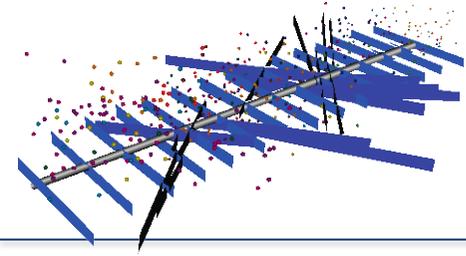




UR Add-on pack



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)

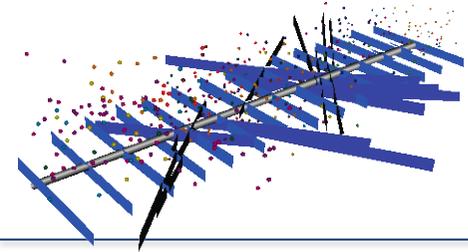
Add-on pack features



- ◆◆ 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

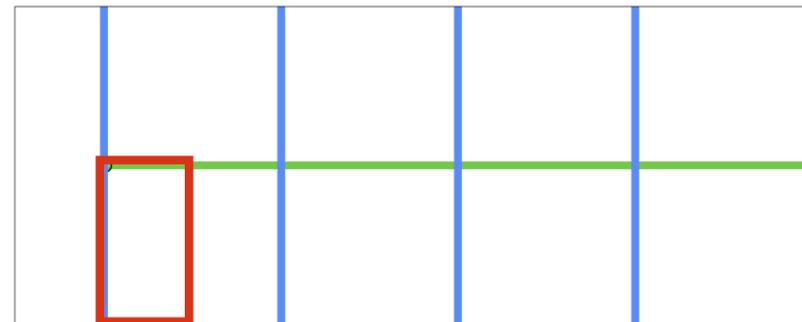
- KURC-2
 - ◆◆◆ Stochastic DFN realizations
 - ◆◆◆ Interference with DFN: Fast Marching Method
 - ◆◆◆ Stimulated zones around the fractures

Fast numerical models

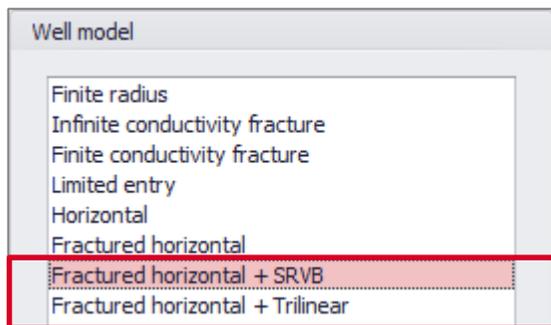
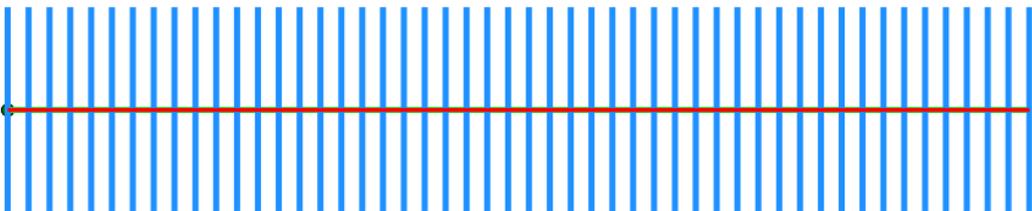
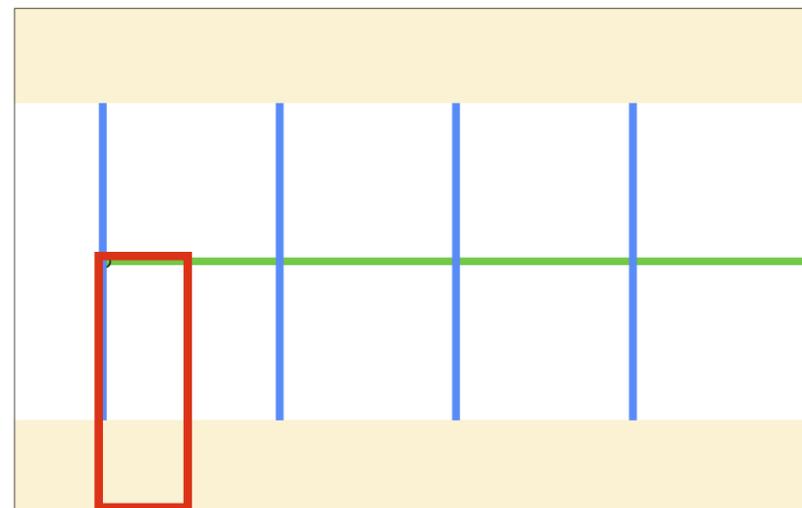


Very useful in the case of complex PVT and a simple but very long MFHW to tune the fracture properties prior to running the full numerical model

Stimulated Reservoir Volume bounded (SRVB)



Trilinear



Can be initiated from an analytical model via the Dashboard

DFN analytical model



- Conjugate fractures: # fissures and geometry

Complex horizontal fractured well

Parameters

Show: All Show short names

Well & wellbore

Skin	0.0000
------	--------

Modeling type: Conjugate fractures

Flow type: Simple

Well length: SRVB

Zw: Trilinear

Complex

Global fracture parameters

Number of fractures	12	
Fracture model	Infinite conductivity	
Fracture half length	806.657	ft
Fracture height	30.0000	ft
Fracture width	0.00328084	ft

Global natural fissure parameters

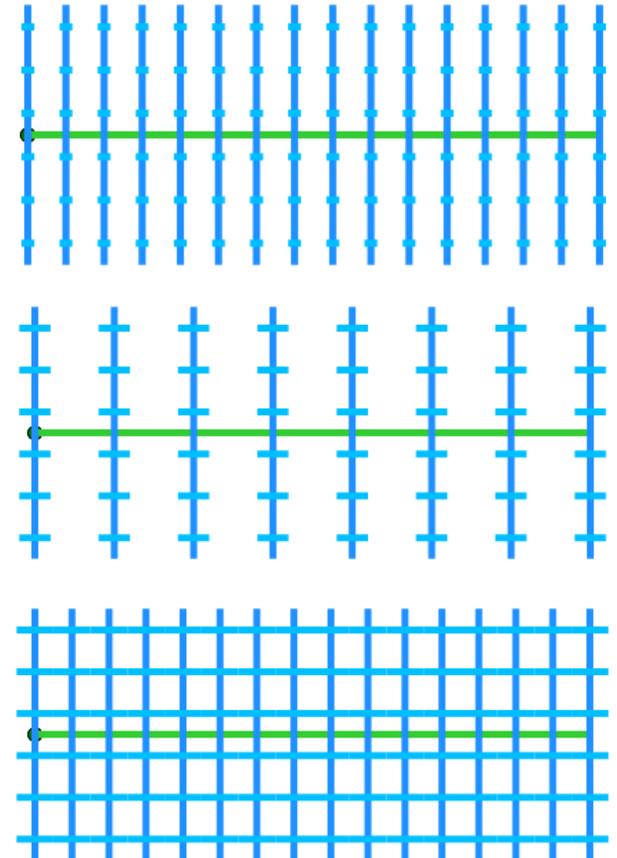
Fissures connected	<input type="checkbox"/>	
Vertical half number of fissures	1	
Fissure half length	80.0000	ft
Fissure height	30.0000	ft
Fissure model	Infinite conductivity	

History constraints

Include constraints	<input checked="" type="checkbox"/>	
Max surface rate constraint	3.00000E+5	Mscf/D
Min surface rate constraint	0.00000	Mscf/D

Reservoir & boundary

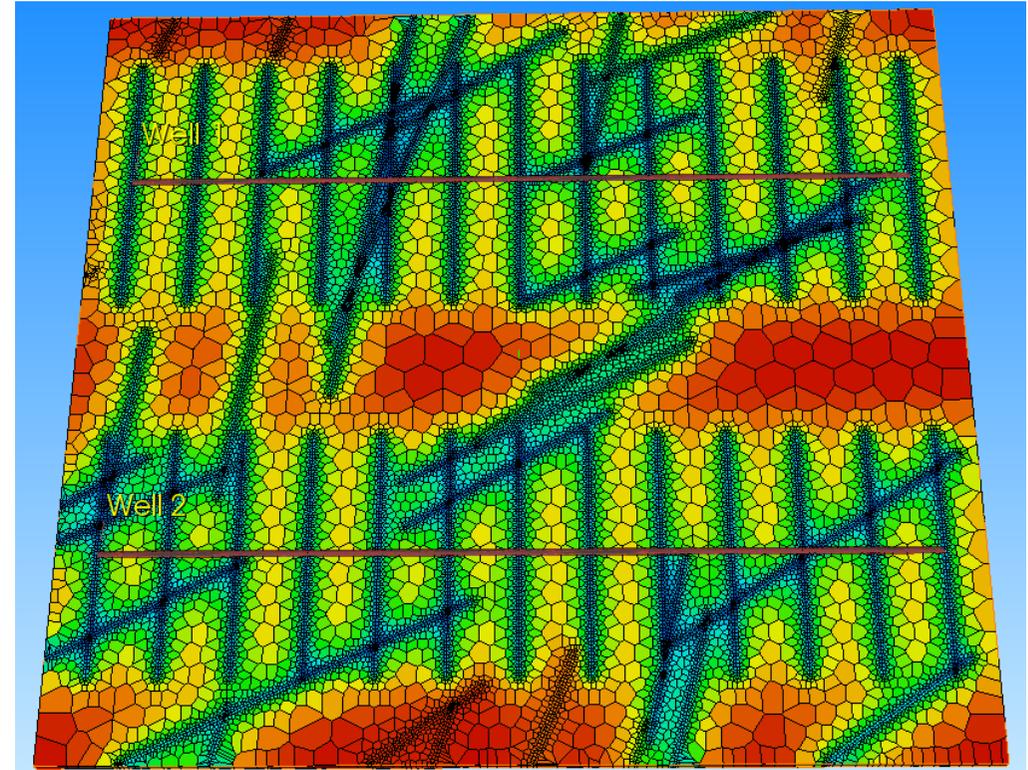
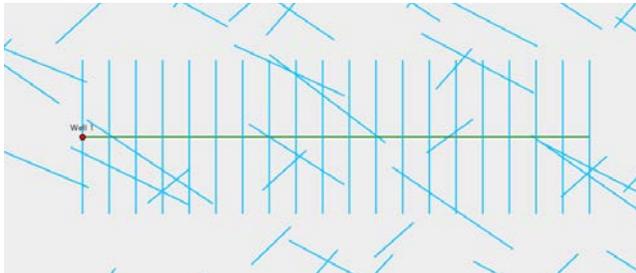
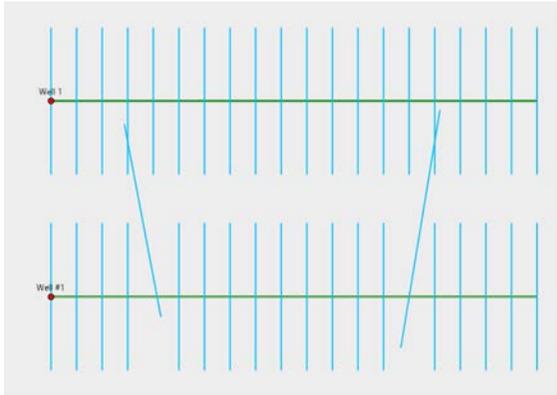
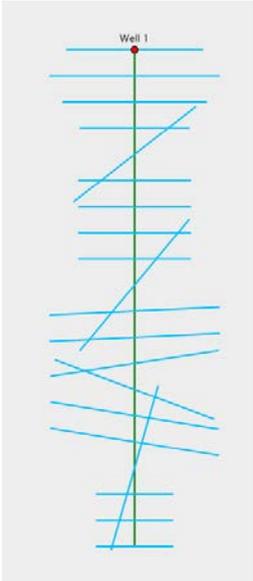
Generate Cancel



Numerical DFN



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

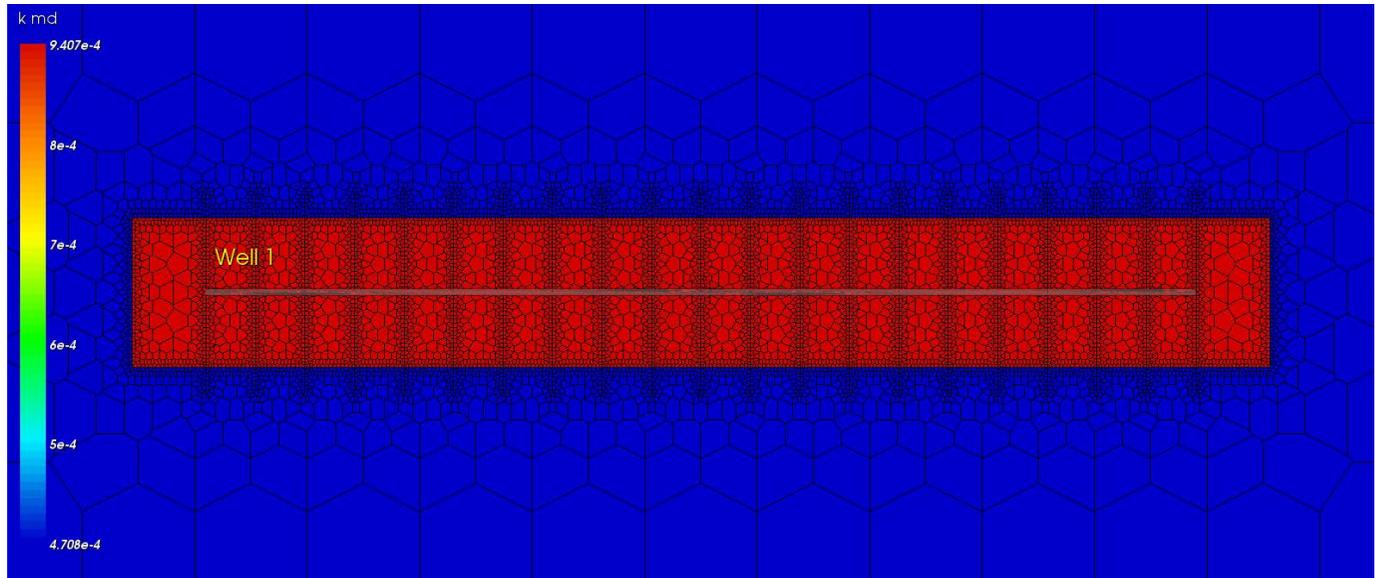
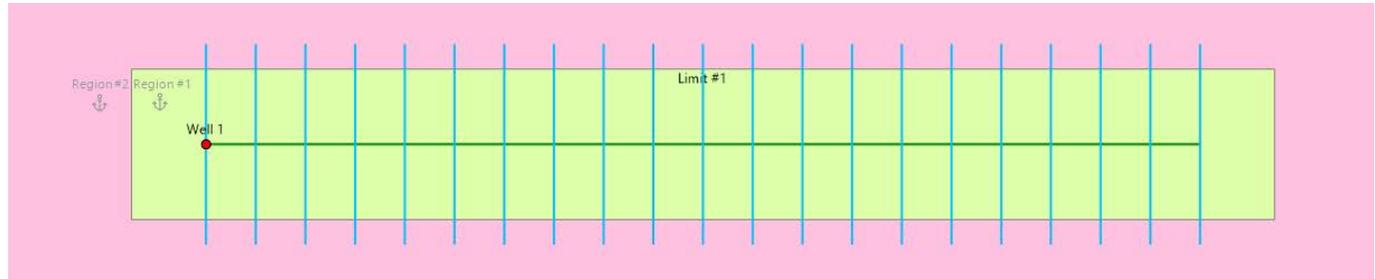


Composite zones



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
D	Dual porosity pseudo steady state
Net-to-gross	1.00000

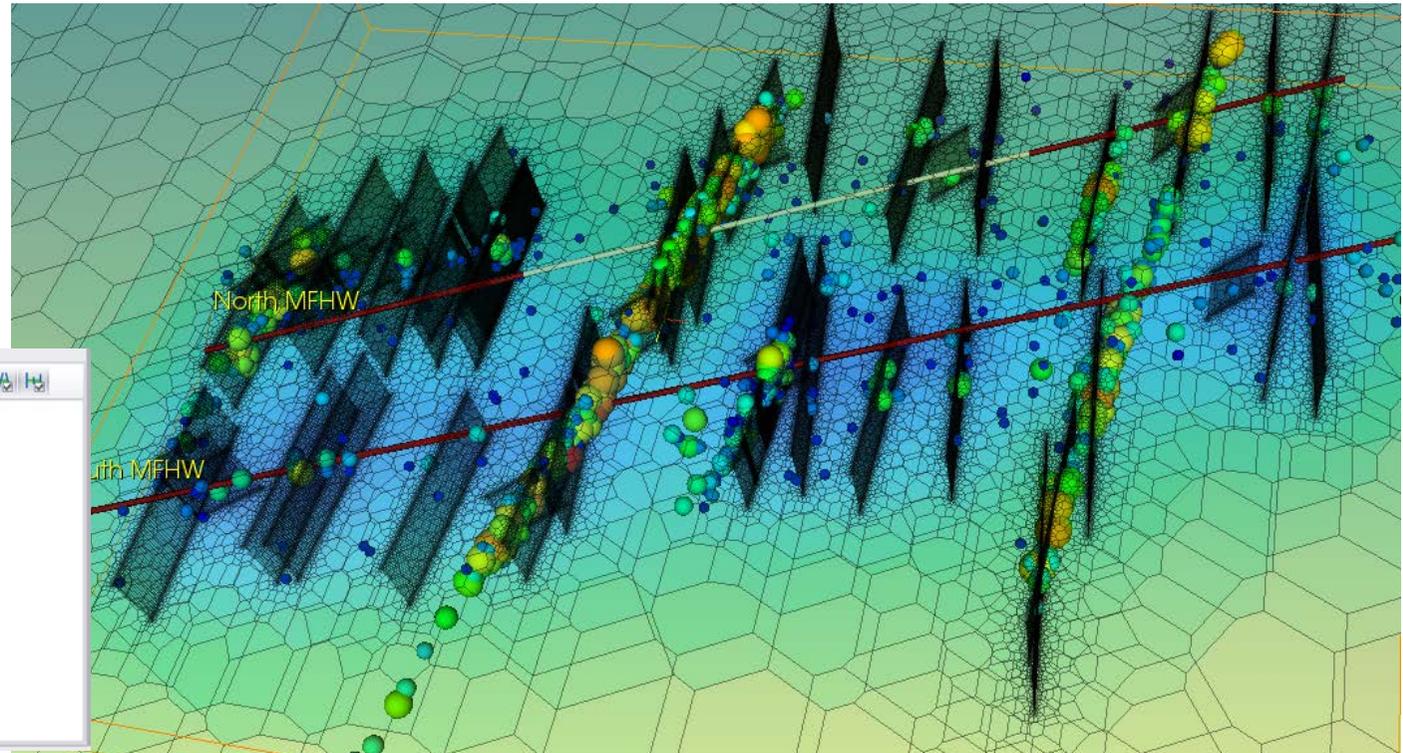
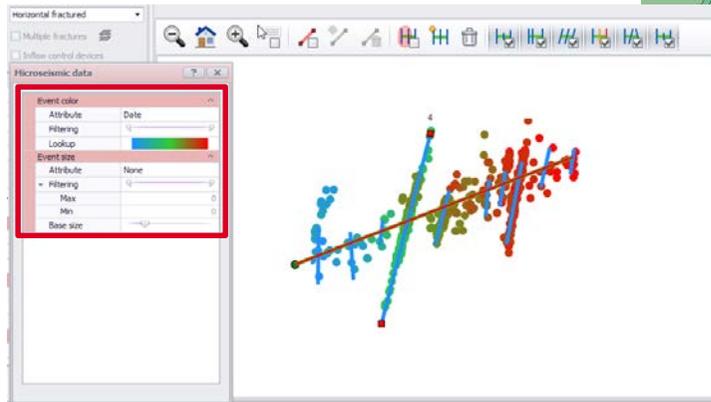


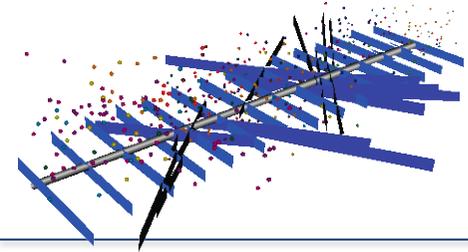
Microseismics



Load and display of microseismic events to constrain the MFHW configuration

Visualizing attributes:
date, amplitude, stage index

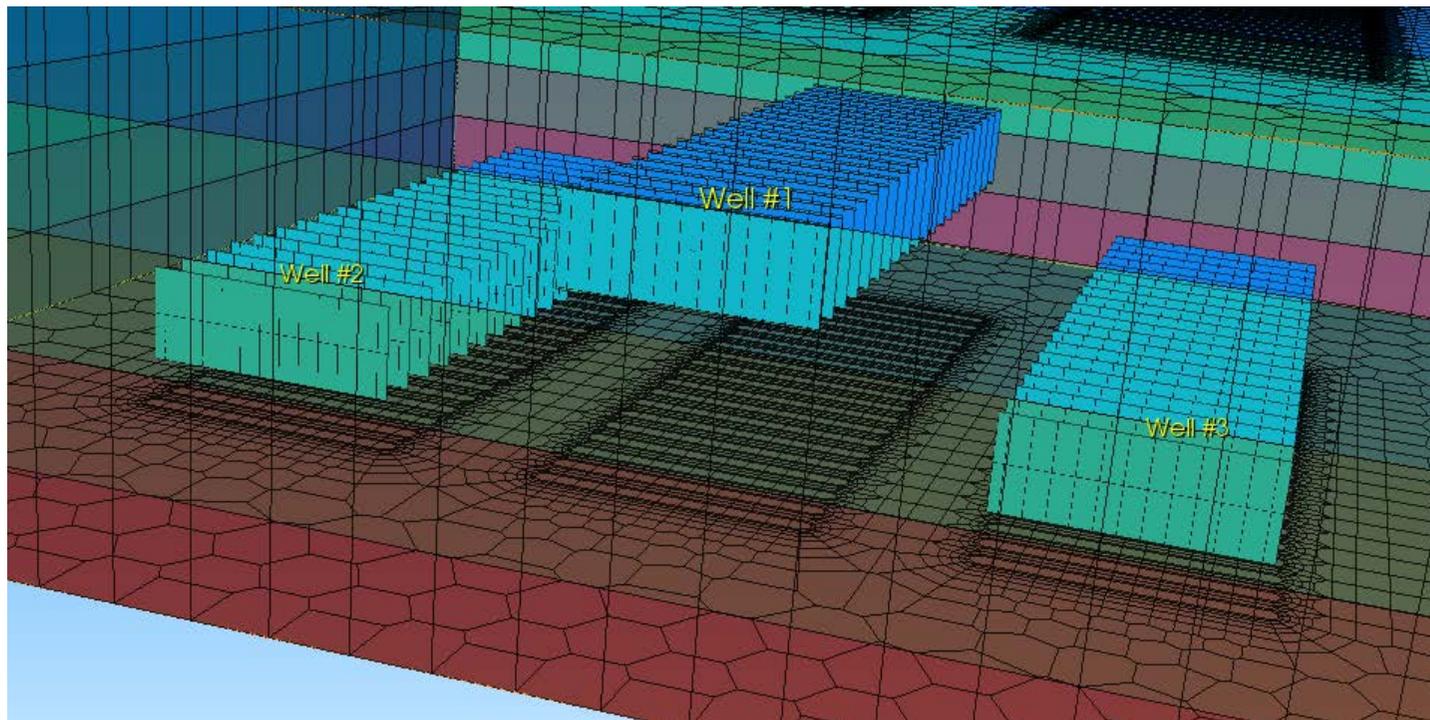




Accelerated initialization



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	<input type="checkbox"/>	
Skin	0.00000	
Wellbore model	None	
Bottomhole MD	6000.00	ft
Include constraints	<input type="checkbox"/>	
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	<input checked="" type="checkbox"/>	
Klinkenberg b	200.000	psia
Net-to-gross	1.00000	
kz/kr	1.00000	

Water flowback

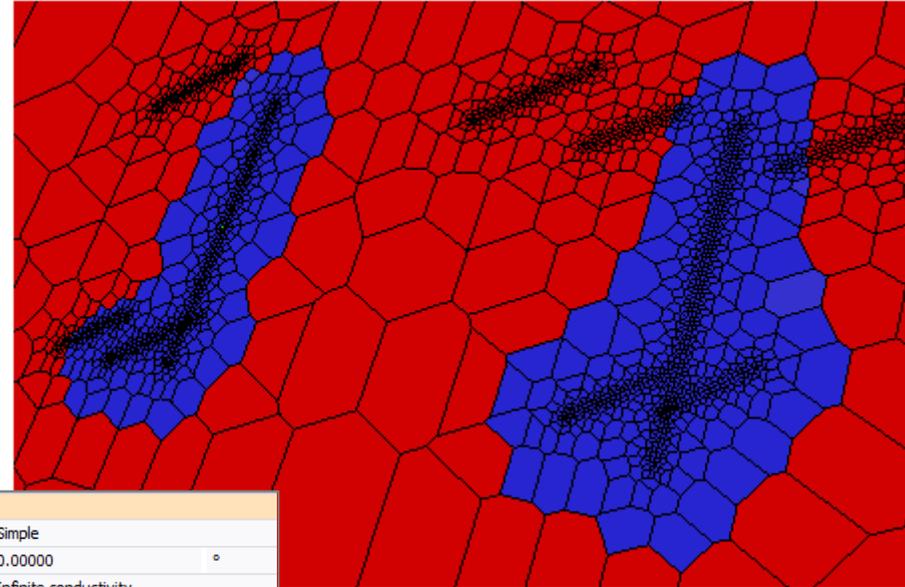


To model the post fracture treatment water flowback:

- 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



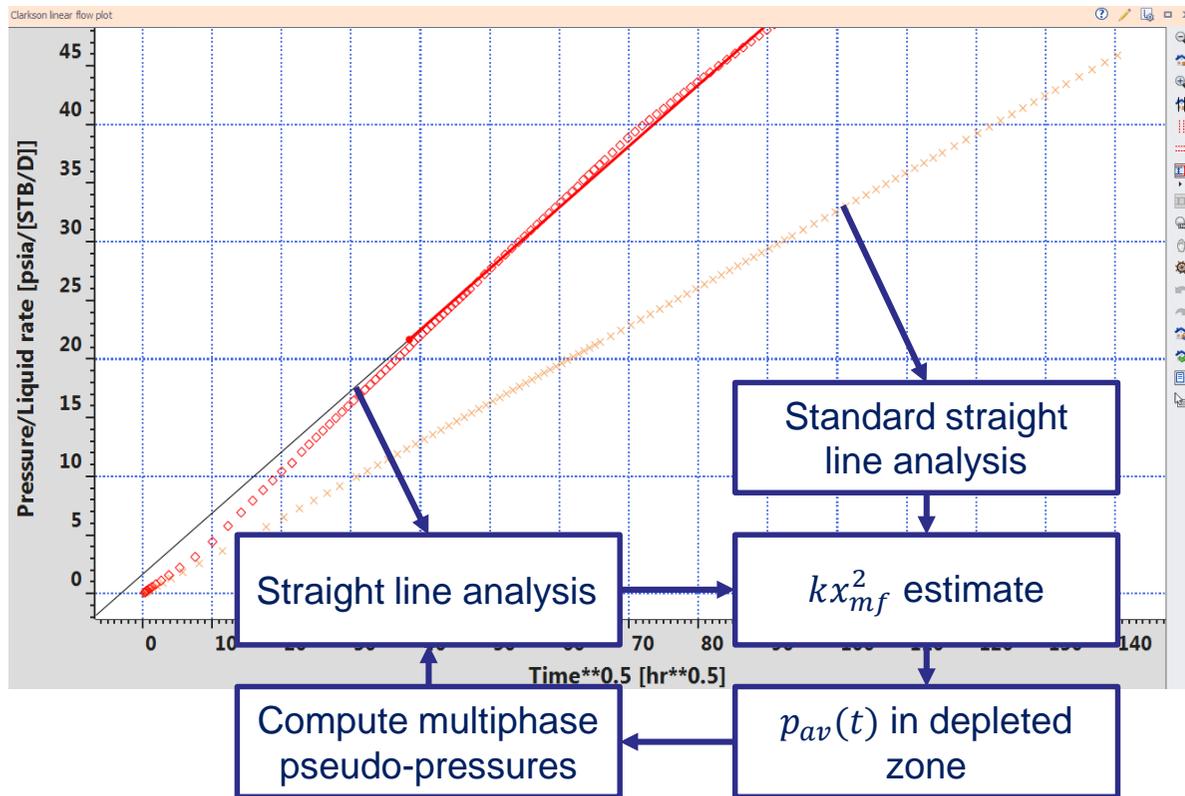
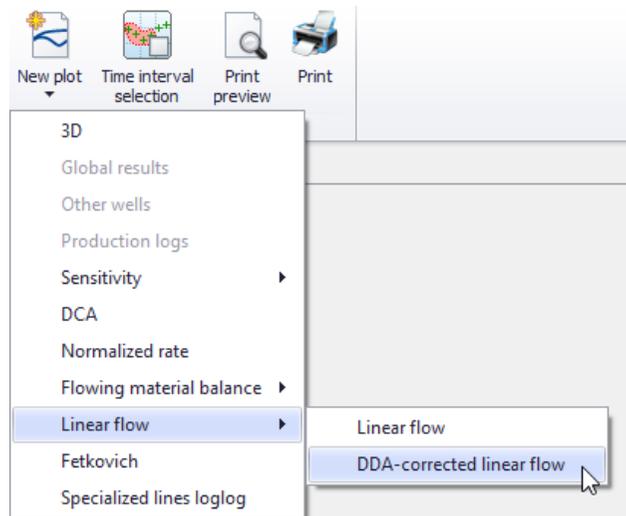
Well 1		
Modeling type	Simple	
Drain angle	0.00000	°
Fracture model	Infinite conductivity	
Number of fractures	15	
Fracture half length	300.000	ft
Fracture height	30.0000	ft
Fracture mid-point height	15.0000	ft
Width	0.00328084	ft
Fracture angle	90.0000	°
Zw	15.0000	ft
Well length	1000.00	ft
Stimulated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

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

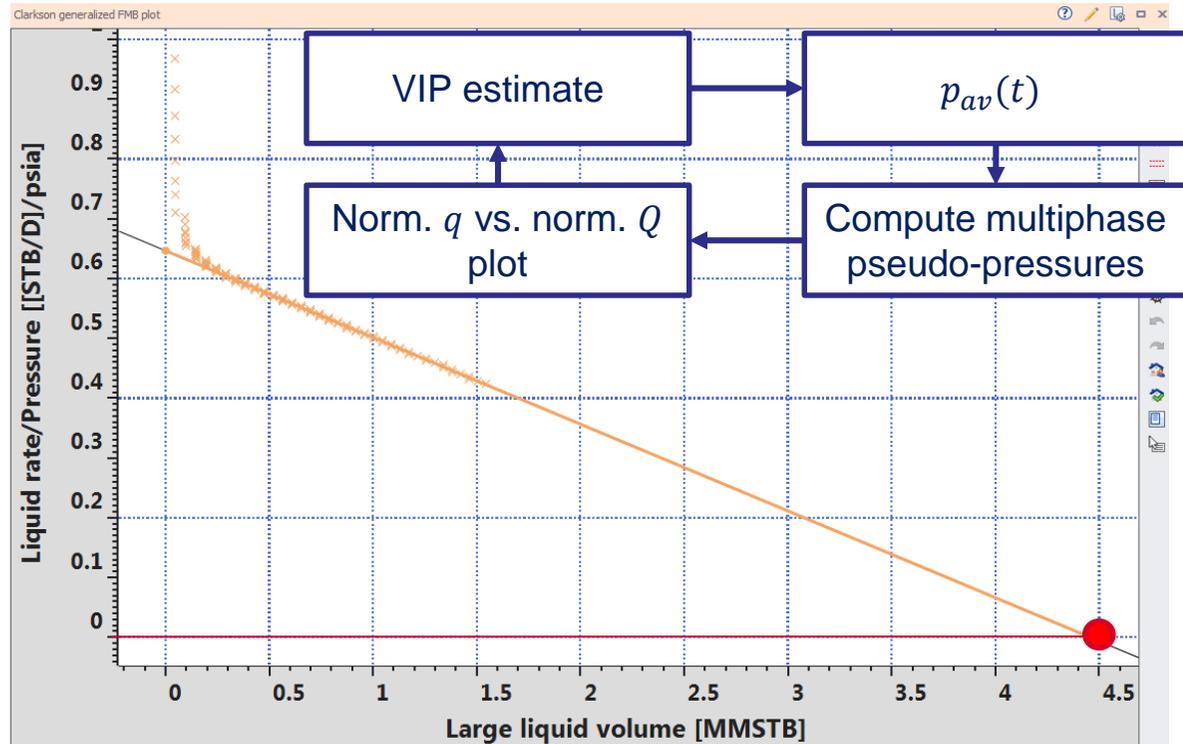
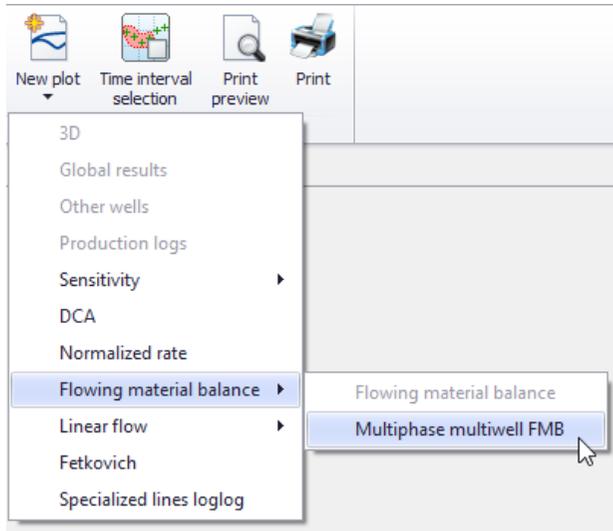


General Flowing Material Balance equation modified using pseudo- p and p_{av} from MB calculations

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

Multiphase extraction

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



Statistical EUR



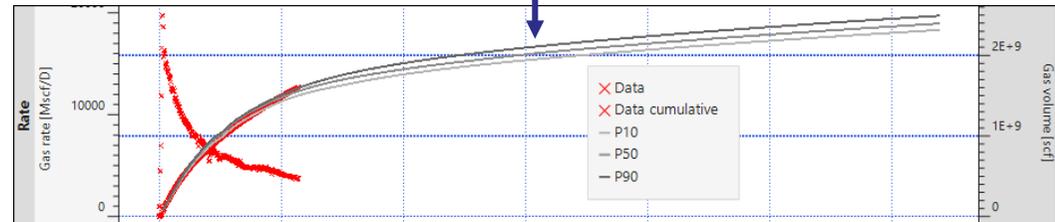
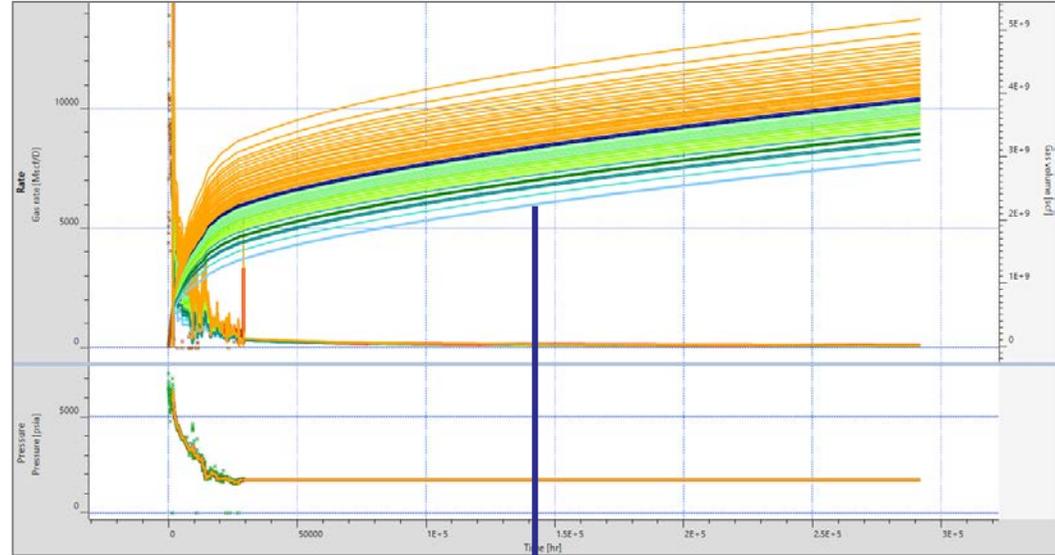
- Single forecast
- Monte Carlo + Improve for uncertainty estimate
- **Monte Carlo + Model Mining**: replacing the CPU expensive nonlinear regression step by a data mining proxy



Model Mining

Model Mining is activated when:

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



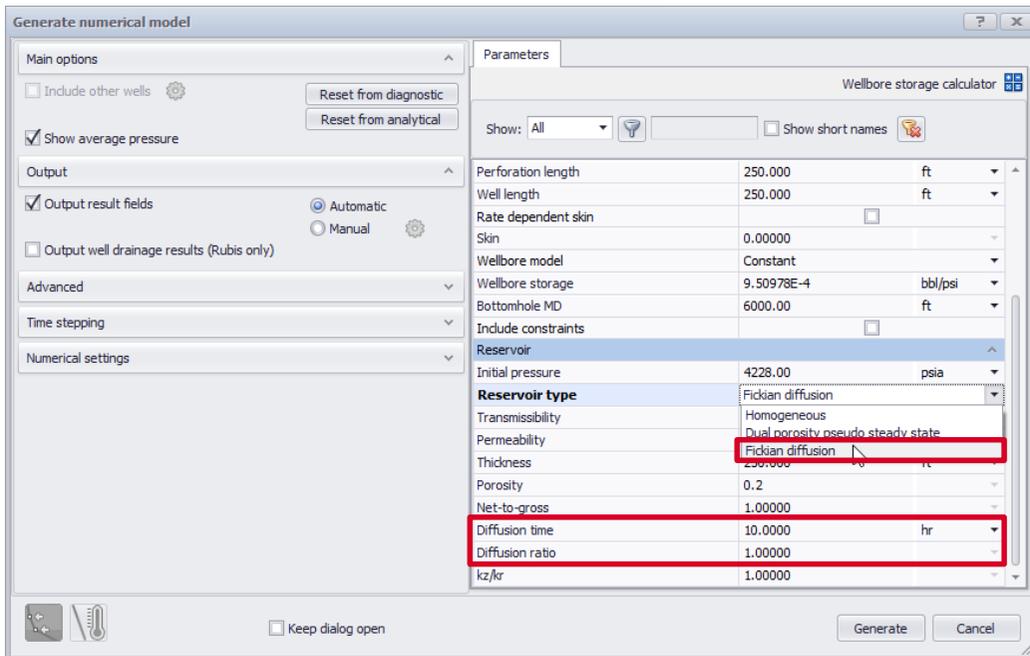
Fickian diffusion



PVT includes gas & Real PVT are used

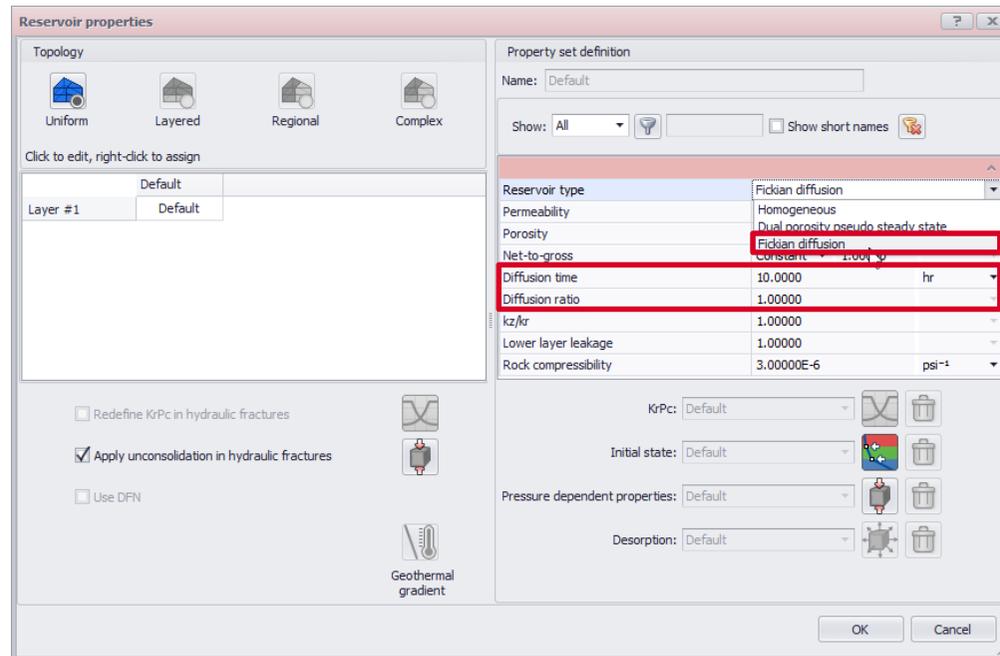
Available under 'Reservoir type' 

or 'Reservoir properties' 



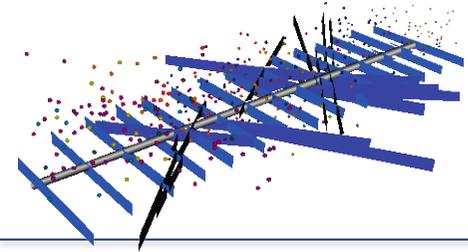
The 'Generate numerical model' dialog box is shown with the 'Parameters' tab selected. The 'Reservoir type' dropdown is set to 'Fickian diffusion'. The 'Diffusion time' and 'Diffusion ratio' fields are highlighted with red boxes. The 'Wellbore storage calculator' section is also visible.

Parameter	Value	Units
Perforation length	250.000	ft
Well length	250.000	ft
Rate dependent skin	<input type="checkbox"/>	
Skin	0.00000	
Wellbore model	Constant	
Wellbore storage	9.50978E-4	bbf/psi
Bottomhole MD	6000.00	ft
Include constraints	<input type="checkbox"/>	
Reservoir		
Initial pressure	4228.00	psia
Reservoir type	Fickian diffusion	
Transmissibility	Homogeneous	
Permeability	Dual porosity pseudo steady state	
Thickness	2500000	ft
Porosity	0.2	
Net-to-gross	1.00000	
Diffusion time	10.0000	hr
Diffusion ratio	1.00000	
kz/kr	1.00000	



The 'Reservoir properties' dialog box is shown with the 'Property set definition' tab selected. The 'Reservoir type' dropdown is set to 'Fickian diffusion'. The 'Diffusion time' and 'Diffusion ratio' fields are highlighted with red boxes. The 'KrPc' and 'Initial state' dropdowns are also visible.

Property	Value	Units
Reservoir type	Fickian diffusion	
Permeability	Homogeneous	
Porosity	Dual porosity pseudo steady state	
Net-to-gross	Constant porosity	
Diffusion time	10.0000	hr
Diffusion ratio	1.00000	
kz/kr	1.00000	
Lower layer leakage	1.00000	
Rock compressibility	3.00000E-6	psi ⁻¹



DFN Upscaling



New in v5.30

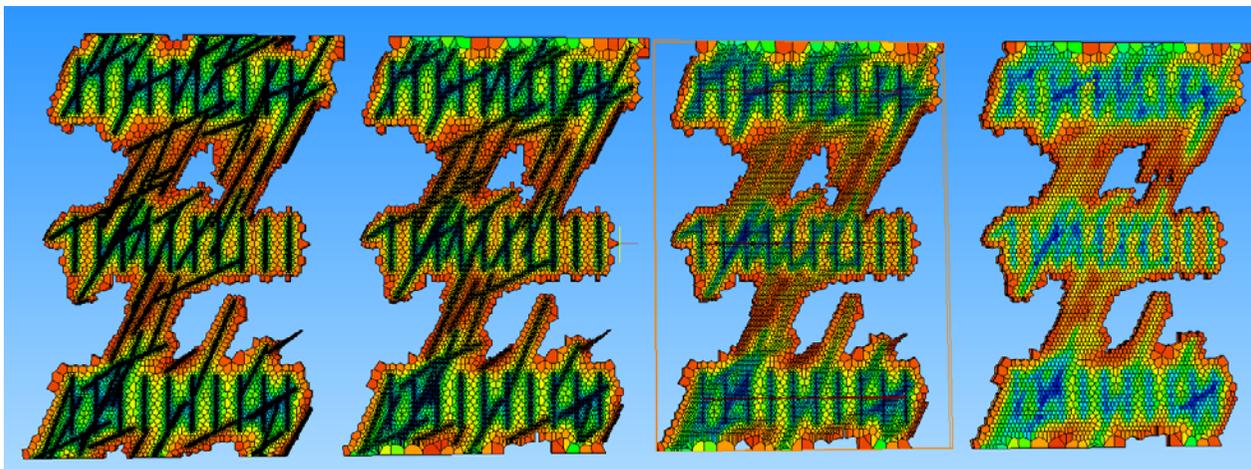


KAPPA

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 
DFN
- Upscaling parameters are available in Grid 
Grid
- Min gridblock size changes from 'DFN resolution' to 'DFN coarse resolution'

DFN upscaling		<input checked="" type="checkbox"/>
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	<input checked="" type="checkbox"/>
Refrac elapsed time	18.0000 Month $\rightarrow T$
Number of fractures at t0	12 $\rightarrow a$
Refrac ratio	4 $\rightarrow b$
Infill	<input type="checkbox"/>

(b) **Irregular** refrac pattern:

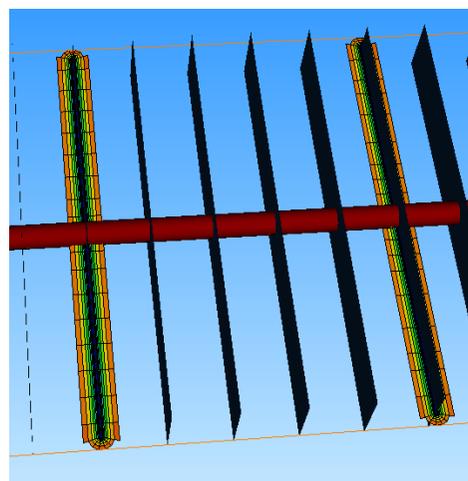
- Complex MFHW + indiv.properties 
- Each fracture has its own refrac time T

(c) **Infill** option:

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

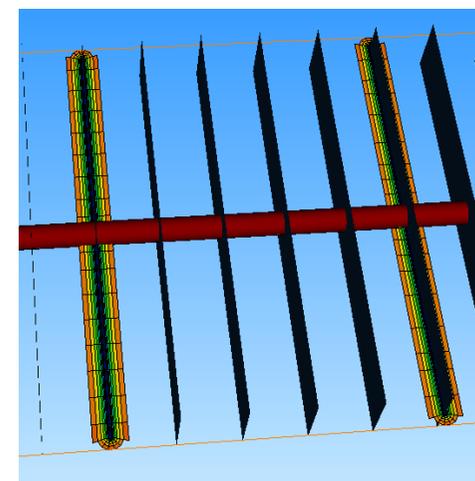
Before refrac (time = 0):

$$N_f = a$$



After refrac (time = T):

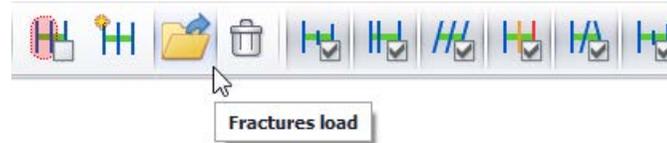
$$N_f = a + b(a - 1)$$



Loading properties of fracs

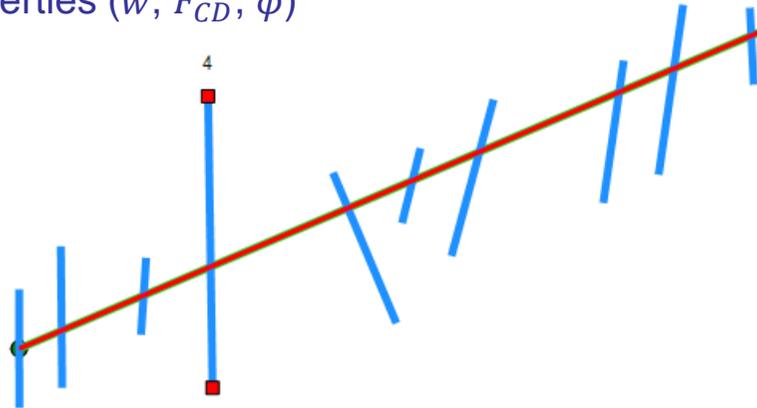
The option allows loading individual fracture properties for a complex MFHW from a file

- 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	



Load from file...

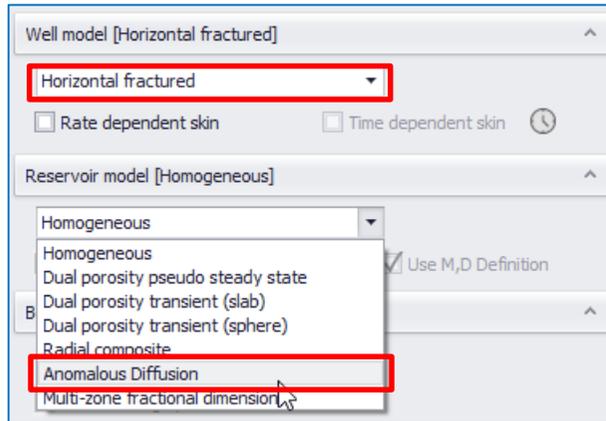
Data Source:  
 C:\Users\kostyleva\Desktop\Fractures definition - Nc ...

Separators: Space Tab
 Others: ;

Column	Column 1	Column 2	Column 3	Column 4	Column 5
Type	Fracture name	MD Start	Xf	Angle	Offset
Unit		ft	ft	°	Undefined
1	Fracture name	MD	Xf	Angle	Fracture name
2			[ft]	[degrees]	Xf
3	Fracture #1	6000	462.151	67.1651	MD Start
4	Fracture #2	6361.64	550.908	67.5127	Angle
5	Fracture #3	7060.38	300	63.117	Offset
6	Fracture #4	7631.17	1134.53	67.8886	Width
7	Fracture #5	8822.01	635.809	48.9681	-6.92786
8	Fracture #6	9350.3	300	53.0675	192.914
9	Fracture #7	9920.6	630.716	51.8192	250.219
10	Fracture #8	11110.2	559.728	58.7486	-42.3358
11	Fracture #9	11576.7	667.894	58.7188	-209.228
12	Fracture #10	12235	300	69.9204	-311.902
					-166.042
					-83.1065

Anomalous Diffusion

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	SRV
Zw	Trilinear
Number of fractures	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)

Multi-zone fractional dimension



New in v5.30

Multi-zone fractional dimension analytical model is made internal
Selected in Well or Reservoir model dialog (the two are synchronized)

A screenshot of a software interface showing three stacked dialog boxes. The top box is titled "Well model [Multi-zone fractional dimension]" and contains a dropdown menu set to "Multi-zone fractional dimension" (highlighted with a red box), and two checkboxes: "Rate dependent skin" (unchecked) and "Time dependent skin" (unchecked). The middle box is titled "Reservoir model [Multi-zone fractional dimension]" and contains a dropdown menu set to "Multi-zone fractional dimension" (highlighted with a red box), a checkbox for "horizontal anisotropy" (unchecked), and a checked checkbox for "Use M,D Definition". The bottom box is titled "Boundary model [Infinite]" and contains a dropdown menu set to "Infinite" and a checkbox for "Show average pressure" (unchecked).

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



THANK YOU

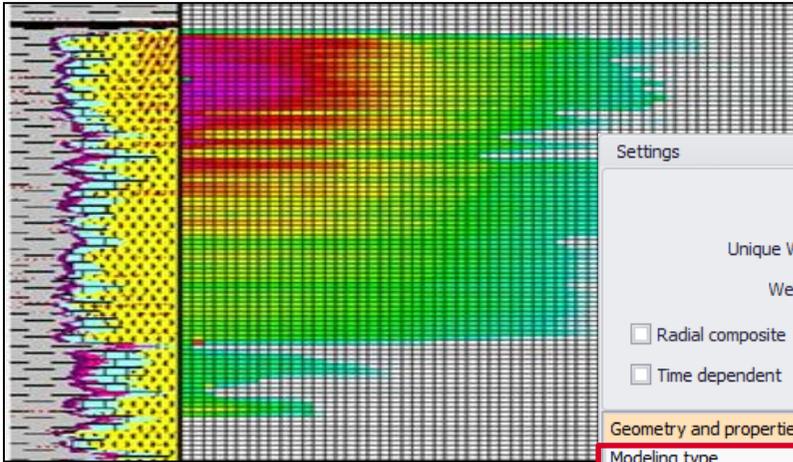


kappaeng.com/ur

Load from fracturing software



Fracture properties can be non-uniform along the fracture plane



Settings

Name: Field H Well 25

Unique Well ID:

Well type: **Horizontal fractured**

Radial composite Multiple fractures

Time dependent Inflow control devices

Geometry and properties

Modeling type	Complex	
Drill floor elevation	0.00000	ft
Well radius	0.3	ft
Drain angle	0.00000	°
Well length	2000.00	ft
Zw	15.0000	ft
Import fracture data	<input checked="" type="checkbox"/>	
Stimulated zones around fract...	<input type="checkbox"/>	
Rate dependent skin	<input type="checkbox"/>	

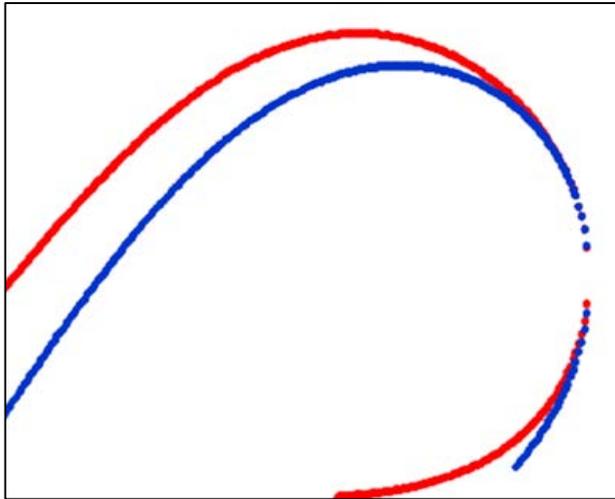
Location

Input well head	<input type="checkbox"/>	
X	-1000.00	ft
Y	0.00000	ft

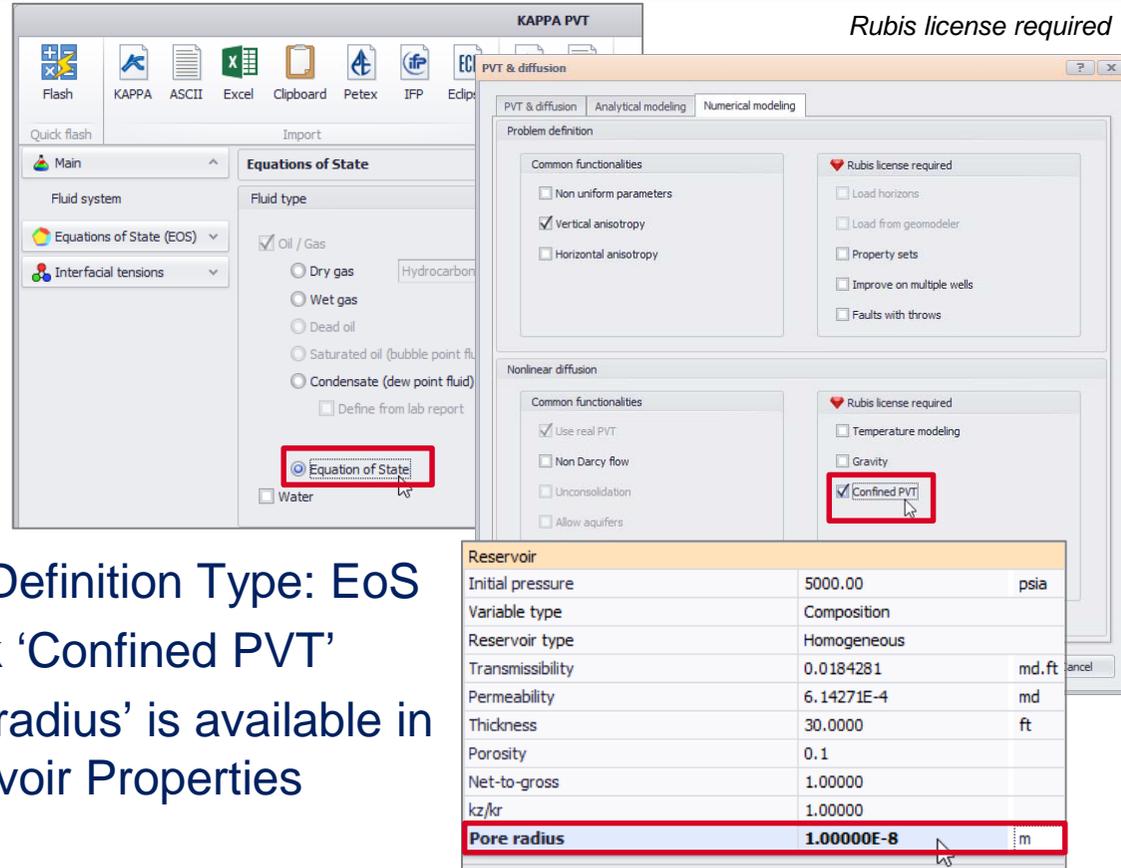
- Define a MFHW as 'Complex'
- Activate 'Import fracture data'
- Load properties from *.csv or *.xml:
 - Index, TVD and location at the well
 - (X,Z): w_f , k_f , F_{CD} , φ , β
- Define fracture MD and angles

Confined PVT

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



Equations of State

Fluid system: Equations of State (EOS), Interfacial tensions

Fluid type: Oil / Gas (checked), Dry gas, Wet gas, Dead oil, Saturated oil (bubble point fluid), Condensate (dew point fluid), Water

Nonlinear diffusion

Common functionalities: Use real PVT (checked), Non Darcy flow, Unconsolidation, Allow aquifers

Problem definition: Rubis license required, Load horizons, Load from geomodeller, Property sets, Improve on multiple wells, Faults with throws

Nonlinear diffusion: Rubis license required, Temperature modeling, Gravity, **Confined PVT (checked)**

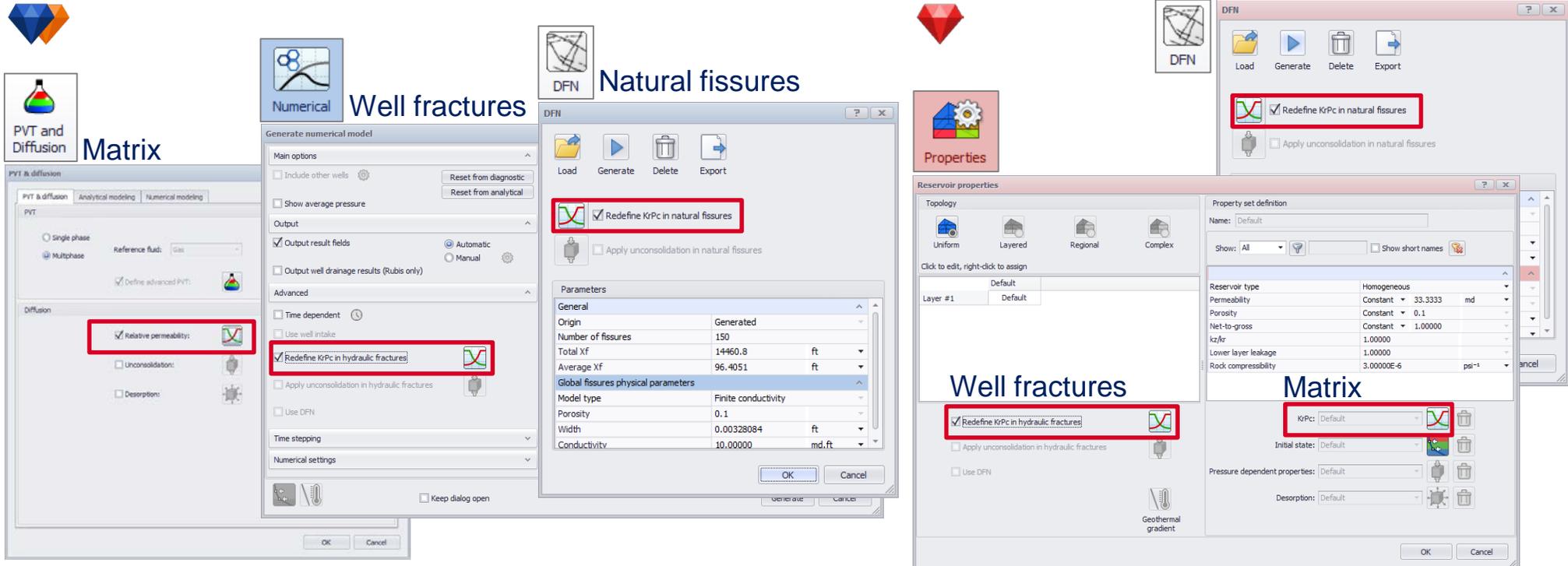
Reservoir		
Initial pressure	5000.00	psia
Variable type	Composition	
Reservoir type	Homogeneous	
Transmissibility	0.0184281	md.ft
Permeability	6.14271E-4	md
Thickness	30.0000	ft
Porosity	0.1	
Net-to-gross	1.00000	
kz/kr	1.00000	
Pore radius	1.00000E-8	m

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

Multiple KrPc

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

- Multiphase PVT is defined & real PVT are used

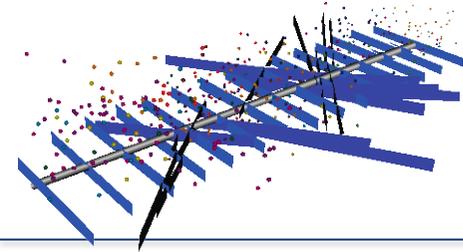


The screenshot displays four overlapping software windows with red boxes highlighting specific settings:

- Matrix (PVT and Diffusion):** The "Relative permeability" checkbox is checked.
- Well fractures (Generate numerical model):** The "Redefine KrPc in hydraulic fractures" checkbox is checked.
- Natural fissures (DFN):** The "Redefine KrPc in natural fissures" checkbox is checked.
- Matrix (Property set definition):** The "KrPc" dropdown menu is set to "Default".

The "Natural fissures (DFN)" window also displays the following parameters:

Parameters	
General	
Origin	Generated
Number of fissures	150
Total Xf	14460.8 ft
Average Xf	96.4051 ft
Global fissures physical parameters	
Model type	Finite conductivity
Porosity	0.1
Width	0.00328084 ft
Conductivity	10.00000 md.ft

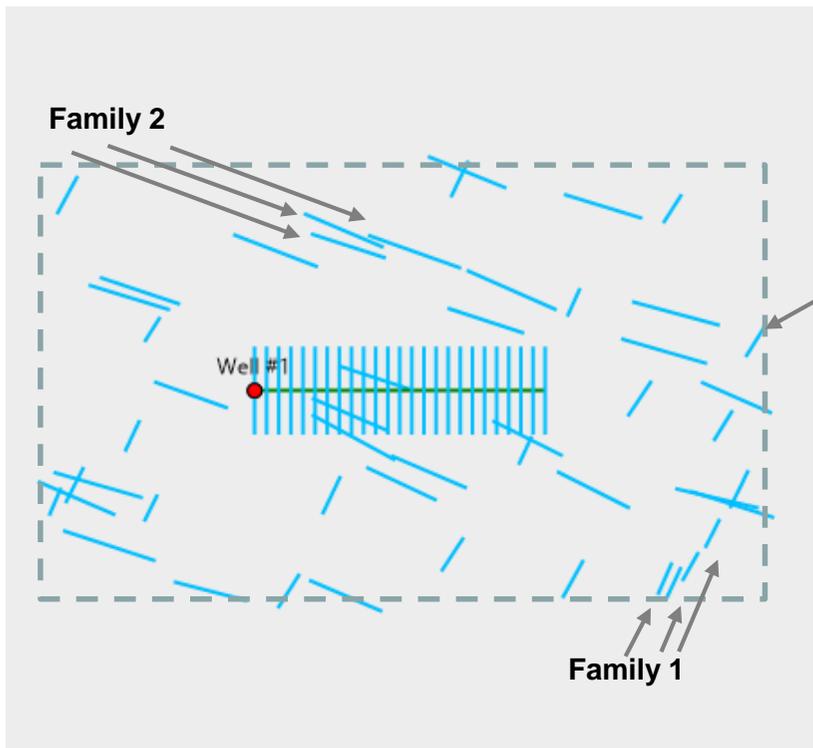


Stochastic DFN realizations



'Map' → 'DFN' → 'Generate'

Location can be defined μ -seismic, if loaded



DFN geometry stochastic generation

Global settings

Fissures parameters

Number of fissures	50	
Use microseisms events	<input type="checkbox"/>	
X minimum	-2500.00	ft
X maximum	2500.00	ft
Y minimum	-1500.00	ft
Y maximum	1500.00	ft
Impose random generator seed	<input type="checkbox"/>	

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



At least 2 wells must exist in the map

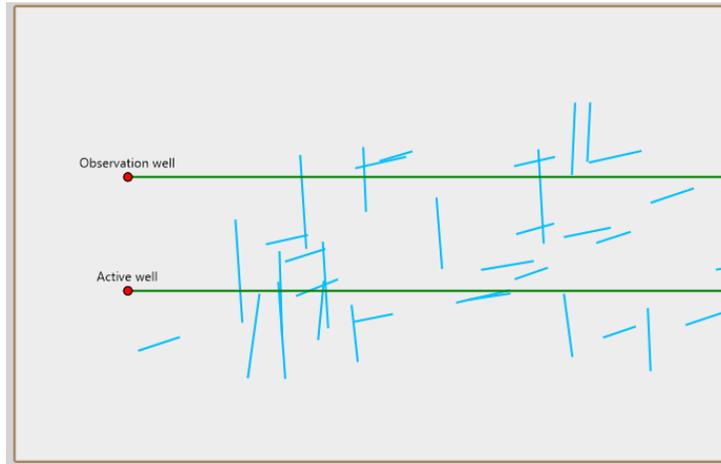
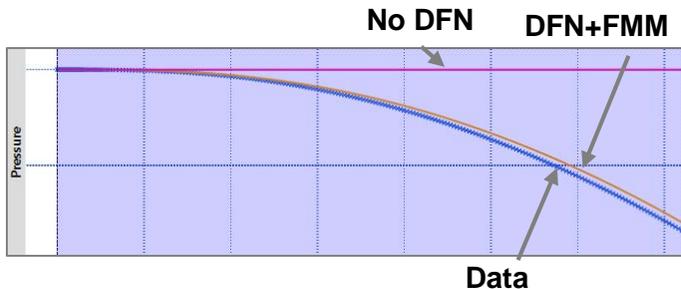
'Map' → 'DFN' → 'Generate'



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



The screenshot shows the 'DFN geometry stochastic generation' dialog box with the following settings:

- Global settings**
 - Fissures parameters
 - Number of fissures: 50
 - X minimum: -4000.00 ft
 - X maximum: 4000.00 ft
 - Y minimum: -1000.00 ft
 - Y maximum: 1000.00 ft
 - Impose random generator seed:
- Fissure families**
 - Family parameters
 - Fraction: 0.5
 - Minimum fissure length: 300.000 ft
 - Maximum fissure length: 500.000 ft
 - Power: 1.50000
 - Strike angle: 75.0000 °
 - K strike: -400.000
 - Family name
 - Family 1
 - Family 2
- Fast marching**
 - Use fast marching
 - Fast marching parameters
 - Well 1: Active well
 - Well 2: Observation well
 - Interference time: 300.000 hr
 - Max realizations: 100
 - Max calibration runs: 5
 - Conductivity: 10.00000 md.ft
 - Width: 0.00328084 ft
 - Porosity: 0.1
 - Final time: 0,0982475 hr
 - Computing fast marching models ...

Stimulated zones

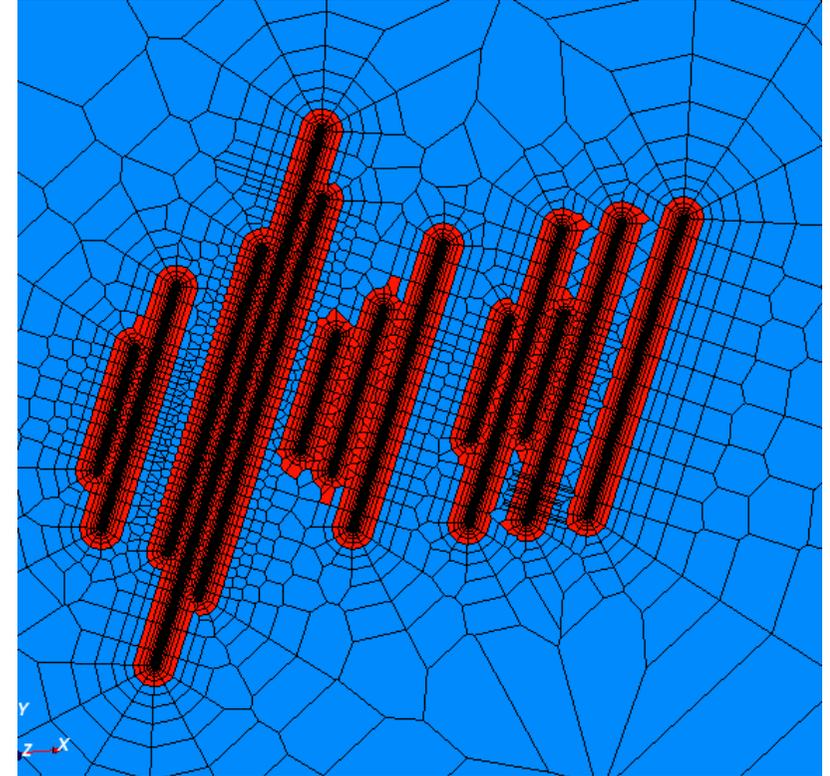
Stimulated zones around fractures of a MFHW

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

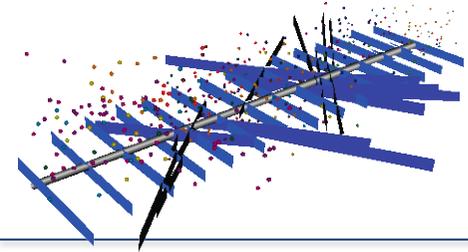
Parameters		
Show:	All	<input type="checkbox"/> Show short names
Well 1		
Modeling type	Simple	
Drain angle	0.00000	°
Fracture model	Infinite conductivity	
Number of fractures	13	
Fracture half length	360.000	ft
Fracture height	30.0000	ft
Fracture mid-point height	15.0000	ft
Width	0.00328084	ft
Fracture angle	90.0000	°
Zw	15.0000	ft
Well length	2000.00	ft
Stimulated zones around fractures	<input checked="" type="checkbox"/>	
Stimulation radius	50.0000	ft
Permeability multiplier	4.00000	
Porosity multiplier	1.00000	
Rate dependent skin	<input type="checkbox"/>	
Wellbore model	None	
Bottomhole MD	6000.00	ft

These parameters can be regressed upon in 'Improve'

Improve	
Parameters	Targets
Constant parameters	
Well 1	
<input type="radio"/>	Theta
<input type="radio"/>	N
<input type="radio"/>	Xf
<input type="radio"/>	Hf
<input type="radio"/>	Zf
<input type="radio"/>	Width
<input type="radio"/>	Beta
<input type="radio"/>	Zw
<input type="radio"/>	Lw
<input checked="" type="radio"/>	Stimulation radius
<input checked="" type="radio"/>	k multiplier
<input checked="" type="radio"/>	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 $\varphi(p)$