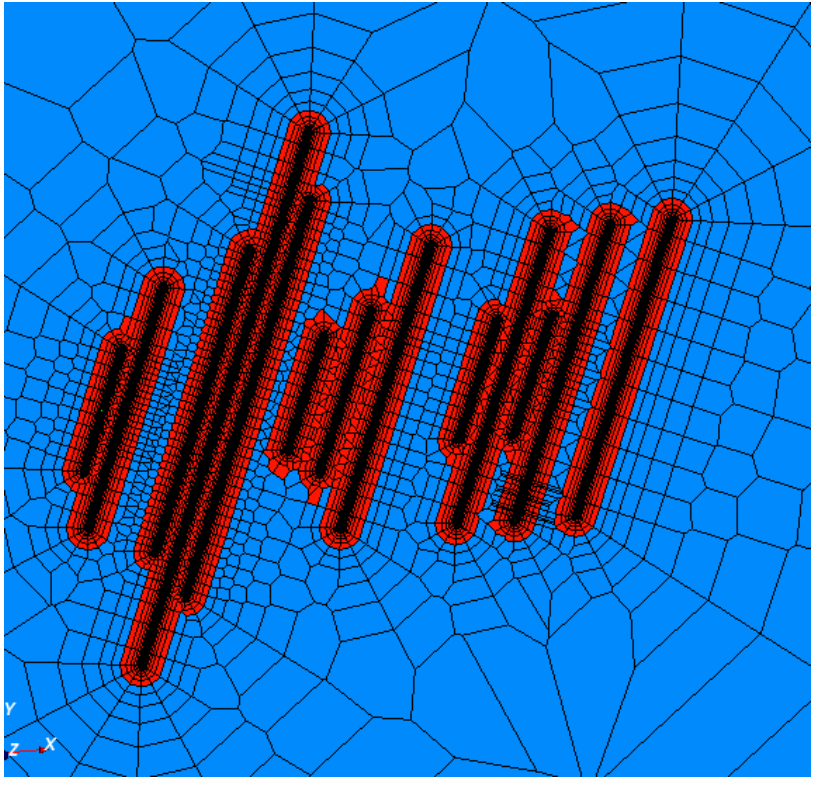
Improve

Parameters | Targets

Constant parameters

Well 1

- Theta
- N
- Xf
- Hf
- Zf
- Width
- Beta
- Zw
- Lw
- Stimulation radius
- k multiplier
- phi multiplier



Compatible with numerical SRVB/Trilinear models

KURC-2 future developments

- MFHW with deviated drain trajectory
- Coupling with geomechanics
- Stimulated zones around the fractures with $k(p)$ and $\varphi(p)$