6X^{online} Introduction

February 2022

RidgewayKite

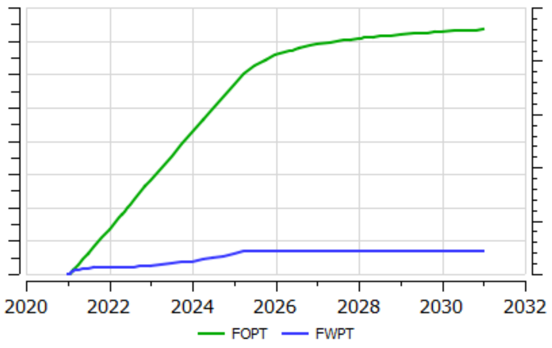
Welcome

Presenter

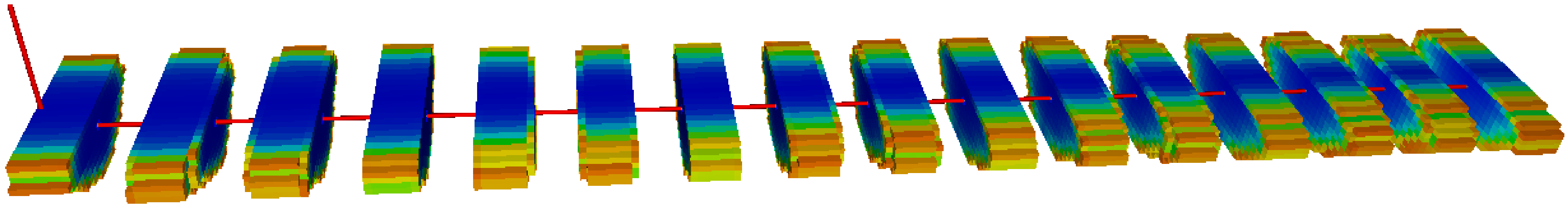
- Peter Forster
- RKS Technical Support, Houston

This presentation will be a combination of

- Slides & Online Demo (60 minutes)
- Closing Discussion (30 minutes)



Please submit questions on the “chat” panel. We will monitor it and incorporate them into the closing discussion



Introduction – why simulate?

Rate Transient Analysis

- Forecasts EUR using analytic models to generate production profiles
- Assumes single phase flow
- Assumes reservoir homogeneity
- Assumes fracture conductivity is constant

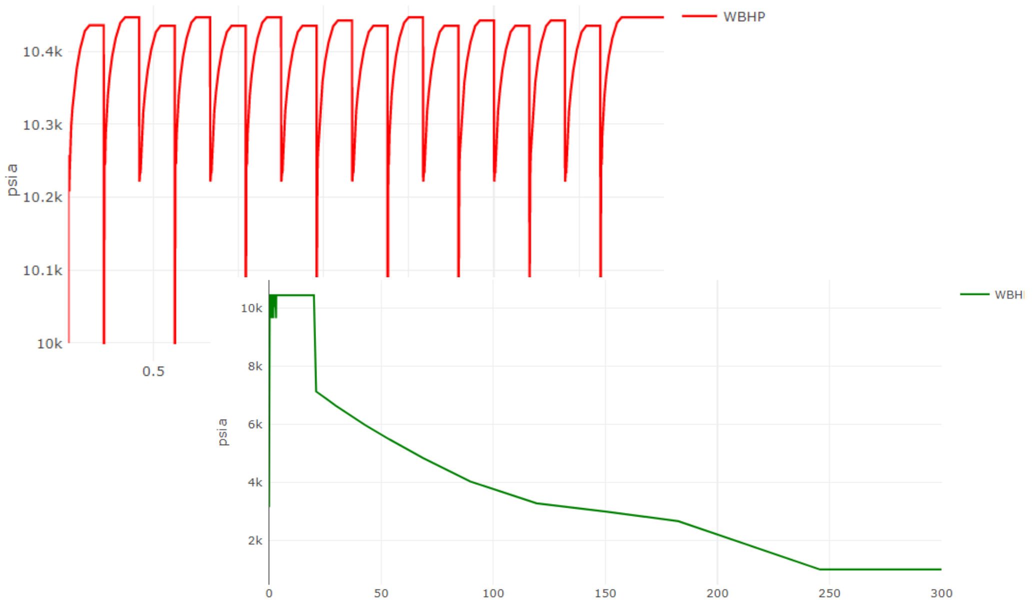
Numerical Simulation

- Predicts production using a finite difference simulator
- Allows for multi-phase black oil or compositional flow
- Is based on an earth model
- Fractures grow and close dynamically based on pumping schedule and depletion

Simulation is the only way to capture all the physical process that contribute to production performance

Introduction – 6X Reservoir Simulator

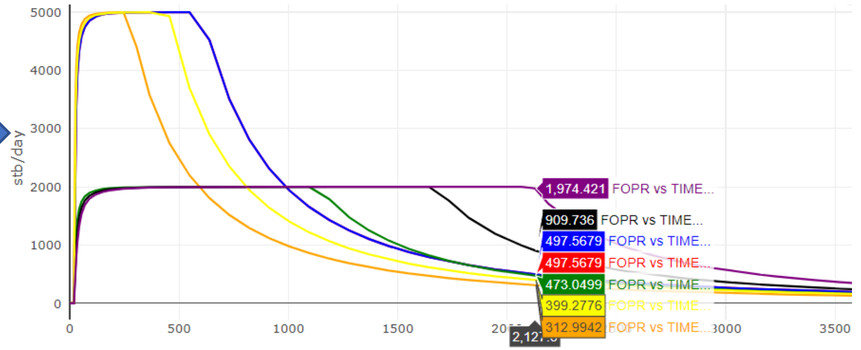
- Integrates flow, frac design and geomechanics in ***<u>one</u>*** model
  - Multi-well, black-oil, compositional
- Requires a definition of the geology, fluids and stress state
- Models pumping schedule, flowback and production
- Focuses on decisions that influence production performance
- Workflows:
  - Well placement & spacing
    - Including interference & stress shadowing
  - Completion design
    - Including details of stages and clusters
  - Cyclic gas injection EOR
  - Re-frac



Introduction – 6X^{online}

- A <u>**web**</u> application to enable routine workflows
  - Supports limited functionality on layer cake models
  - Collates data
  - Runs 6X simulator
    - Locally or on an external server or on the cloud
  - Cases can be exported and customized to access advanced functionality

<u>Note:</u>
6X^{online} does not access all of the 6X functionality

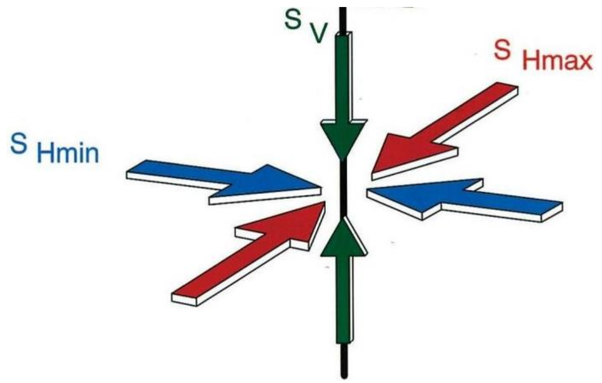


What do we mean "Integrates flow, frac design and geomechanics"?

6X Conceptual overview – Input initial state

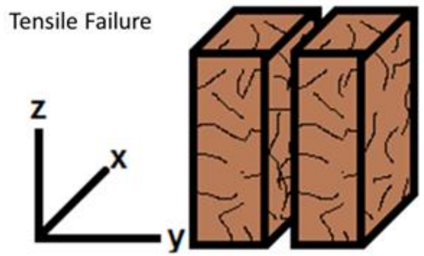
Stresses:

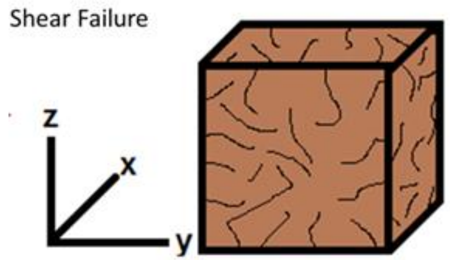
- Shmin, Shmax, Sv
- Strength
  - A measure of the extra force required to break the rock



Fracture enhancement parameters

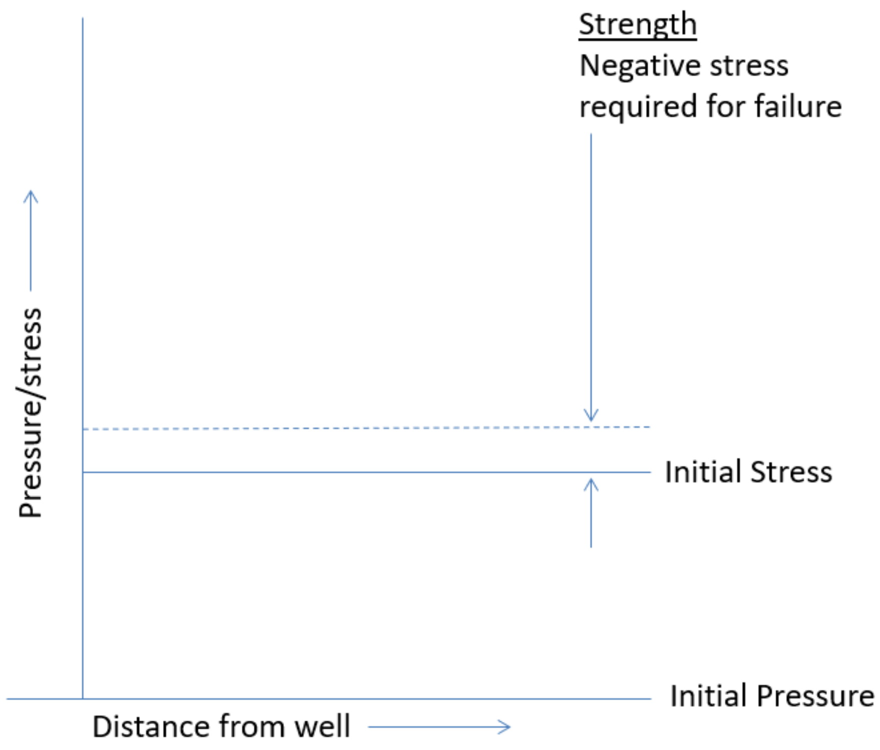
- Pore volume expansion
  - The expansion rate when the rock breaks and the fractures expand
- Tensile
  - The maximum amount of permeability to be added
- Shear
  - The maximum amount of matrix-fracture interface (surface area)
- Residual connectivity
  - The amount of permeability which will remain post-closure
    - For propped and unpropped volume





6X Conceptual overview

Model geomechanics of rock breakage

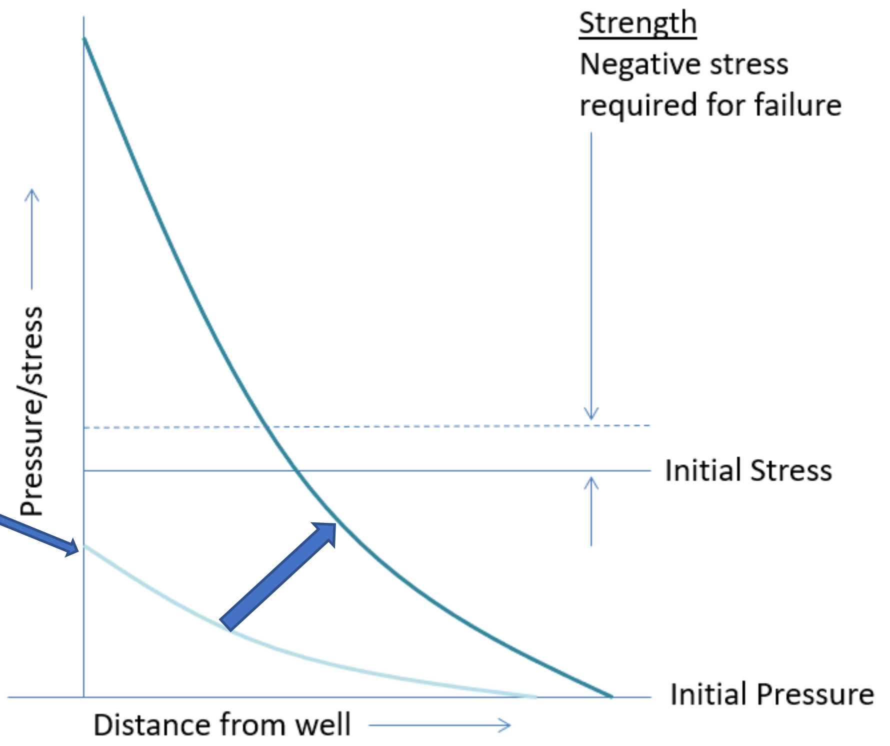


6X Conceptual overview

Model geomechanics of rock breakage

- As pressure increases due to pumping
  - Pressure exceeds the minimum stress and net stress becomes negative

As pumping initiates, the pressure
- Gets higher at the well
- Moves out into the reservoir



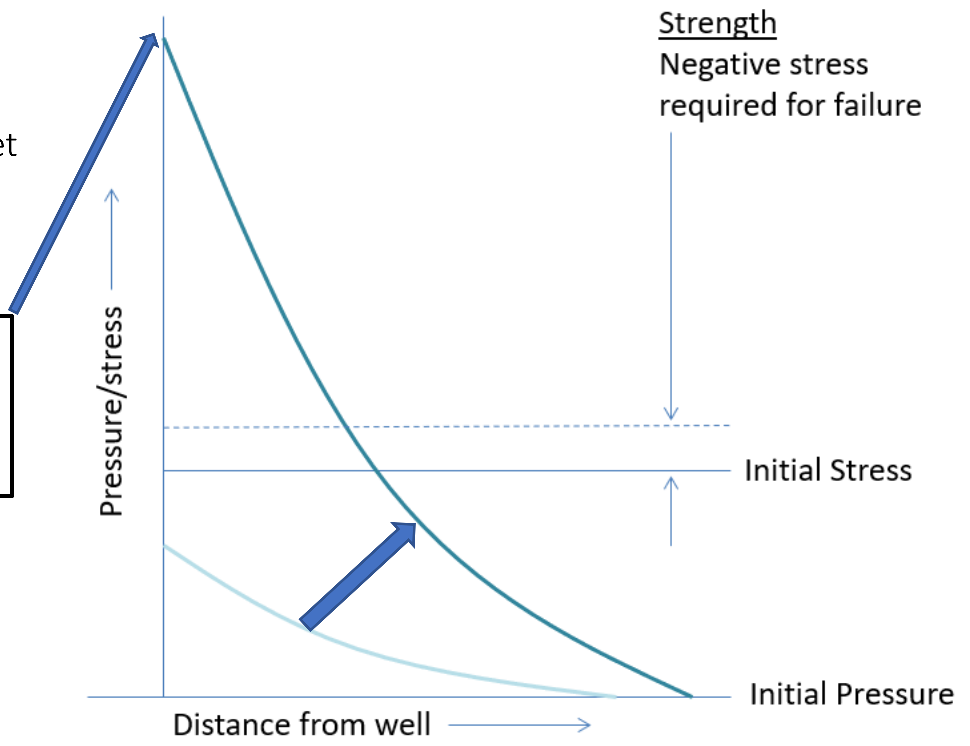
6X Conceptual overview

Model geomechanics of rock breakage

- As pressure increases due to pumping
  - Pressure exceeds the minimum stress and net stress becomes negative

As pumping progresses the pressure

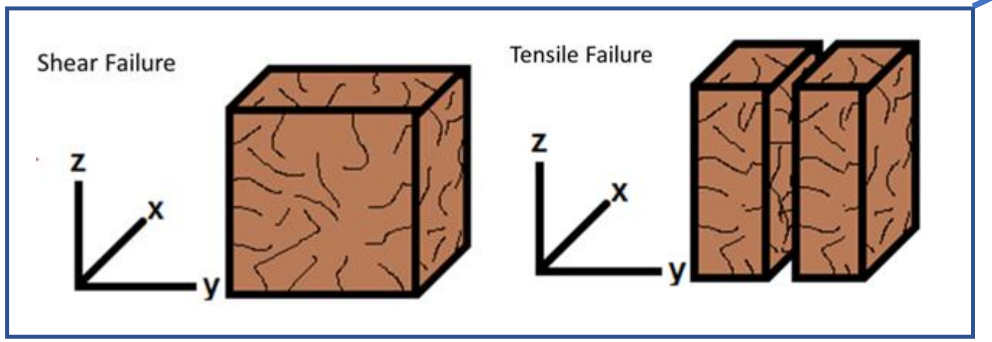
- Ultimately exceeds the initial stress
- Moves further out into the reservoir

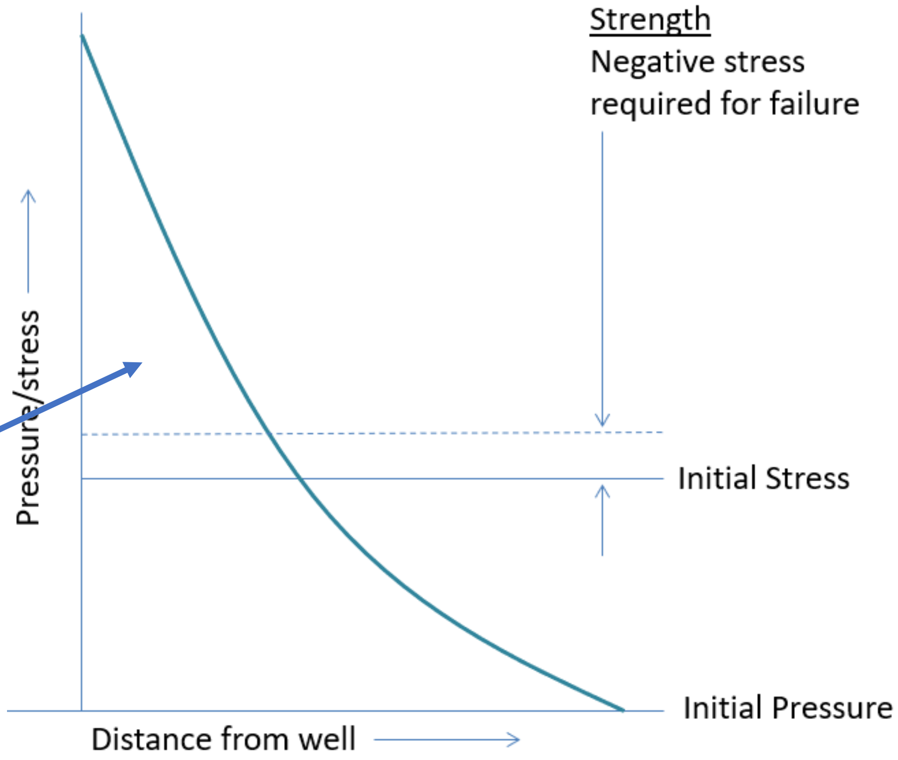


6X Conceptual overview

Model geomechanics of rock breakage

- As pressure increases due to pumping
  - Pressure exceeds the minimum stress and net stress becomes negative
- In the area of negative stress
  - Tensile failure adds permeability due to long cracks
  - Shear failure adds surface area due to 'rubblization'





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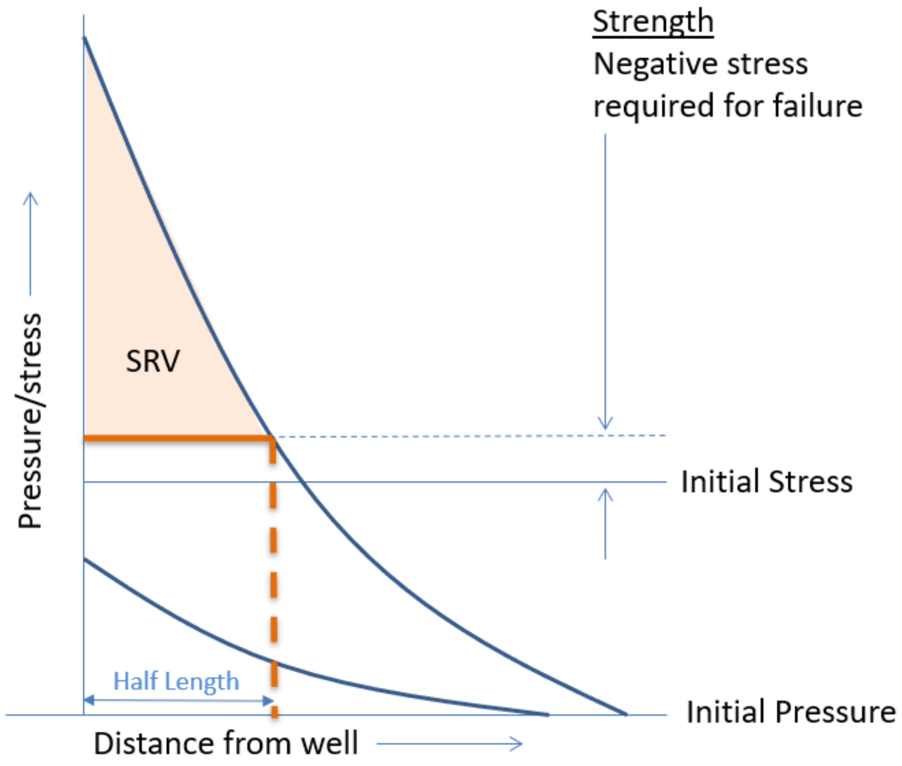


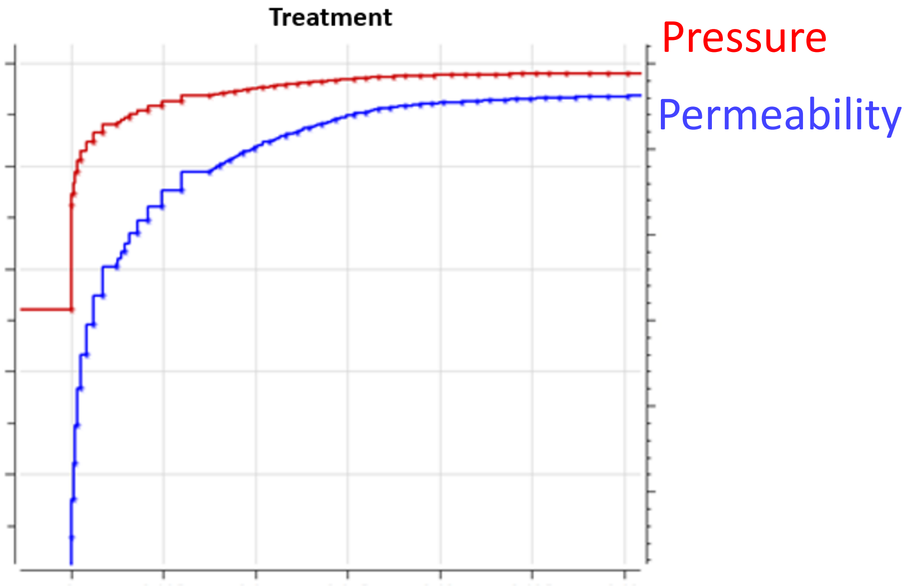
6X Conceptual overview

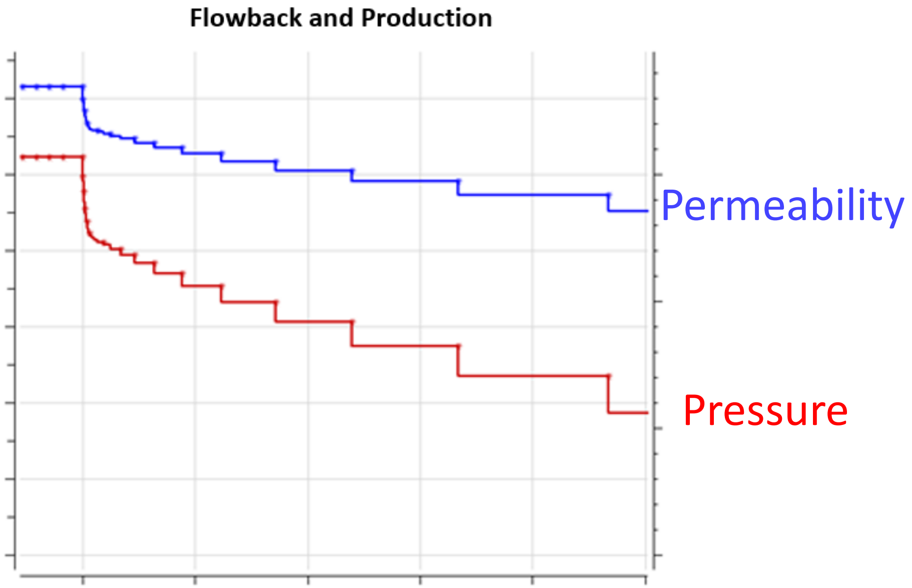
As pressure increases due to pumping

- Tensile failure adds permeability due to long cracks
- Shear failure adds surface area due to ‘rubblization’

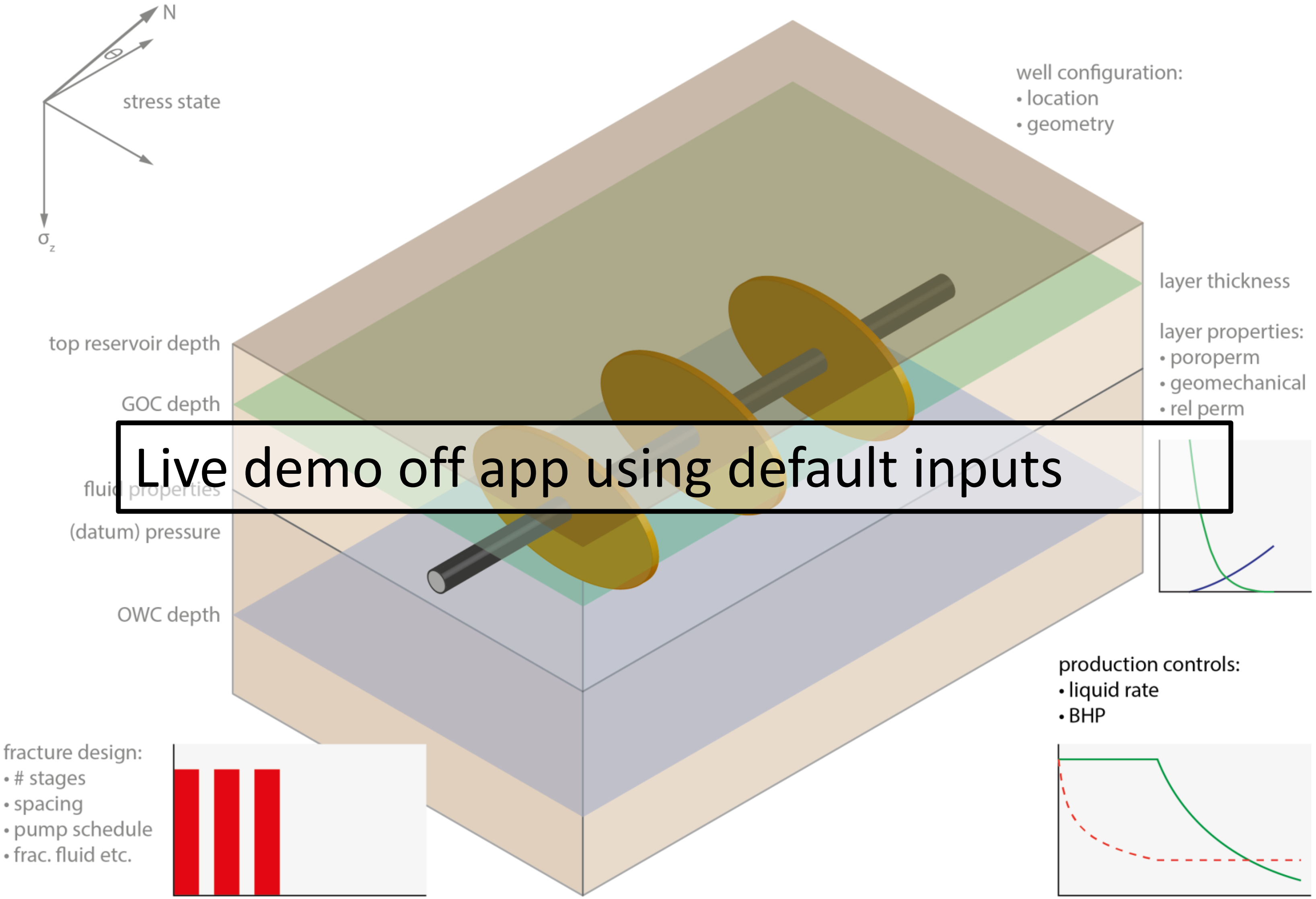
As pressure decreases due to flowback and production

- Net stress increases
- Permeability declines to a defined residual value





Live demo off app using default inputs



Example 1 – Well with a single frac

- The objective of this example is to show:
  1. Construction of a single stage model
     - Data input
     - Build, check & run
     - Plot and analyze the results

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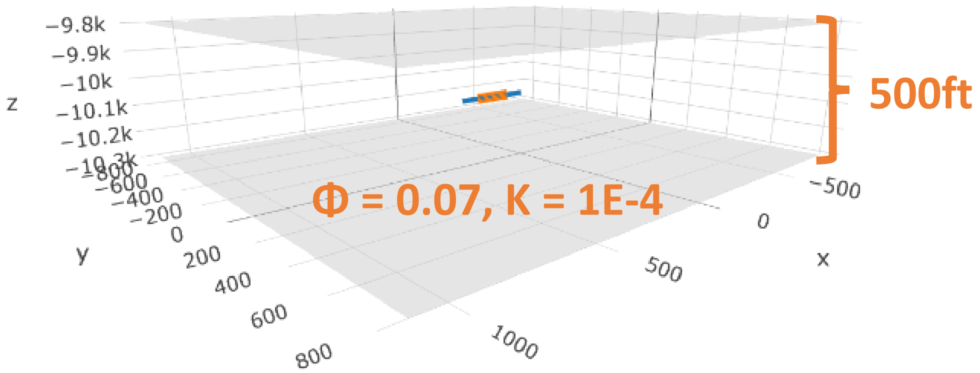
Example 1

The reservoir has a top depth of **9,800 ft** and consists of a single unit:

- Properties
  - Permeability = 0.0001 mDarcy, Porosity = 7%, Thickness = 500 ft
- Fluid
  - Light oil, at **7,200 psia**, with a bubble point of **4,000 psia**
  - Gas Contact at **8,900 ft** TVDSS (above)
  - Water Contact at **12,000 ft** TVDSS (below)
- Stresses:
  - SHmin **9,000 psia,** SHmax **12,000 psia,** SV **14,000 psia**
- Fracture enhancement
  - Pore volume expansion **900 μSips,** Tensile + **1000 mDarcy,** Shear + **2 1/ft2,** Residual connectivity stim **0%**, prop **40%**



The well has

- Depth **10,070 ft**, Length **300 ft**

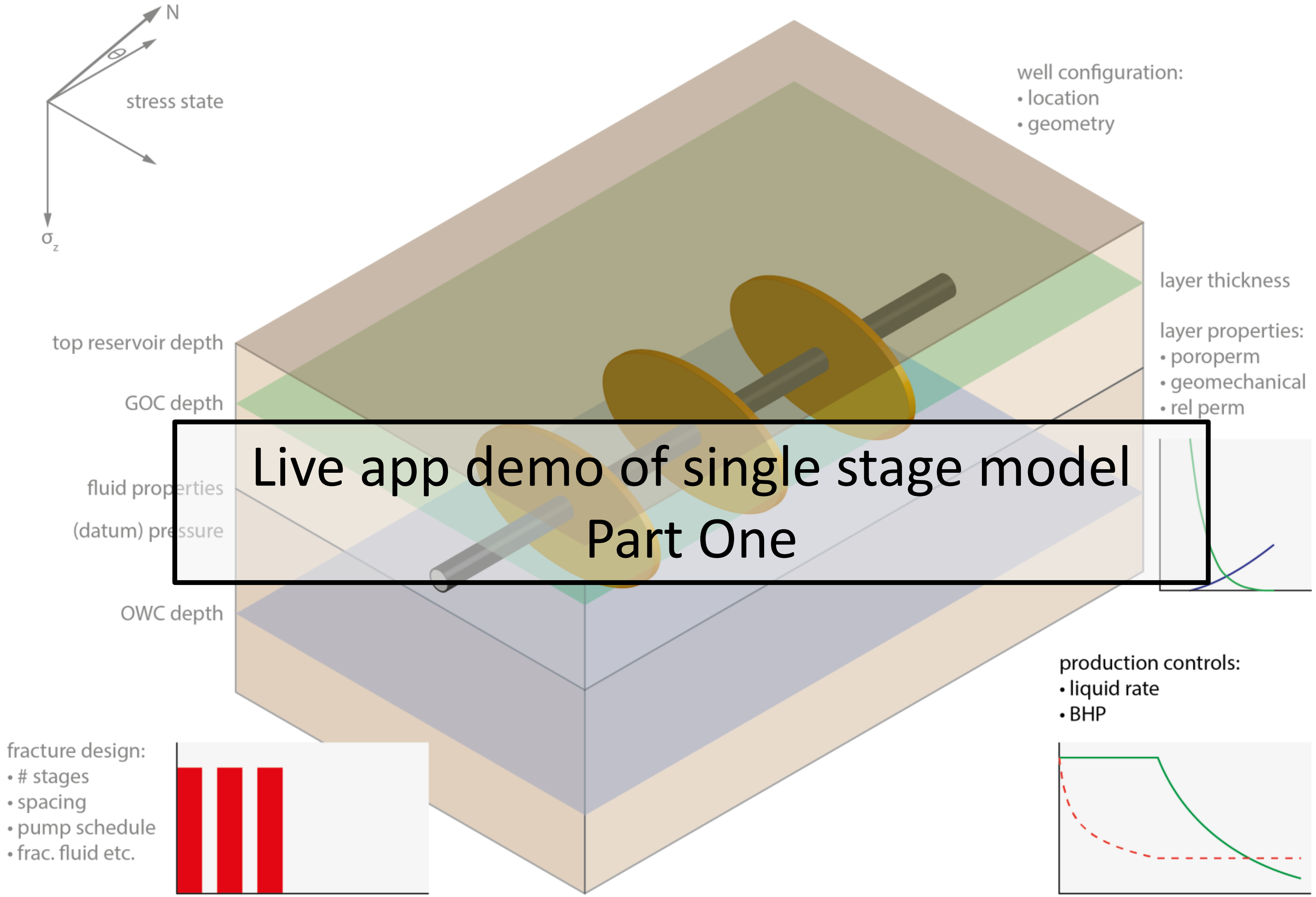
Stage

- Length **150 ft**, Spacing **75 ft**
- Rate **20 barrels / min** (28.8k/ day), pumping for 45 minutes, wireline operations **1 hour**

Production

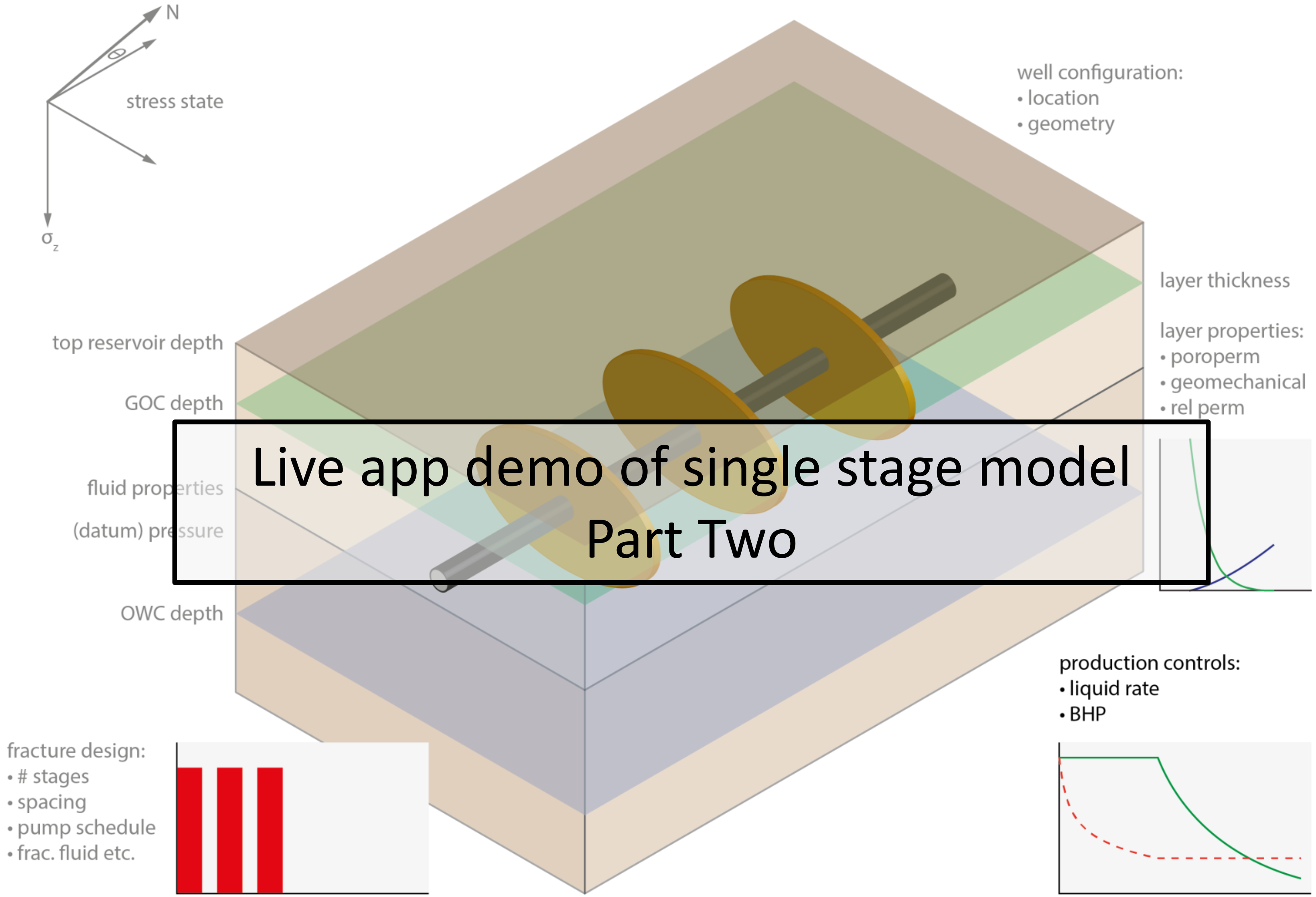
- **250 barrels / day** of liquid for **0.25 years**
- Min BHP **1,000 psia**

Live app demo of single stage model Part One



Example 1 – Well with a single frac

- The objective of this example is to show:
  1. Construction of a single stage model
     - Data input
     - Build, check & run
     - Plot and analyze the results
  2. Showing the impact of data edits on model performance
     - Change the amount of SHEAR fracturing… to reduce leak off
     - Build, check & run
     - Plot & compare results from 2 models



Live app demo of single stage model Part Two

Example 1 – Well with a single frac

The objective of this example is to show:

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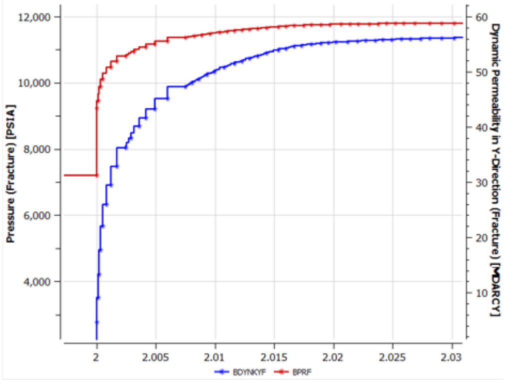
We can CALIBRATE the model inputs to MATCH historical performance

6X Conceptual overview - recap

Model geomechanics of rock breakage

- As pressure increases due to pumping
  - Pressure exceeds the minimum stress and net stress becomes negative
- In the area of negative stress
  - Tensile failure adds permeability due to long cracks
  - Shear failure adds surface area due to 'rubblization'
- The SRV size is determined by how far from the well the "negative stress zone" has reached
- As pressure decreases due to flowback and production
  - Net stress increases
  - Permeability declines to a defined residual value

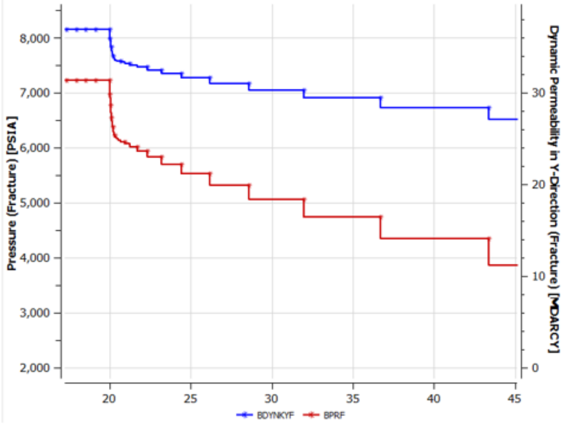
Treatment



As fluid is pumped:

- Pressure increases until minimum stress is exceeded
  - Net stress becomes negative
  - Tensile failure adds permeability
  - Shear failure adds surface area due to rubblization

Flowback and Production



As flowback and production progresses:

- Pressure decreases
- Enhancement decays to a defined residual

6X Conceptual overview

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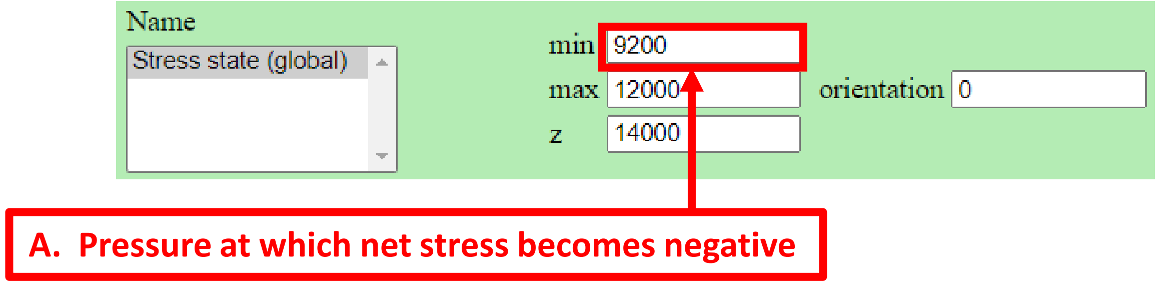

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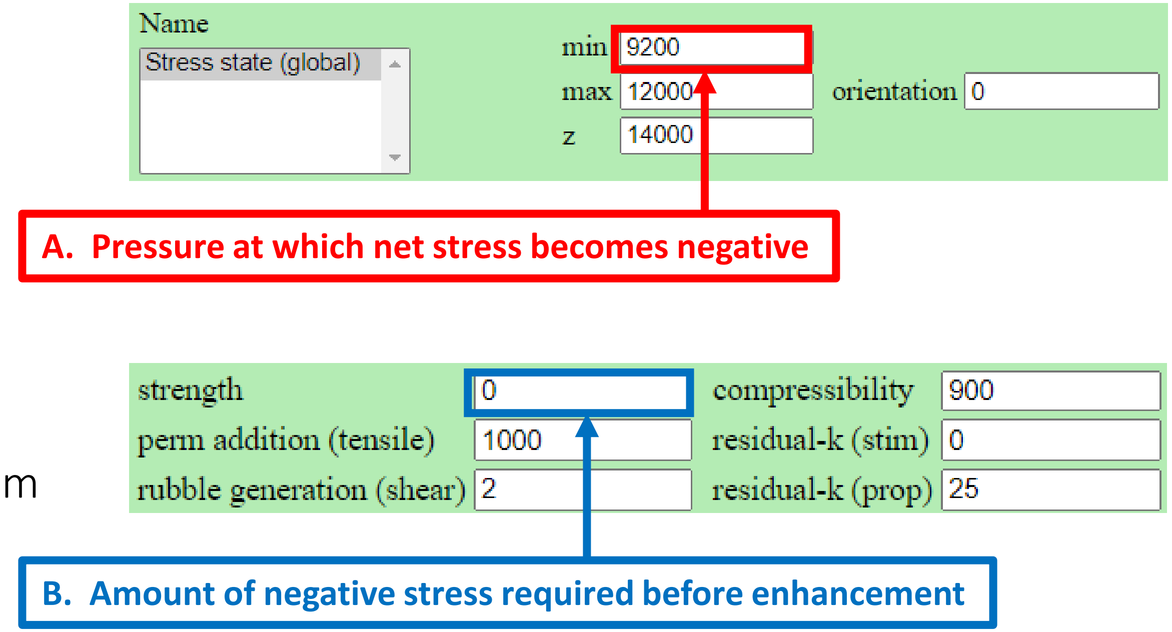

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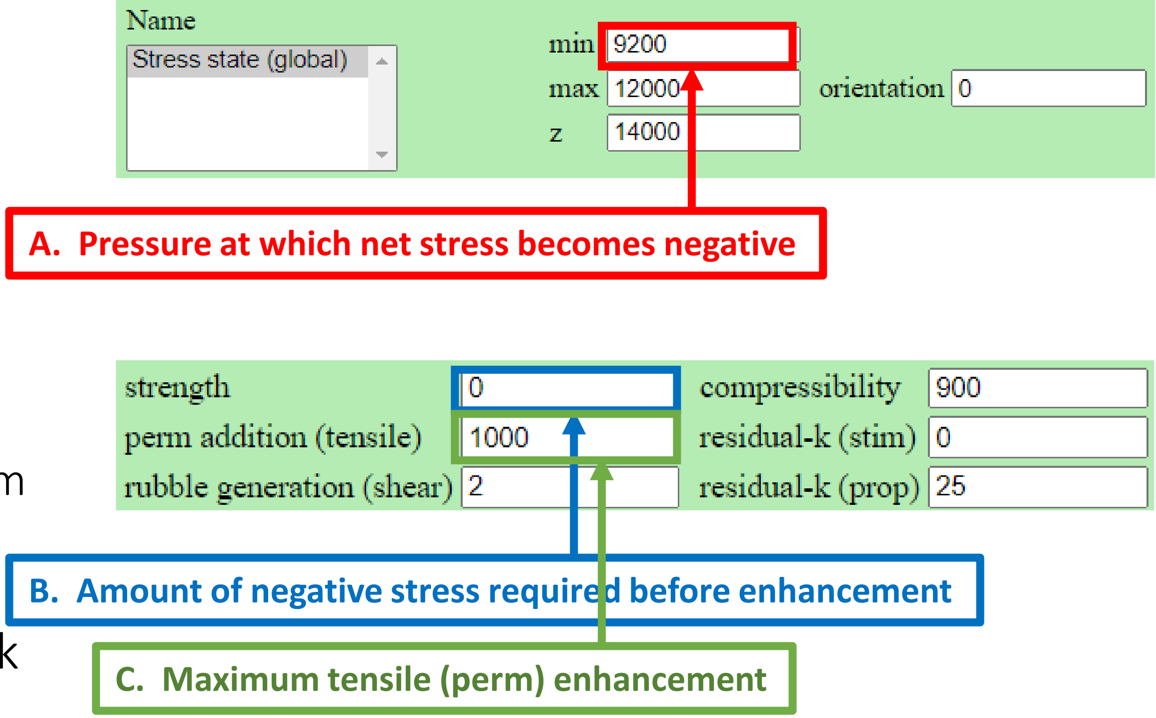

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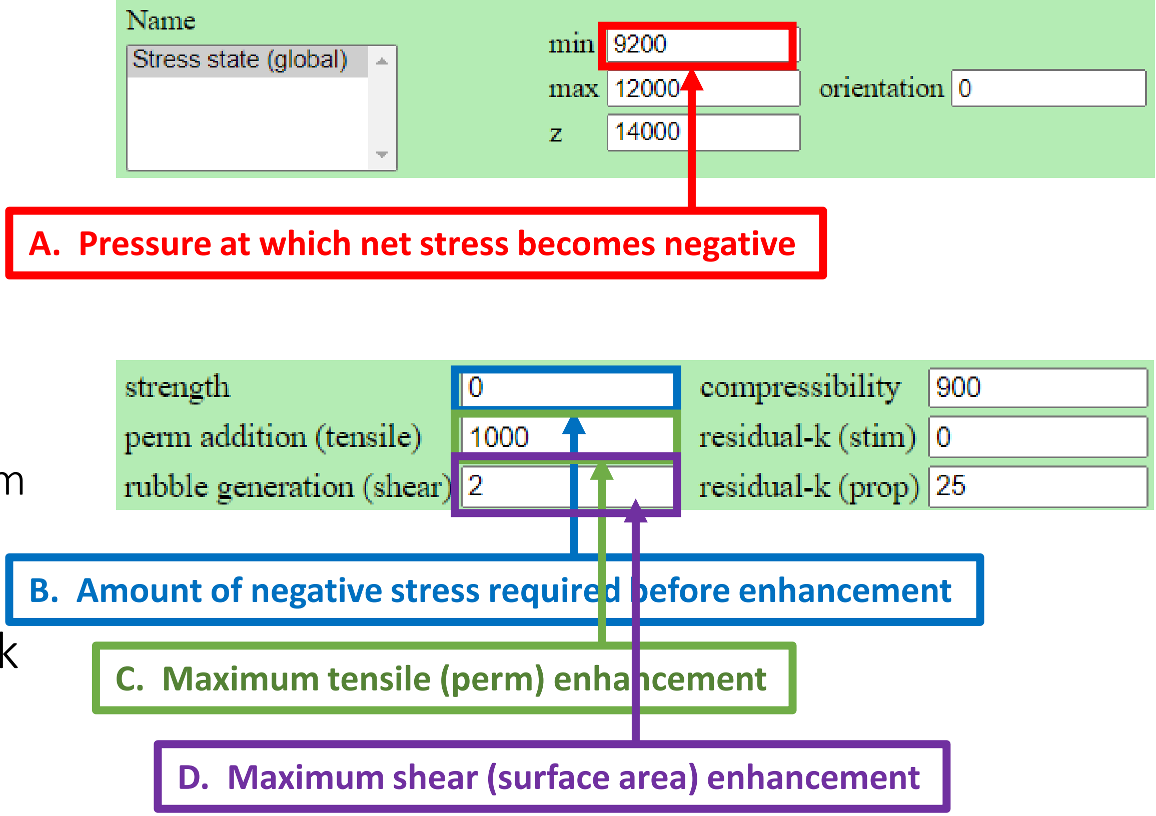

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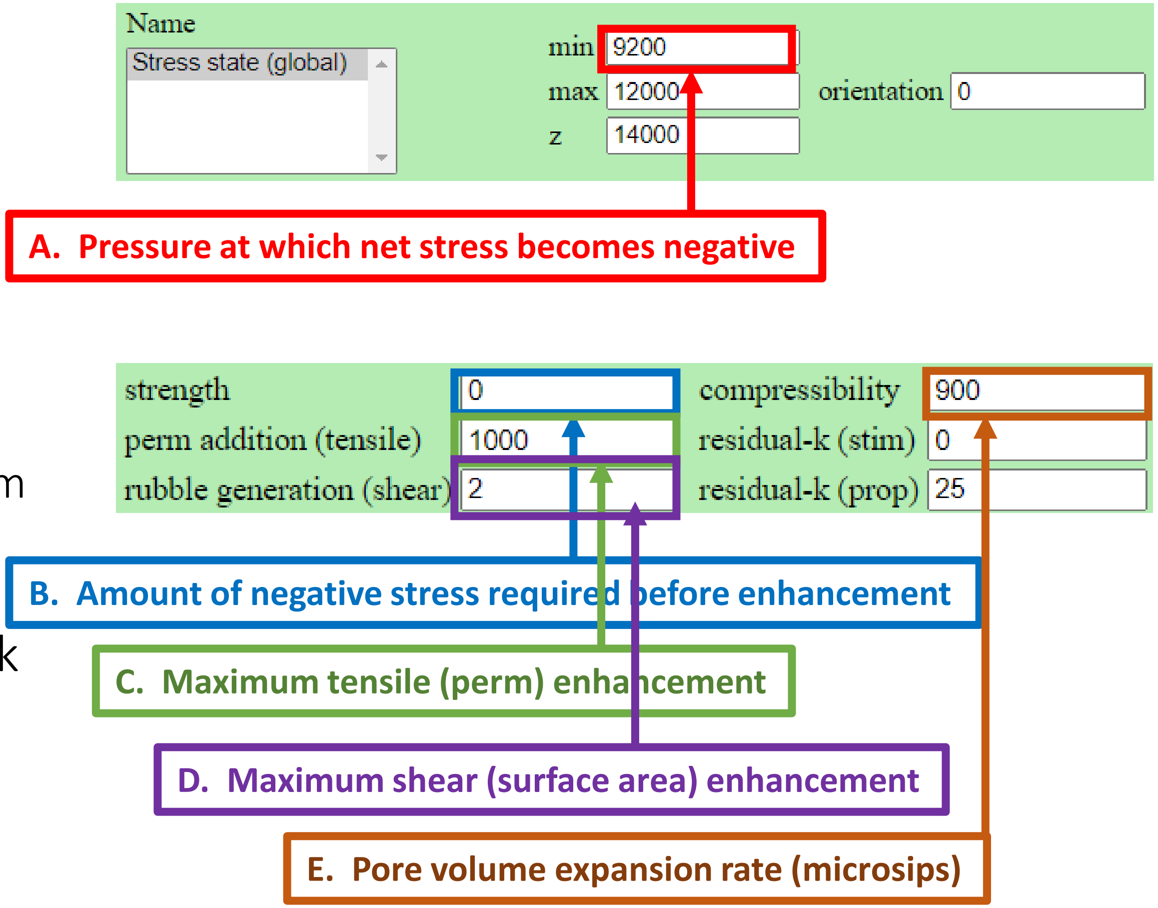

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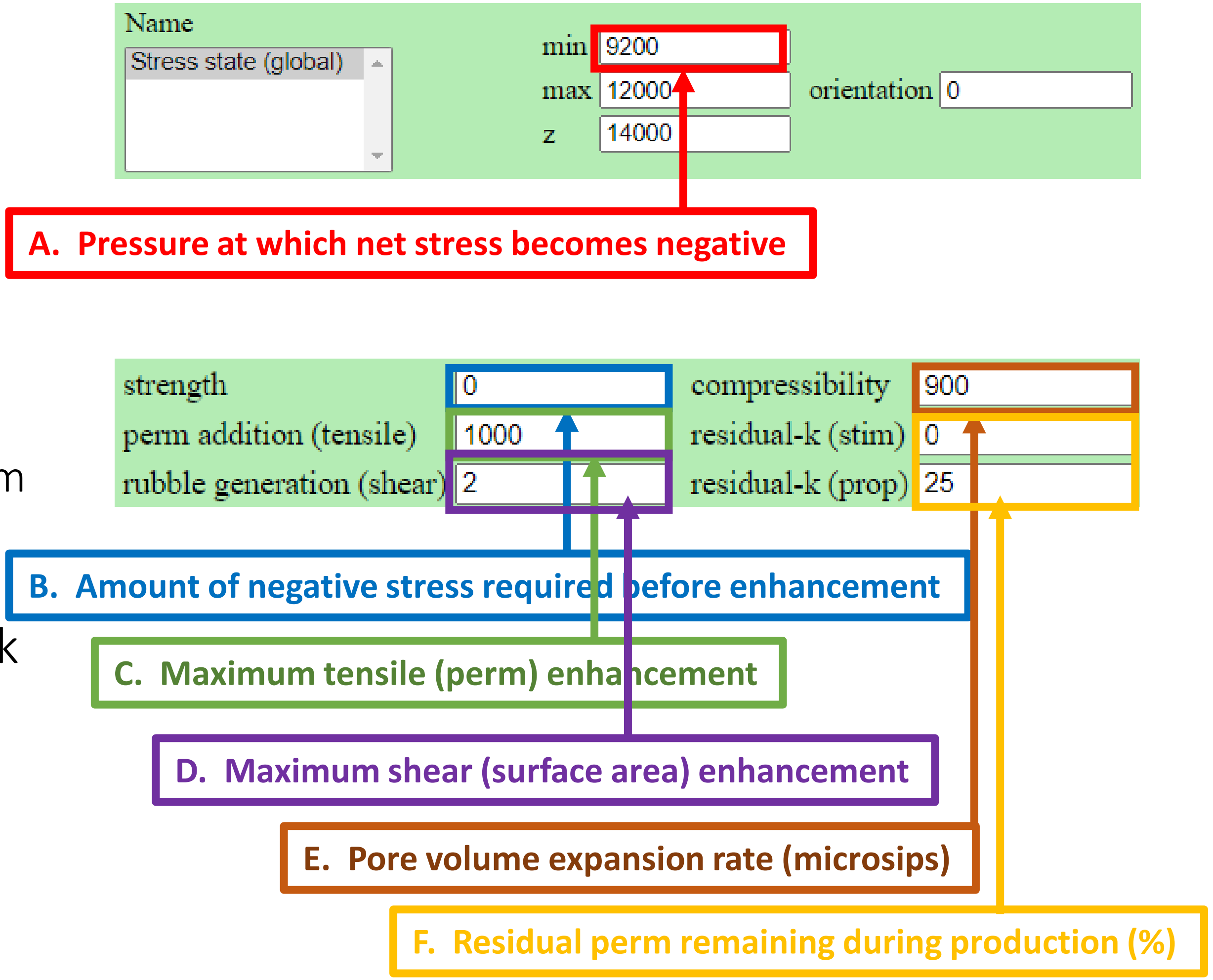


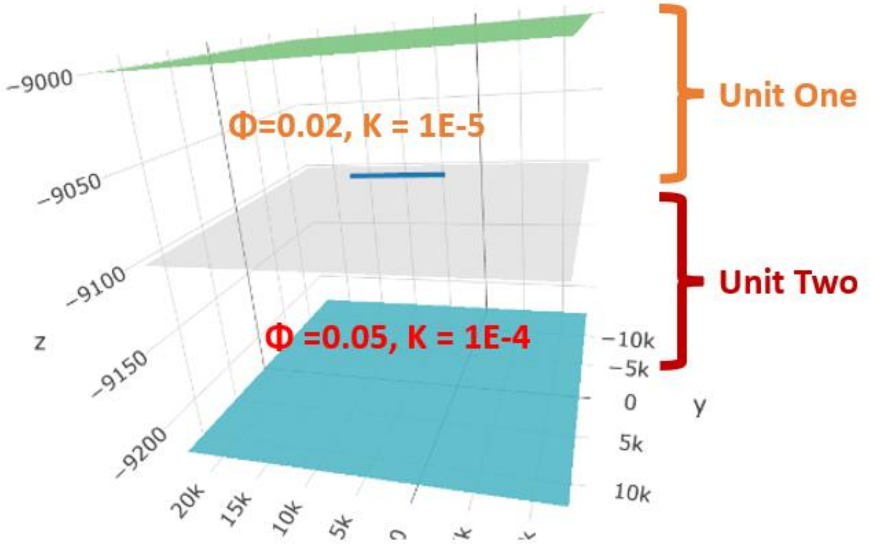
Example 2 – Entire well with various stage counts

- The objective of this example is to show:
  - Construction of a 24 stage model
    - Data input
    - Build, check & run
    - Plot and analyze the results

Example 2 – Reservoir and fluid properties

The reservoir has a top depth of **9,000 ft** and consists of TWO units:

- Unit One
  - Permeability = **1E-5 mDarcy,** Porosity = **2%,** Thickness = **100 ft**
- Unit Two
  - Permeability = **1E-4 mDarcy,** Porosity = **5%,** Thickness = **120 ft**



The units are in communication so have the same:

- Fluid
  - Light oil, with a bubble point of **3,500 psia**
  - Gas Contact at **8,900 ft** TVDSS (above unit One)
  - Water Contact at **12,000 ft** TVDSS (below unit Two)
- Pressure
  - Initial pressure **7,200 psia**
- Stresses:
  - SHmin **9,200 psia,** SHmax **12,000 psia,** SV **14,000 psia**
- Fracture enhancement
  - Pore volume expansion **900 µSips,** Tensile + **1000 mDarcy,** Shear + **2 1/ft2,** Residual connectivity stim **0%**, prop **25%**

Example 2 – Well and frac jobs

The well has

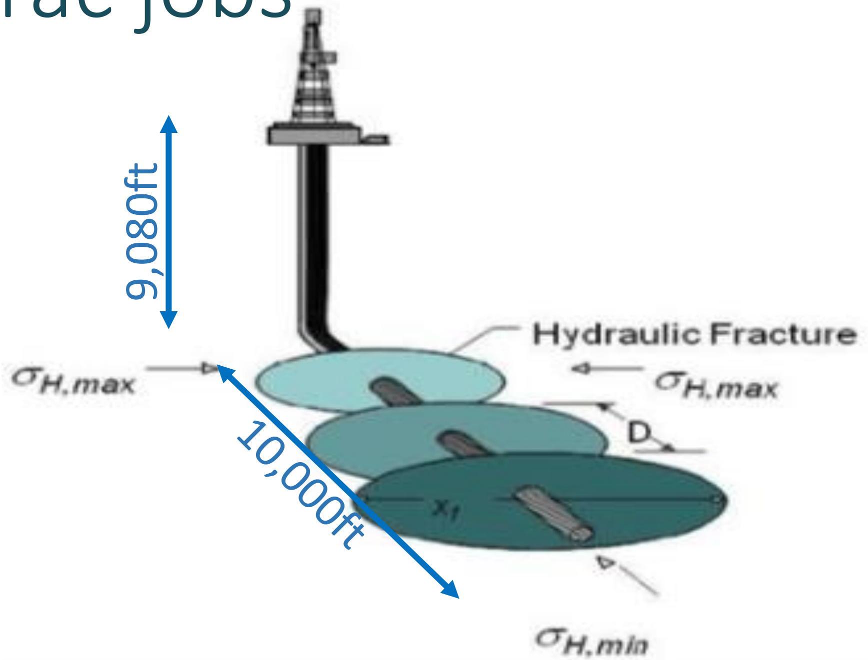
- Depth **9,080 ft,** Length **10,000 ft**
- Stages **24***

Each stage

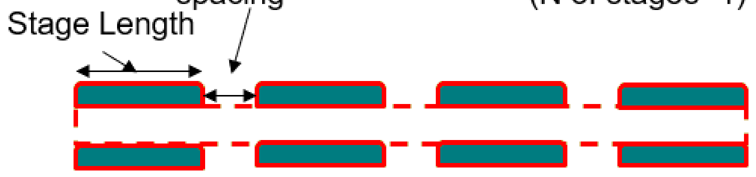
- Length **300 ft**
- Spacing **120ft***
- Rate **20 barrels / min** (28.8k/ day)
- Pumping time **3 hours**
- Wireline operations **2 hours**

Production

- **2,000 barrels / day** of liquid
- **4 years**
- Min BHP **1,000 psia**



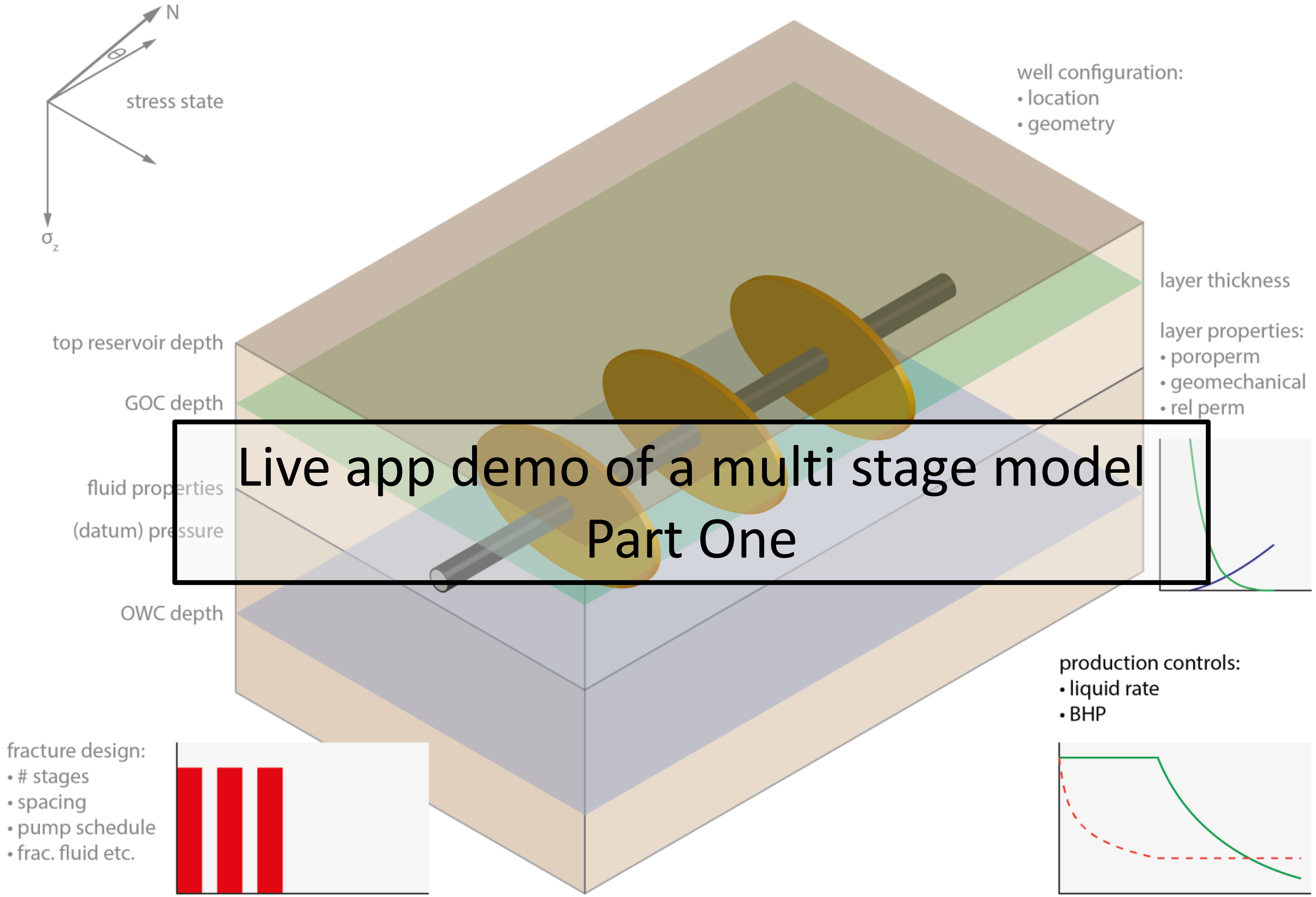
$$\text{Stage spacing} = \frac{\text{Hz Well Length - Stage Length x N of stages}}{\text{(N of stages -1)}}$$



EG, for 24 stages

Spacing = (10,000 – (300 x 24)) / 23 ≈ **120 ft**

*



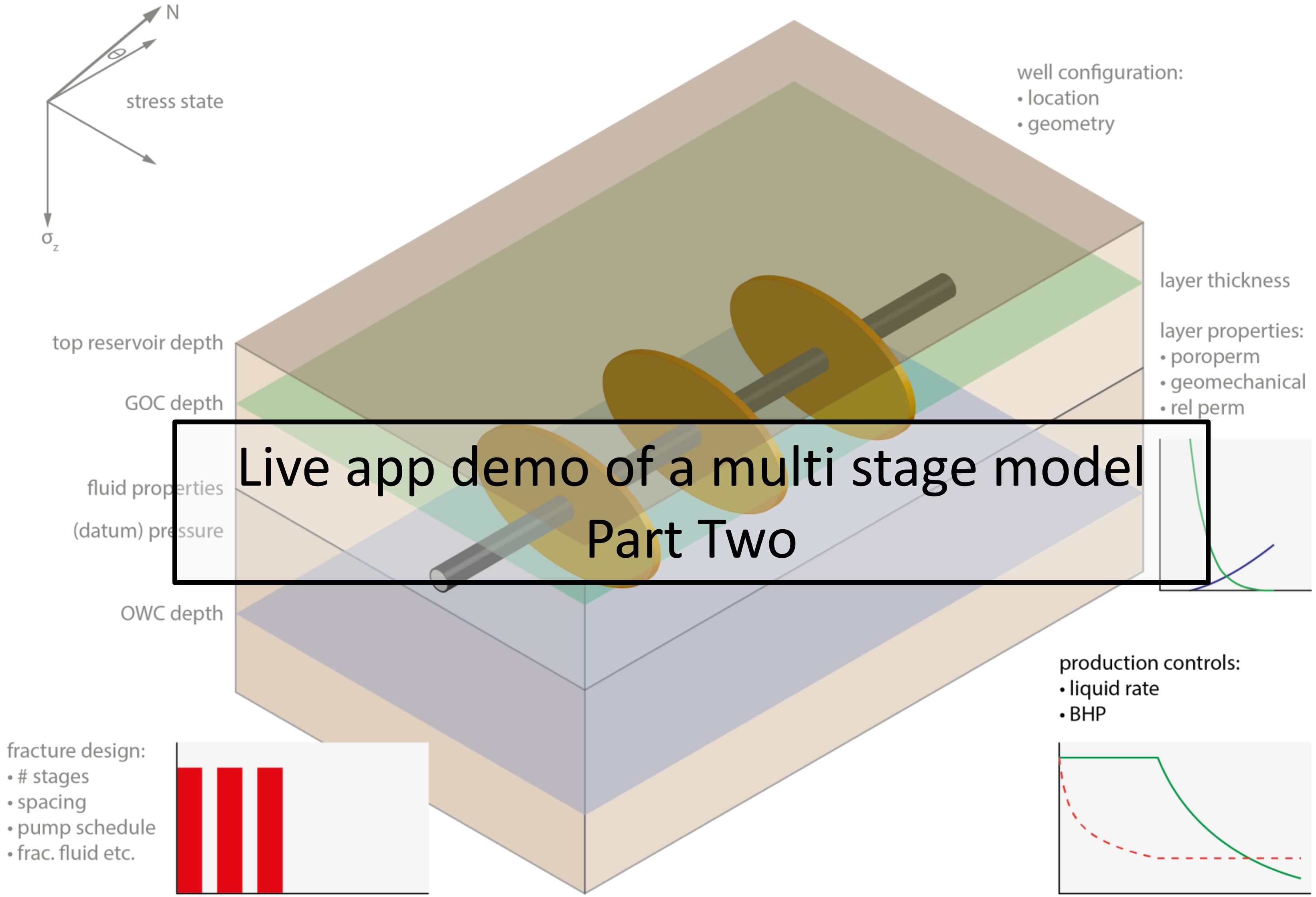
Live app demo of a multi stage model Part One

Example 2 – Entire well with various stage counts

The objective of this example is to show:

- Construction of a 24 stage model
  - Data input
  - Build, check & run
  - Plot and analyze the results
- Showing the impact of changing the stage count
  - Vary the stage count and spacing to accommodate
    - 16 stages
    - 32 stages
  - Build, check & run
  - Plot & compare results from 3 models

Live app demo of a multi stage model Part Two



Example 2 – Results Analysis and Conclusions

16 stages

- Produces the most per stage

24 stages

- Per stage contribution declines

32 stages

- Per stage contribution declines further
- Produces the largest amount of oil
- Is the maximum # that will fit

# Stages	Cum. oil	Per stage
	(K bbl)	(K bbl)
16	778	48
24	1,132	47
32	1,268	40

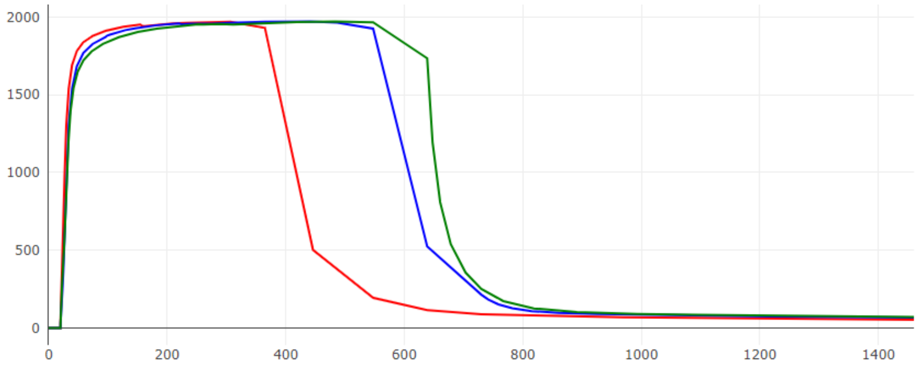
# Stages	Additional, Per stage*		
	Cost ($K)	Oil (K bbl)	Revenue ($K)
16	-	-	
24	180	44	2,200
32	180	28	850

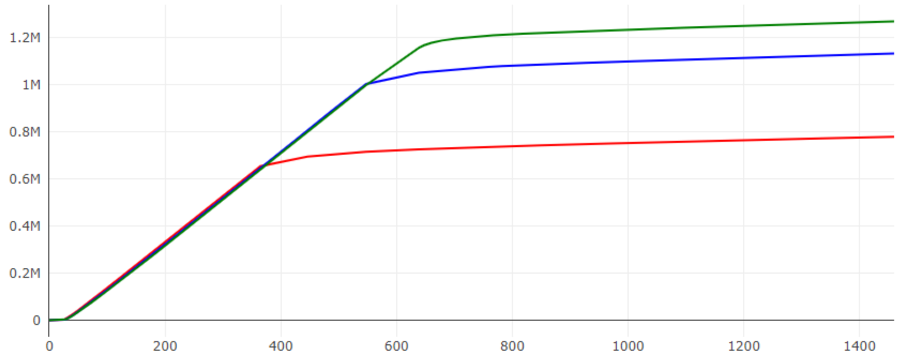
*Based on

- $600 per foot completion costs
- $50 per barrel oil price

Considerations

1. More stages produce more oil by extending the plateau
2. Is the extra upfront investment justified?





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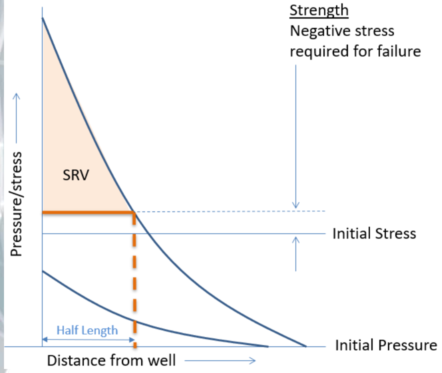
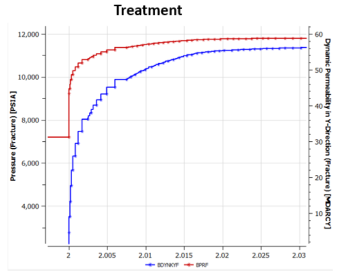
We can EXPERIMENT with alternate development strategies and EVALUATE the impact on production

Summary – Introduction to 6X and $6X^{online}$

- We have shown:
  - Single well – single stage
    - Changing the rock's response
      - allows **CALIBRATION**
  - Single well – multiple stages
    - Changing design, e.g. stage count
      - allows **EXPERIMENTATION**
- Contact
  - Peter Forster
    - to request more information
      - pforster@ridgewaykitesoftware.com
  - Tommy Miller
    - to request access to **6X**^{online}
      - tmiller@ridgewaykitesoftware.com
  - Also: www.ridgewaykite.com





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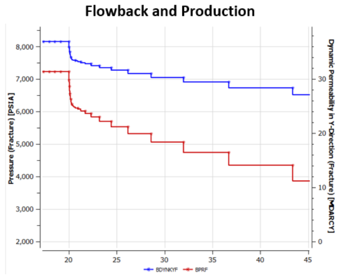
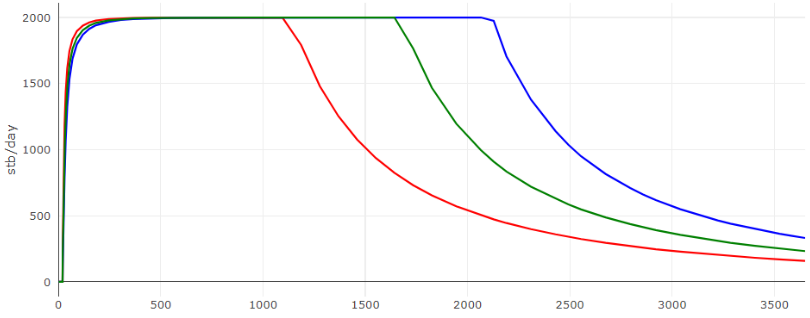
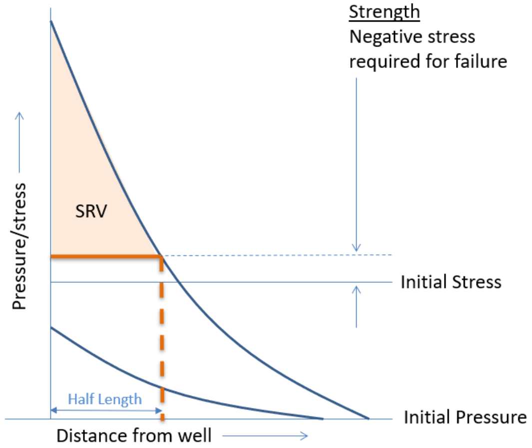


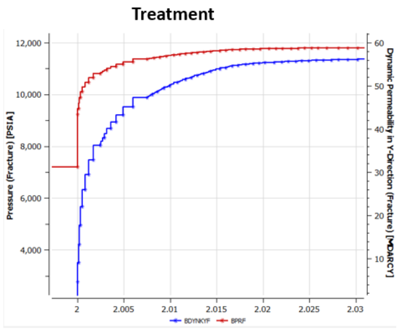
As flowback and production progresses:
- Pressure decreases
- Enhancement decays to a defined residual



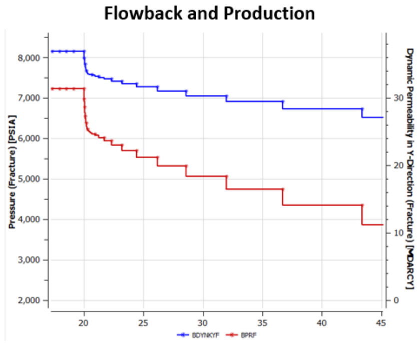
Questions?

- From the Chat panel
- Live...





As fluid is pumped:
- Pressure increases until minimum stress is exceeded
  - Net stress becomes negative
  - Tensile failure adds permeability
  - Shear failure adds surface area due to rubblization



As flowback and production progresses:
- Pressure decreases
- Enhancement decays to a defined residual

- We will be back with a second presentation soon

The END of Introduction