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Fluid Imbibition - Hydraulic Fracture Flowback Dynamics

Robert Hawkes
Manager Reservoir Services

Buenos Aires

Thursday, Nov 21, 2018

TRICAN



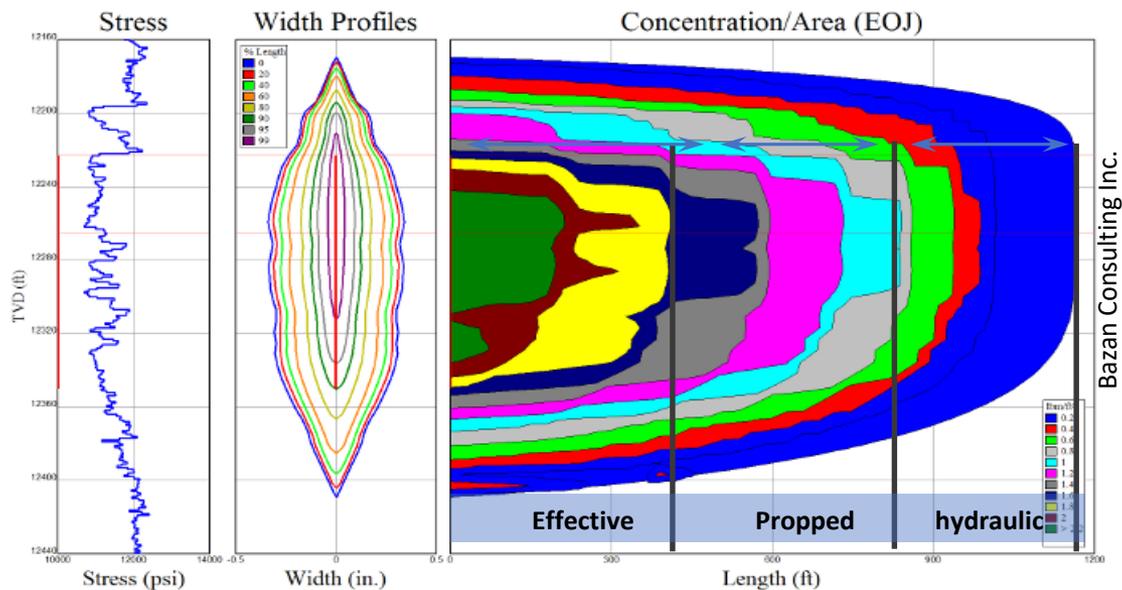
Society of Petroleum Engineers
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What is *YOUR* idealized hydraulic fracture result:

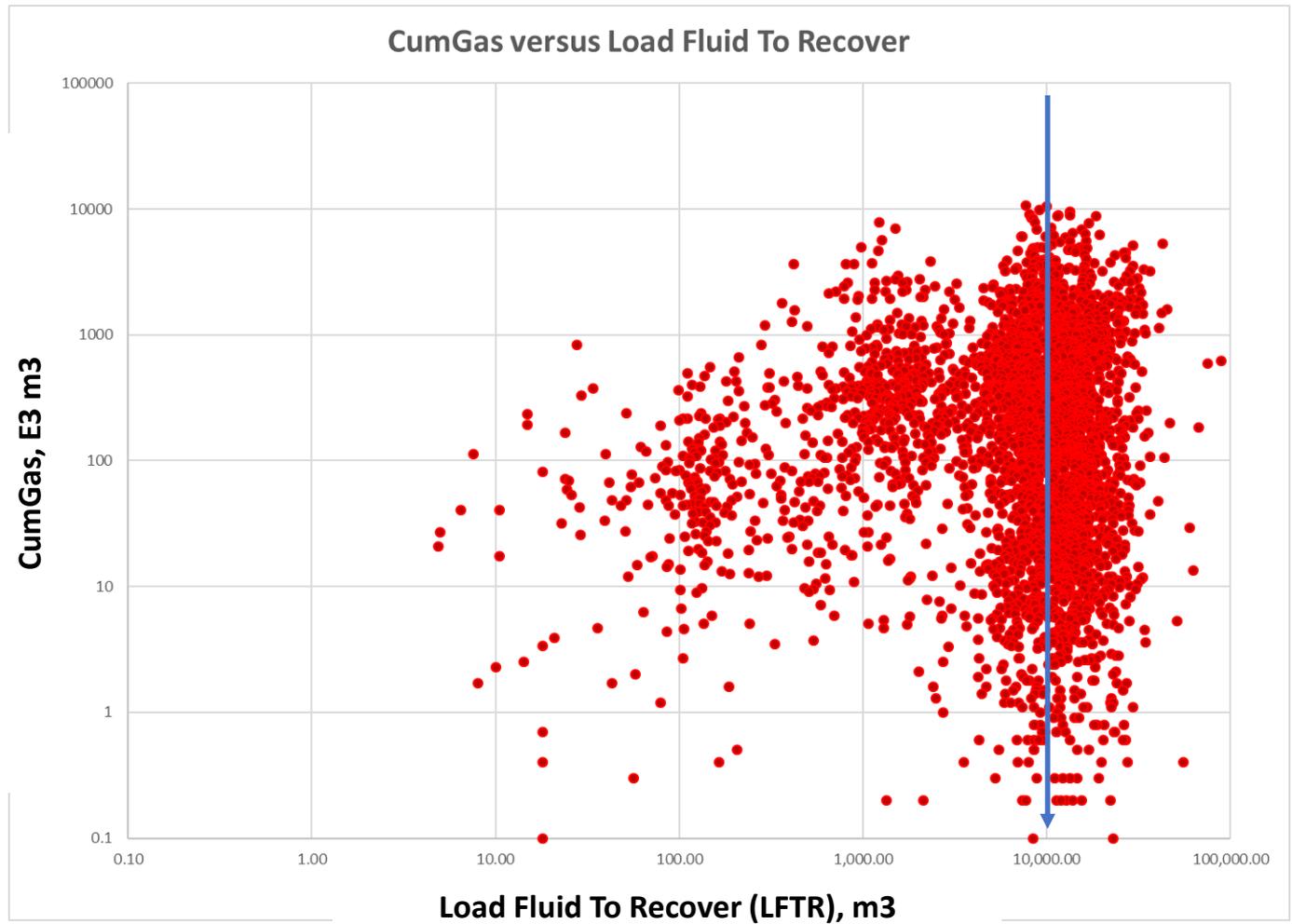
➤ 100% Load Fluid Recovery?

or

➤ 0% Load Fluid Recovery?



This is a
LogLog plot
showing
**CumGas vs
LFLTR** after
Flowback.



BCOGC AOF Test Data (MNTN)

LFLTR: Load Fluid To Recover, m3

Outline

1. Properties of Unconventional Reservoirs
2. Laboratory Observations
3. Dynamic Field Observations
 - Load Fluid Recovery Diagnostics
4. Summary and Comments

Properties of Unconventional Reservoirs

Ultra-low-permeability rock, including sandstone, siltstone, shale, and carbonates.

Sub-irreducible state and organically rich.

Requires a great amount of fracturing fluid to create multiple fractures to increase wellbore and reservoir contact.

Why do some wells Flowback less load fluid?

Does extended shut-in time improve hydrocarbon productivity?

Where did all the Frac water go?

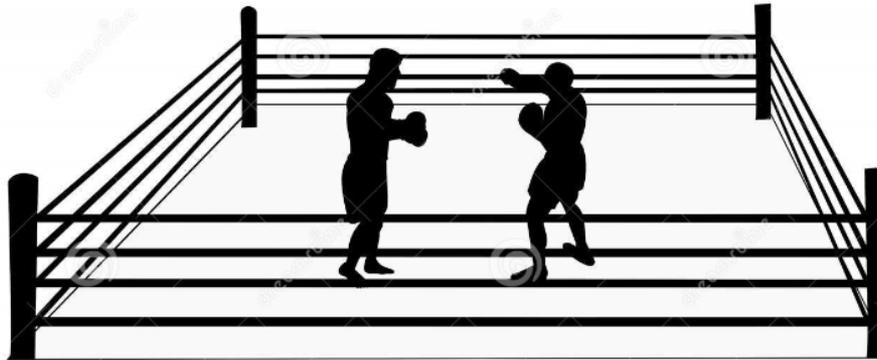


.....and what are the implications to long term production?

Production Delays and Extended Shut-ins

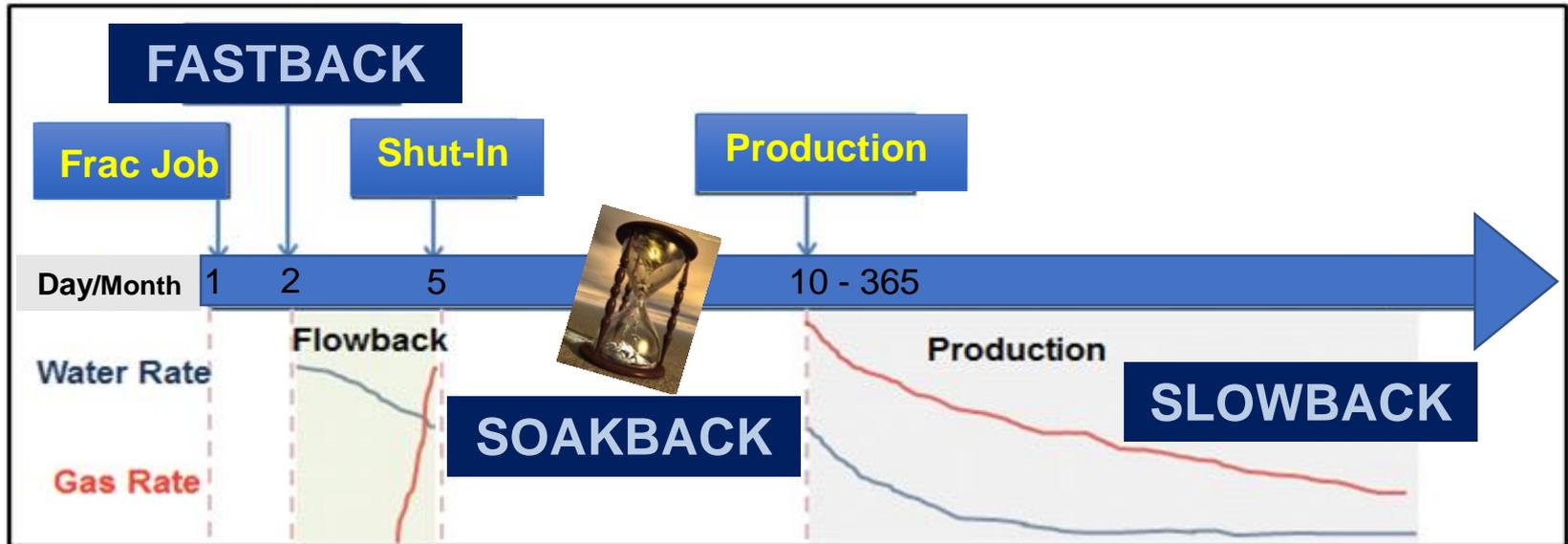
What is an engineer to do?

Flowback as
soon as possible



Take your Time

Hydraulic Fracture Flowback Dynamics



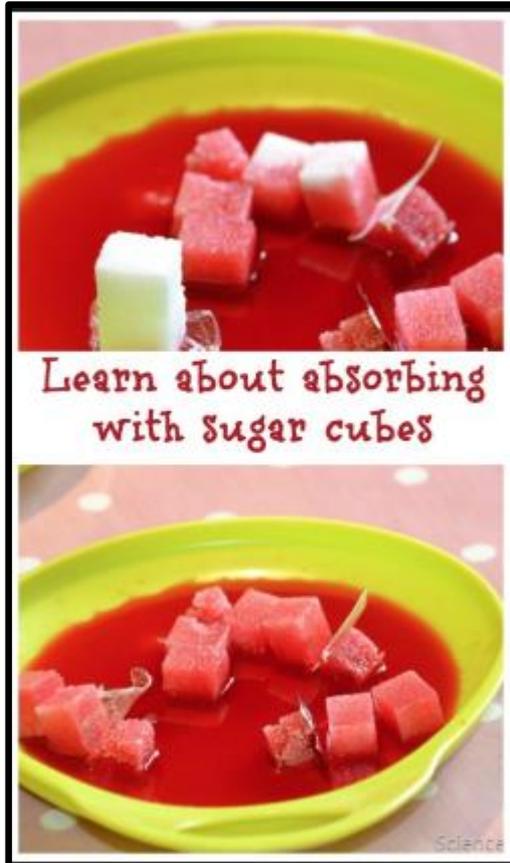
Modified from SPE 166279

Rock Fabric Drivers to Observed Flowback Dynamics

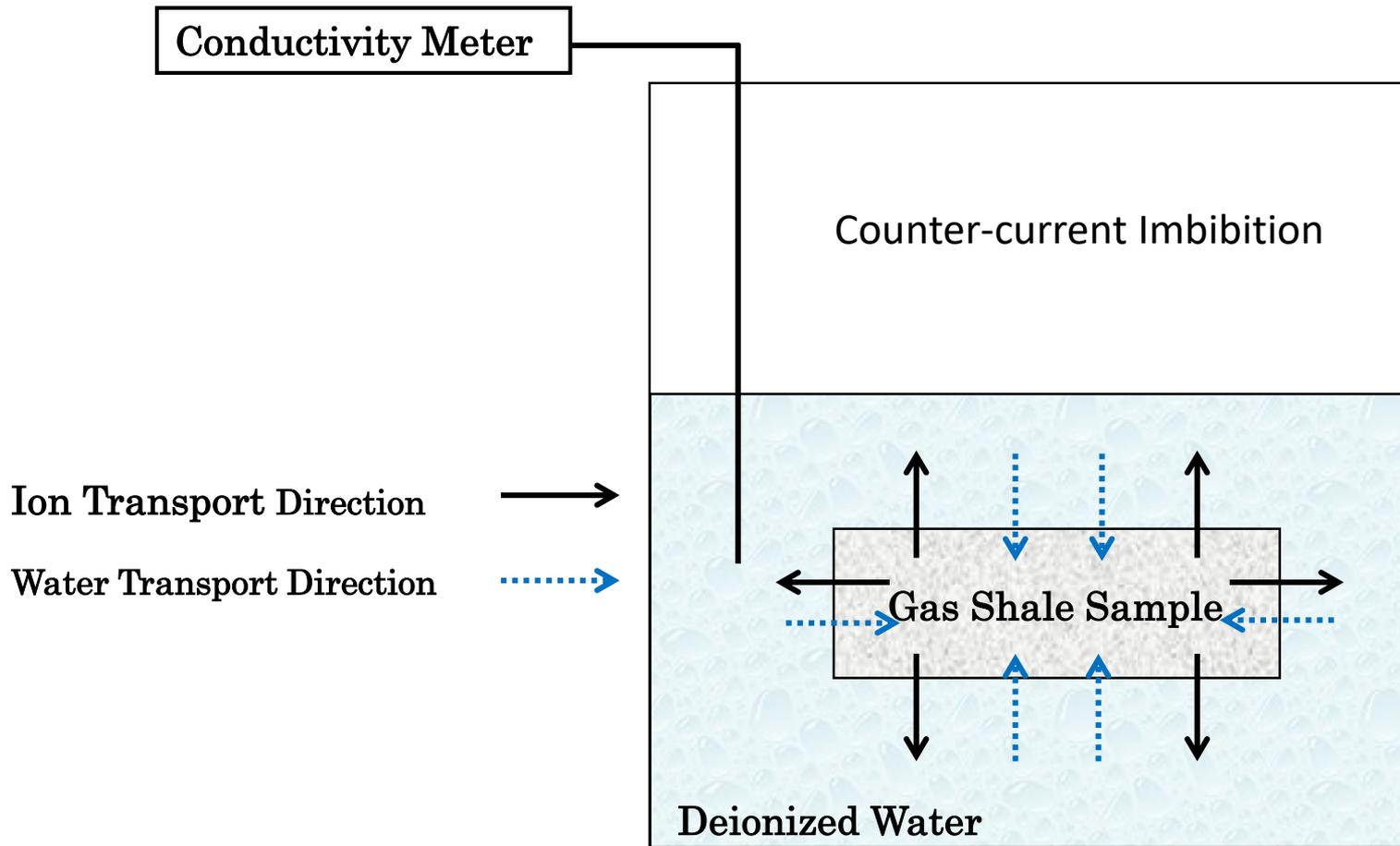


- Spontaneous Imbibition
 - Wettability
 - IFT
- Clay Type
- Osmosis
- Total Organic Content
- SW_{ir}
- Rock Fabric

Key Observations In the Laboratory



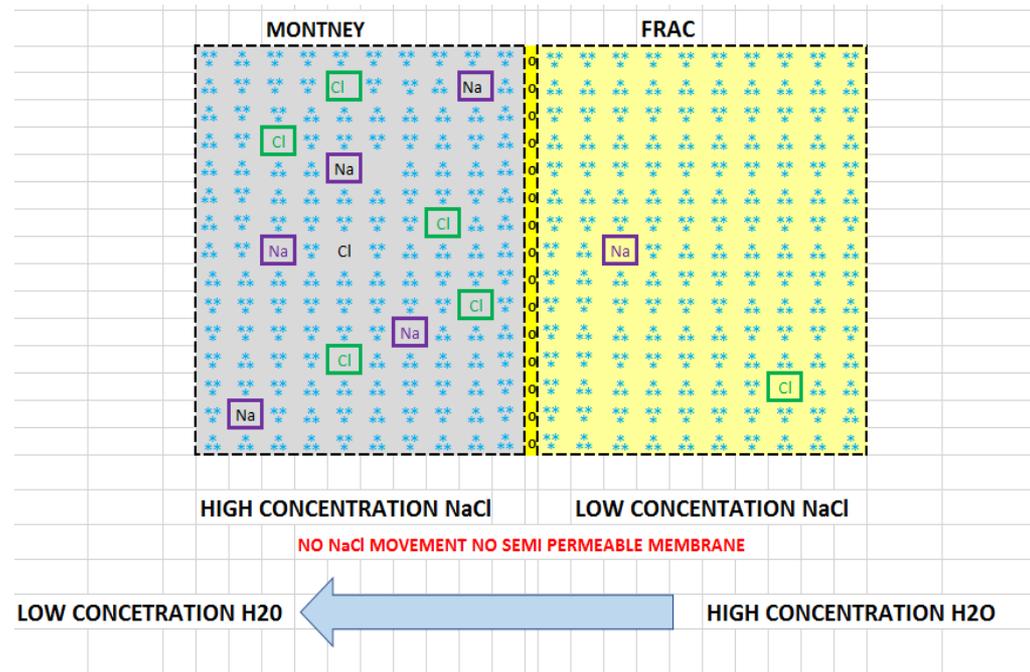
Obs 1: Water Imbibition and Salt Diffusion



Obs 1: Water Imbibition and Salt Diffusion

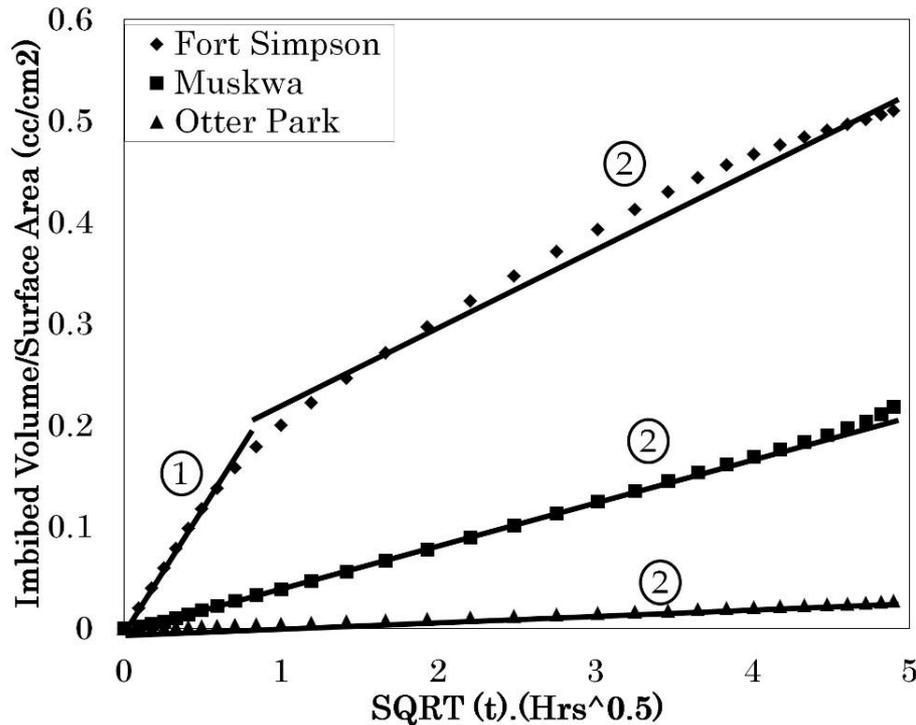
Chemical Osmosis

- As water is a polar molecule, the NaCl in water causes the Na and Cl to have six polar water molecules surrounding them increasing their hydration diameters (Conway, 1981).
- The space between the illite sheets is small enough to allow water to move through but not Na and Cl with six polar molecules attached and this creates a semi permeable membrane to fresh water but not to salty water.

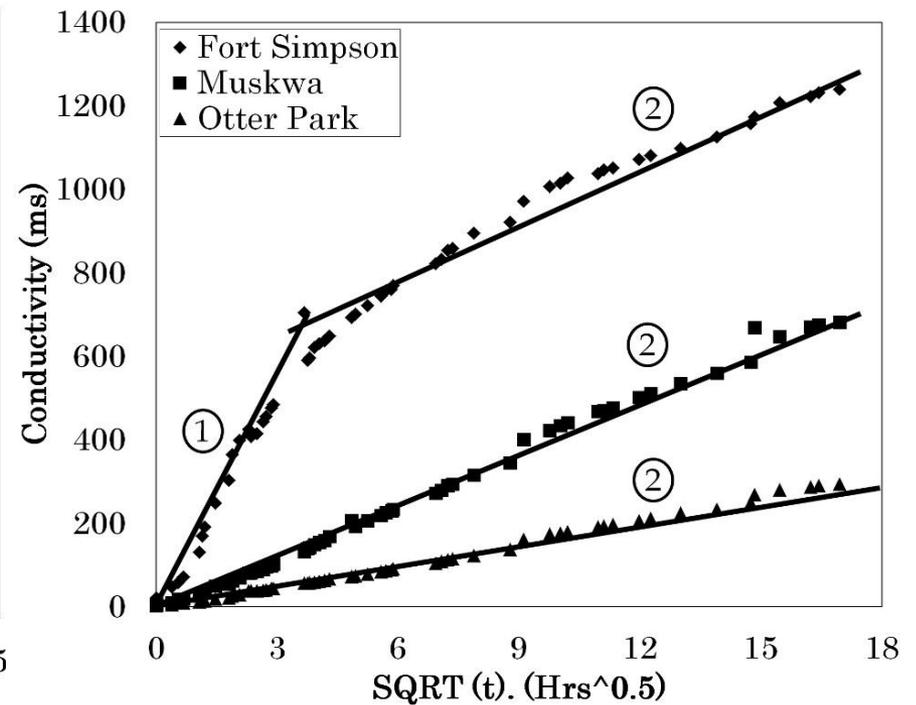


Obs 1: Water Imbibition and Salt Diffusion (Shale Gas, Horn River Basin, B.C.)

Water Imbibition



Salt Diffusion



SPE-167165

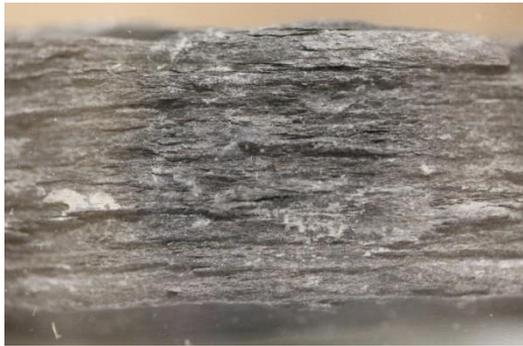
Obs 1: Water Imbibition and Salt Diffusion (Shale Gas, Horn River Basin, B.C.)

Fort Simpson

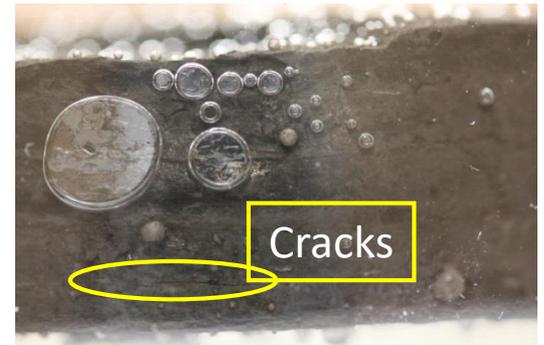
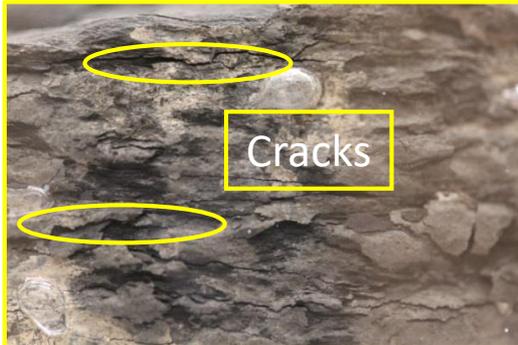
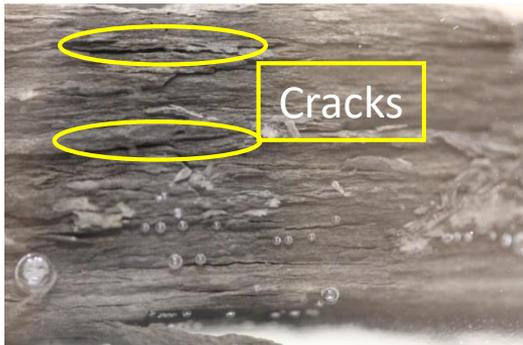
Muskwa

Otter Park

0 Hours



52 Hours

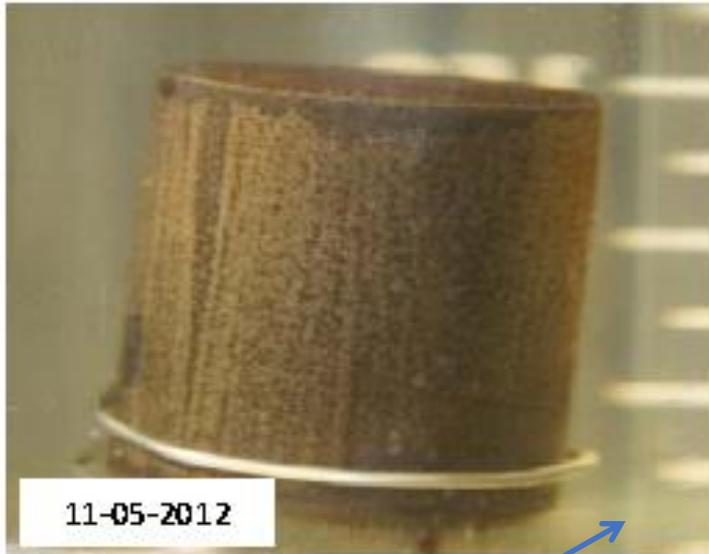


2.4 cm

SPE-167165

Obs 2: Salinity-Dependent Imbibition (Bakken Case Study)

Soak Time: 5 d



High-salinity solution

Soak Time: 6 d



Low-salinity solution

SPE-168998

Obs 2: Salinity-Dependent Imbibition (Bakken Case Study)

1) Initially, oil occupies most of the pore space while formation water is bound to the clay platelets



2) Low-salinity (slick water frac fluid) flows into clay structure due to osmotic force.



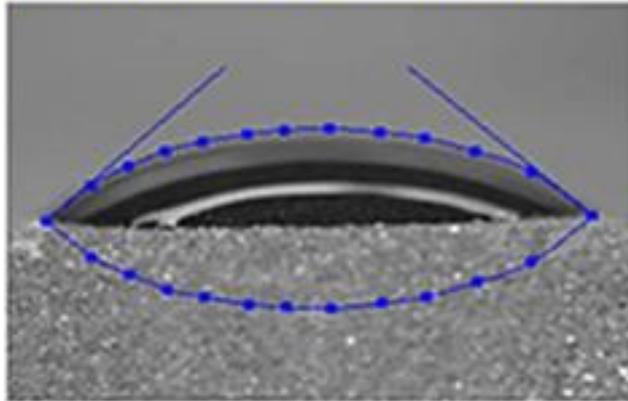
3) Oil is expelled due to osmotic-pressure increase

- High-salinity solution
- Low-salinity solution
- Oil

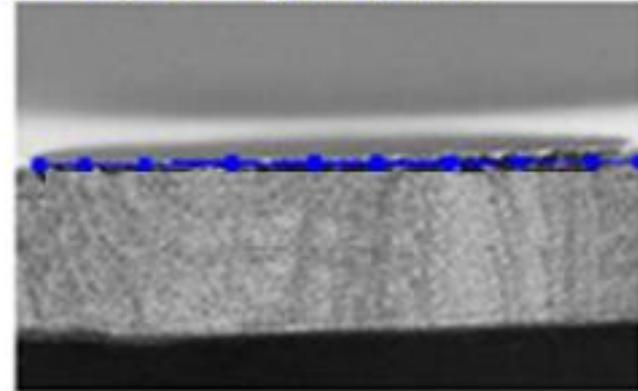
SPE-168998

Obs 3: Mixed Wettability (Montney Core)

Water



Oil



Time

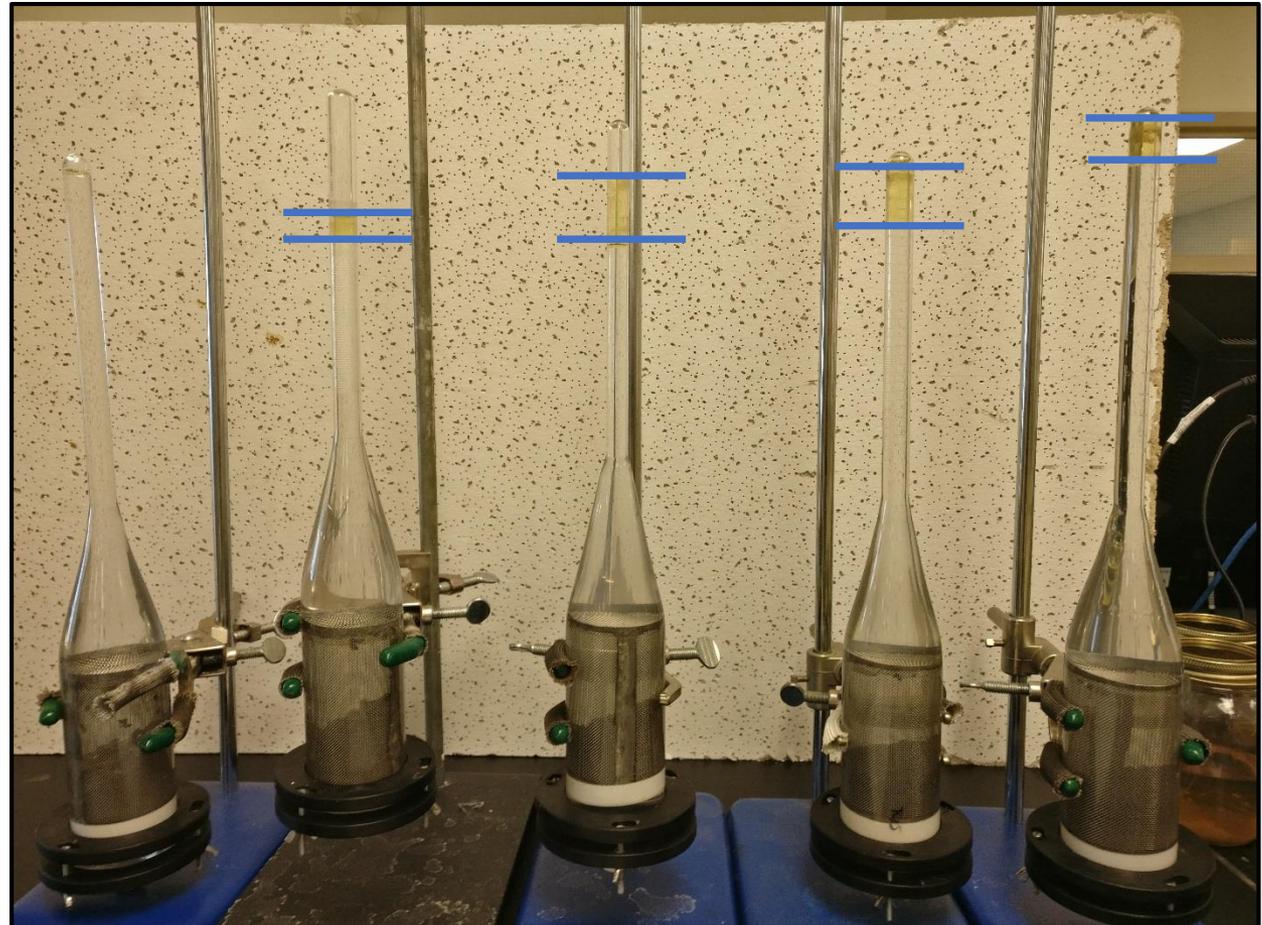


Time

University of Alberta

Obs 4: Amott Cell Testing

- Montney Drill cuttings
- Pre-soak cuttings in oil for 5 days
- Placed in surfactant solution



BLANK

FracFluid

1

FracFluid

2

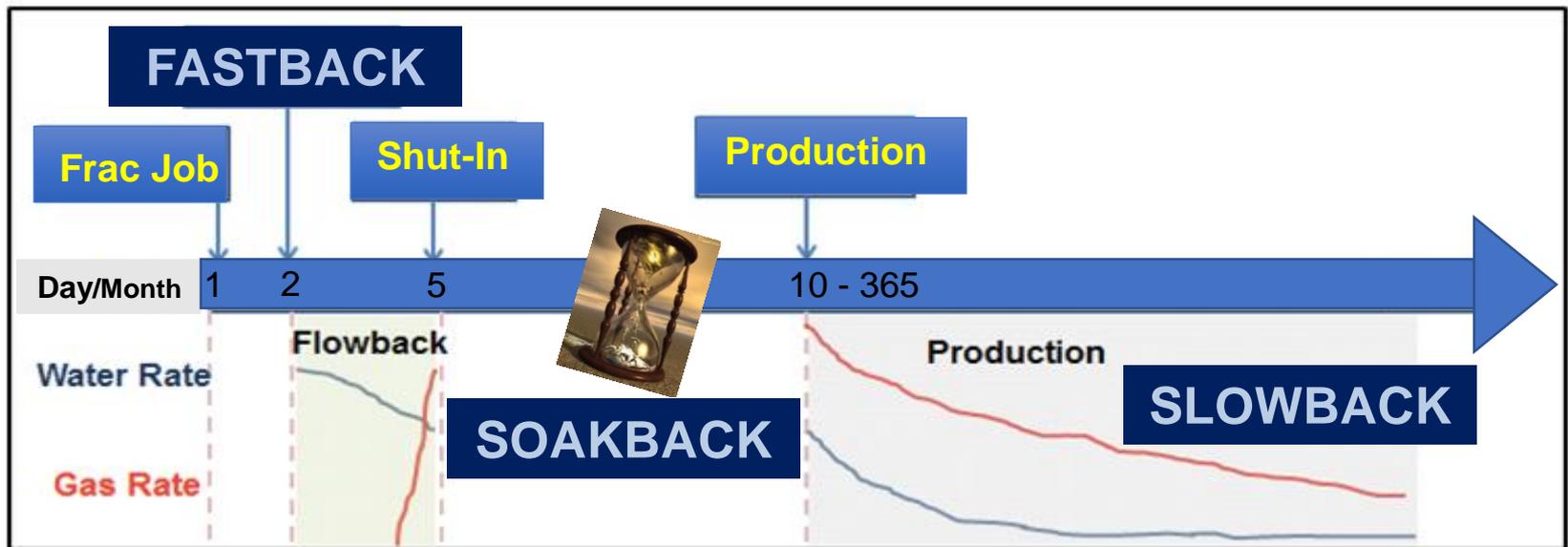
FracFluid

3

FracFluid

4

Flowback Dynamics



Fundamental Flowback Dynamics:

1. COMPACTION DRIVE

- *Compaction drive* represents the portion of flowback recovery due to effective fracture pore-volume as closure pressure approaches

2. DEPLETION DRIVE

- *Depletion drive* represents the portion of flowback recovery due to water drainage

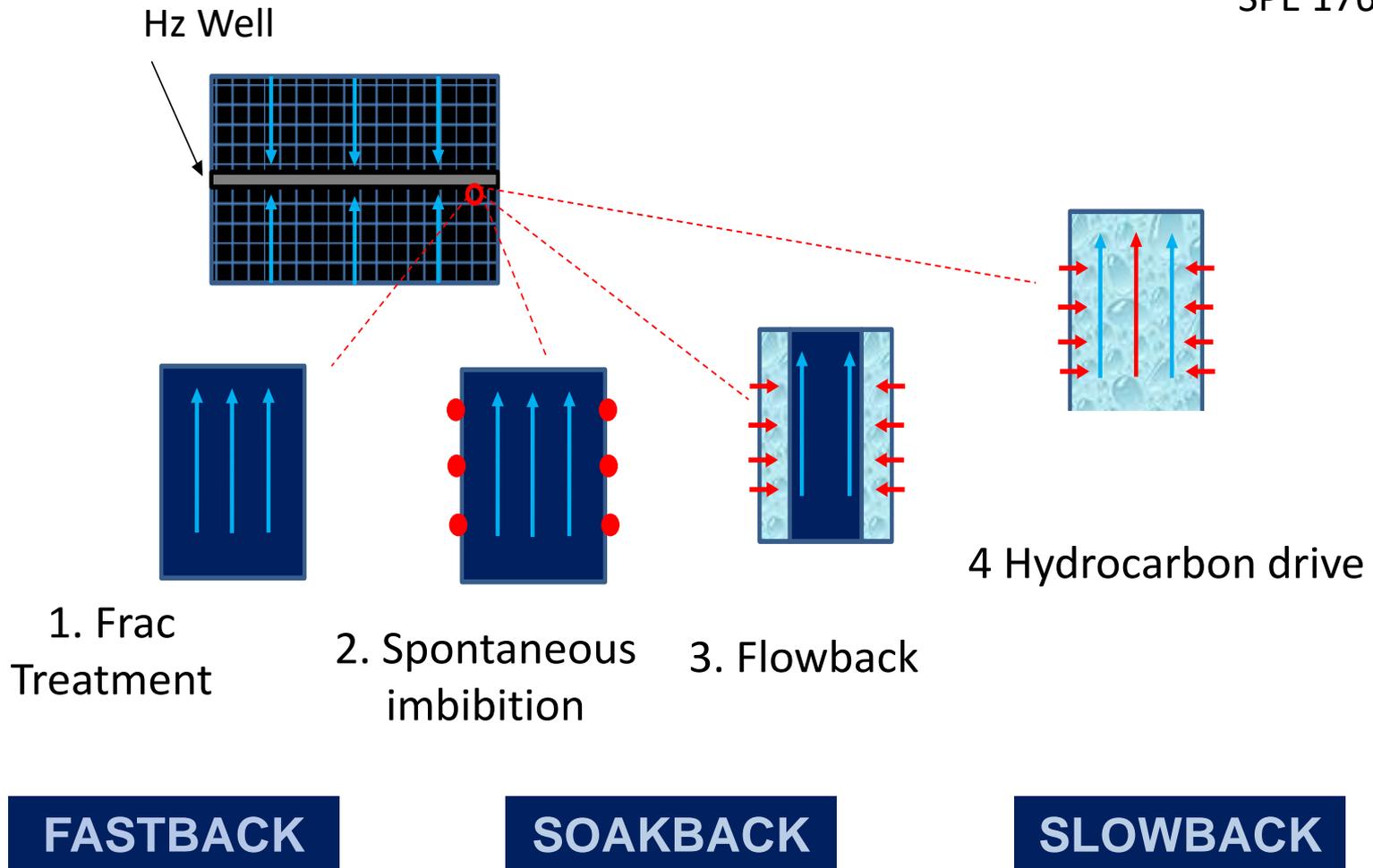
3. HYDROCARBON DRIVE

- *Hydrocarbon* represents the portion of flowback recovery due to gas/oil expansion as pressure drops

SPE 175143

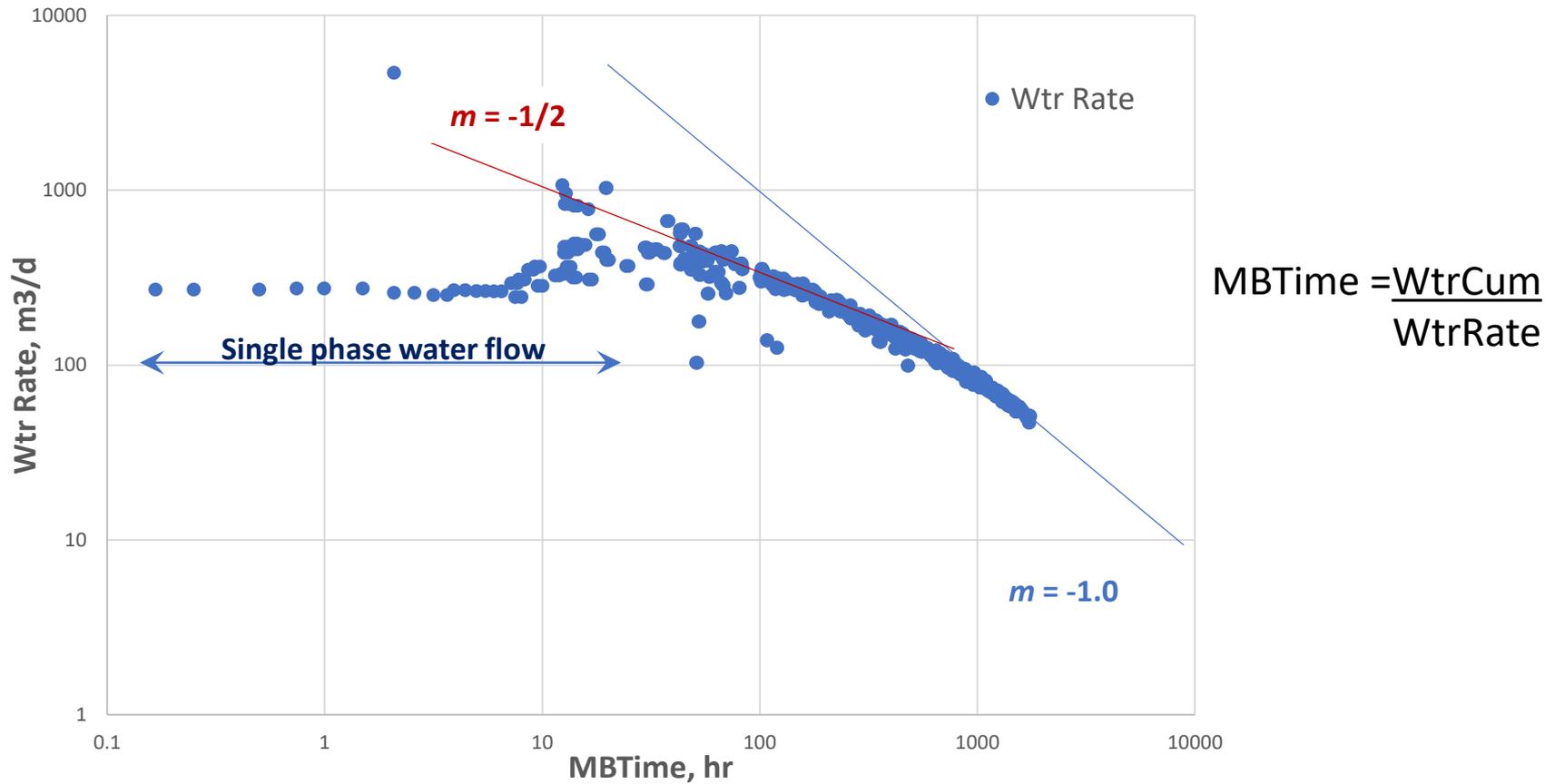
Adopted (CBM) Concept from Dr. Chris Clarkson, UofC

SPE 176869

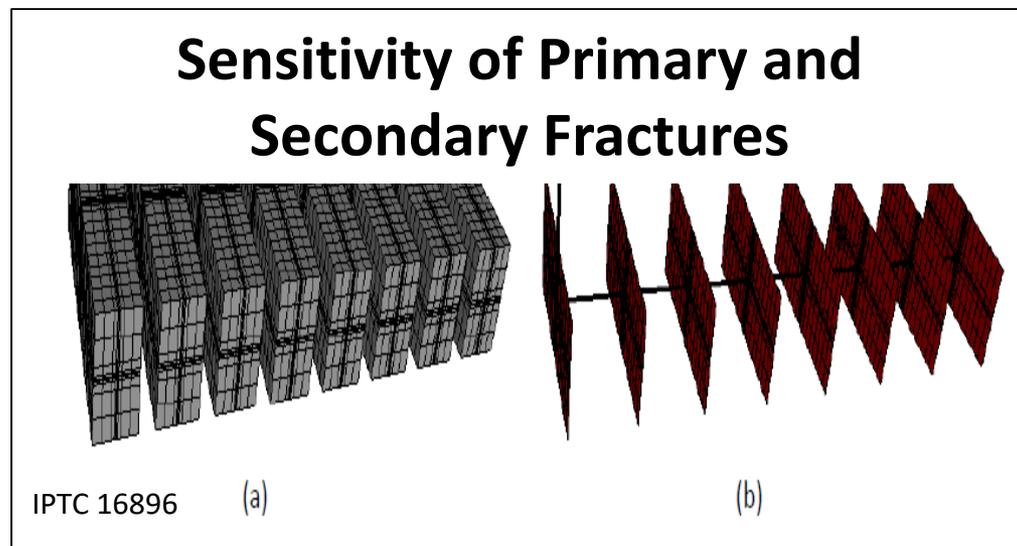
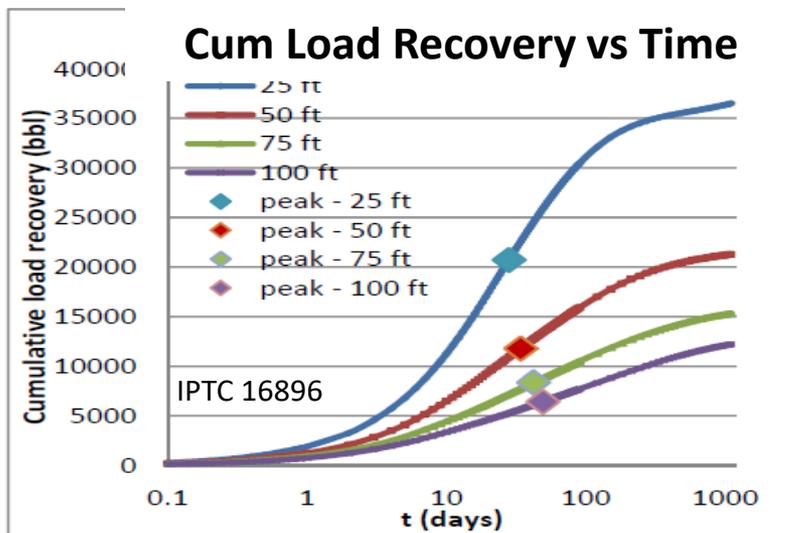
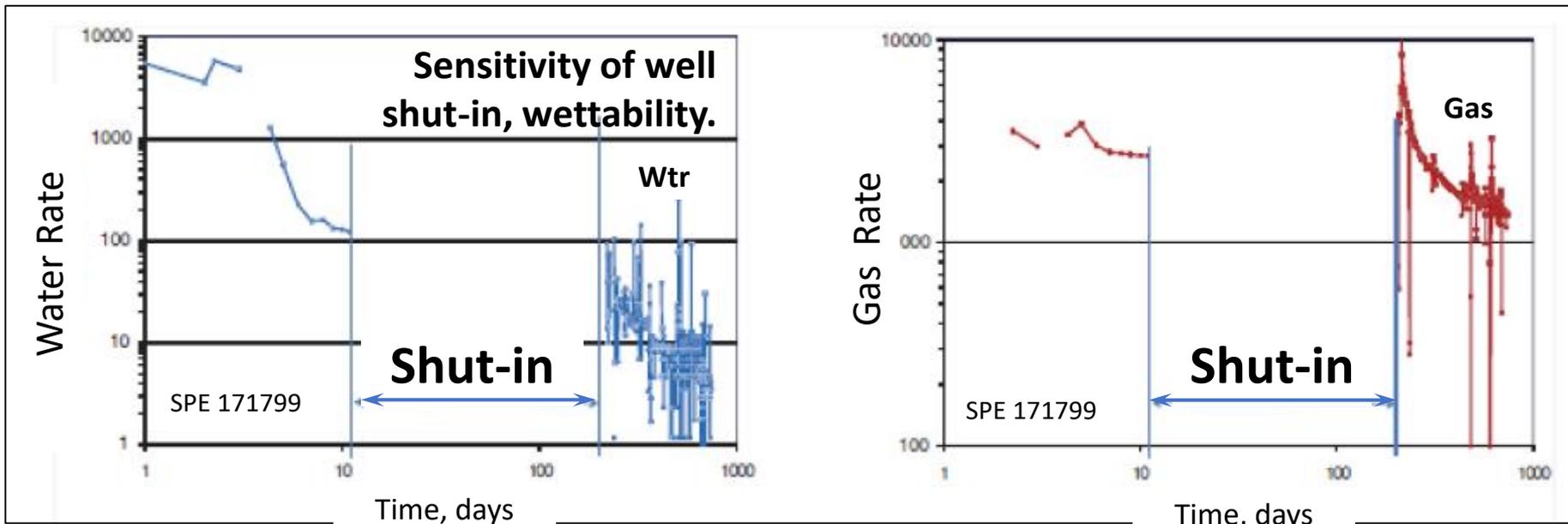


Adopted (CBM) Concept from Dr. Chris Clarkson, UofC

Flowback Plot of Wtr Rate vs MB Time

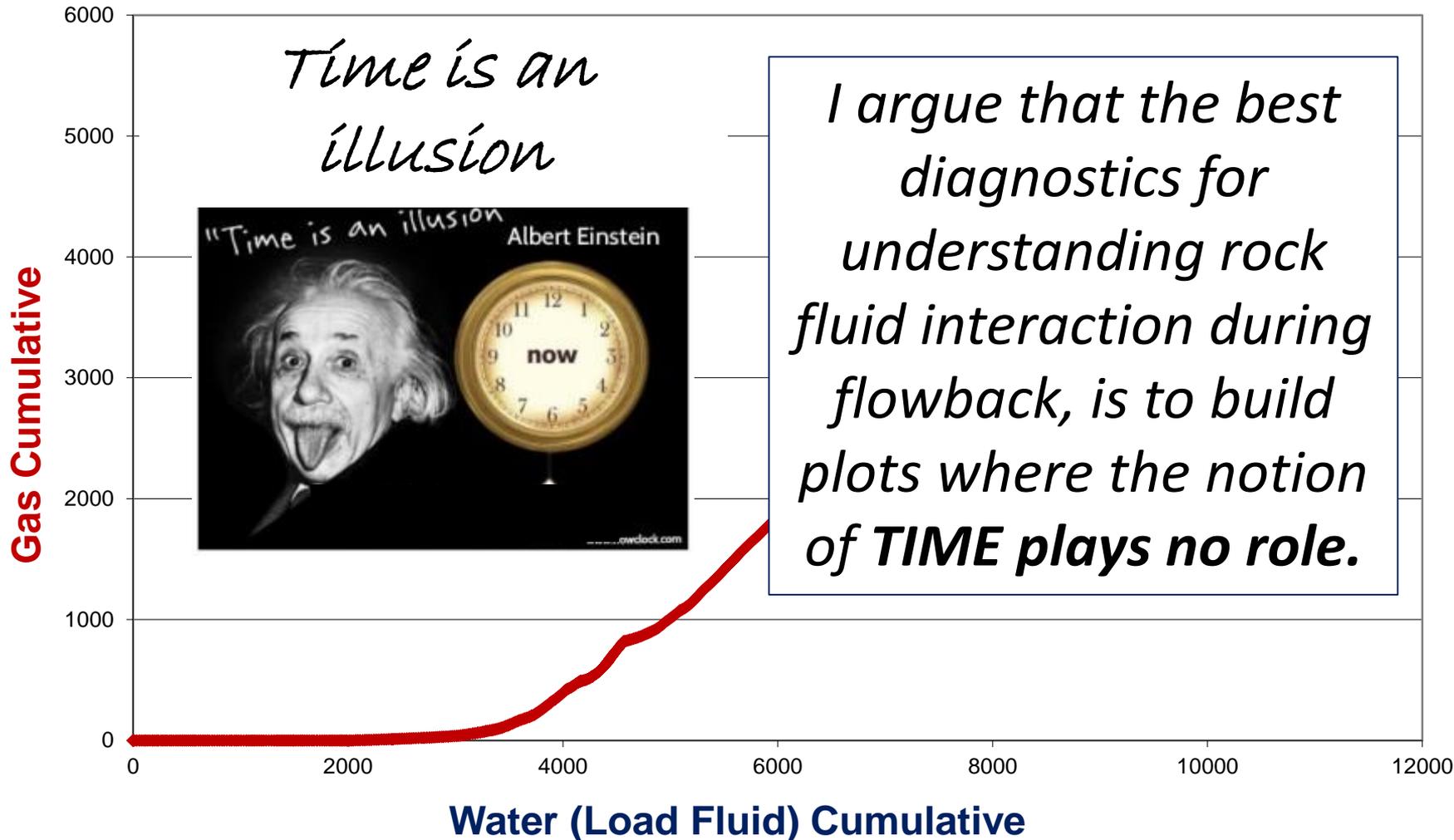


Flowback Dynamics – A Reservoir Simulation Perspective



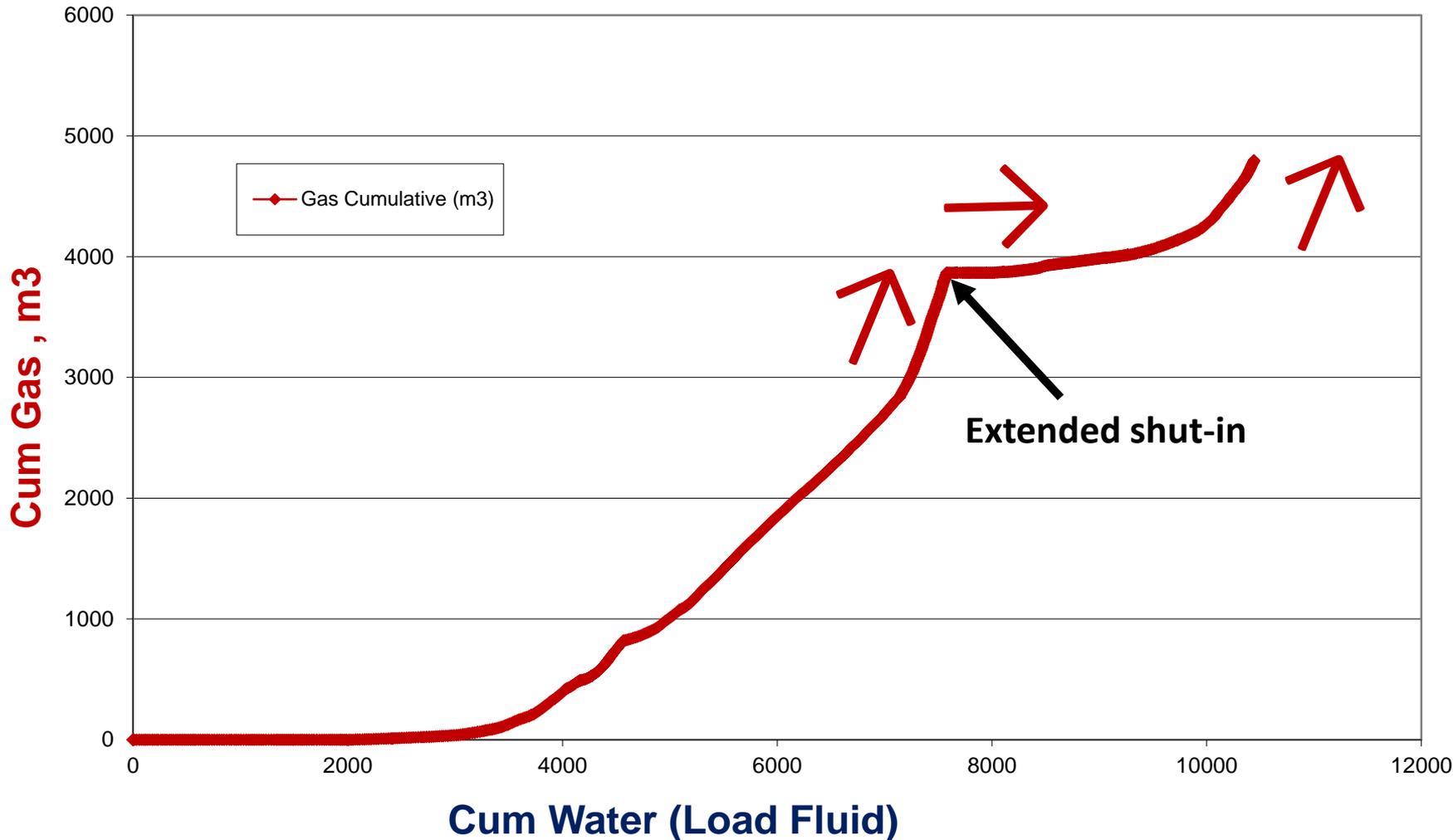
Flowback Dynamics – A *Diagnostics* Perspective

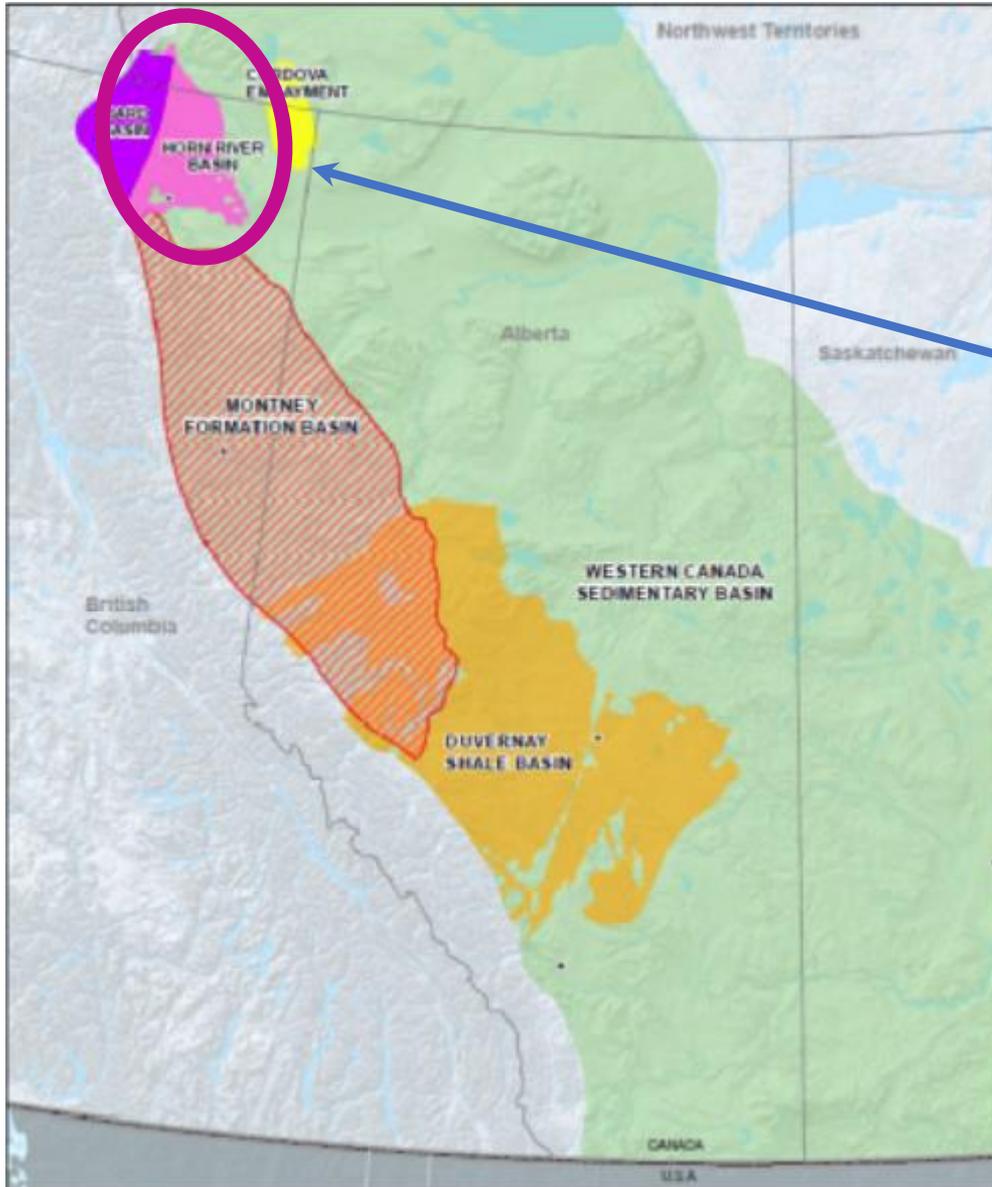
Gas Cumulative vs Water (Load Fluid) Cumulative



Flowback Dynamics – A *Diagnostics* Perspective

Cumulative Gas vs Cumulative Water (Load Fluid)





Shale Gas

Horn River Basin

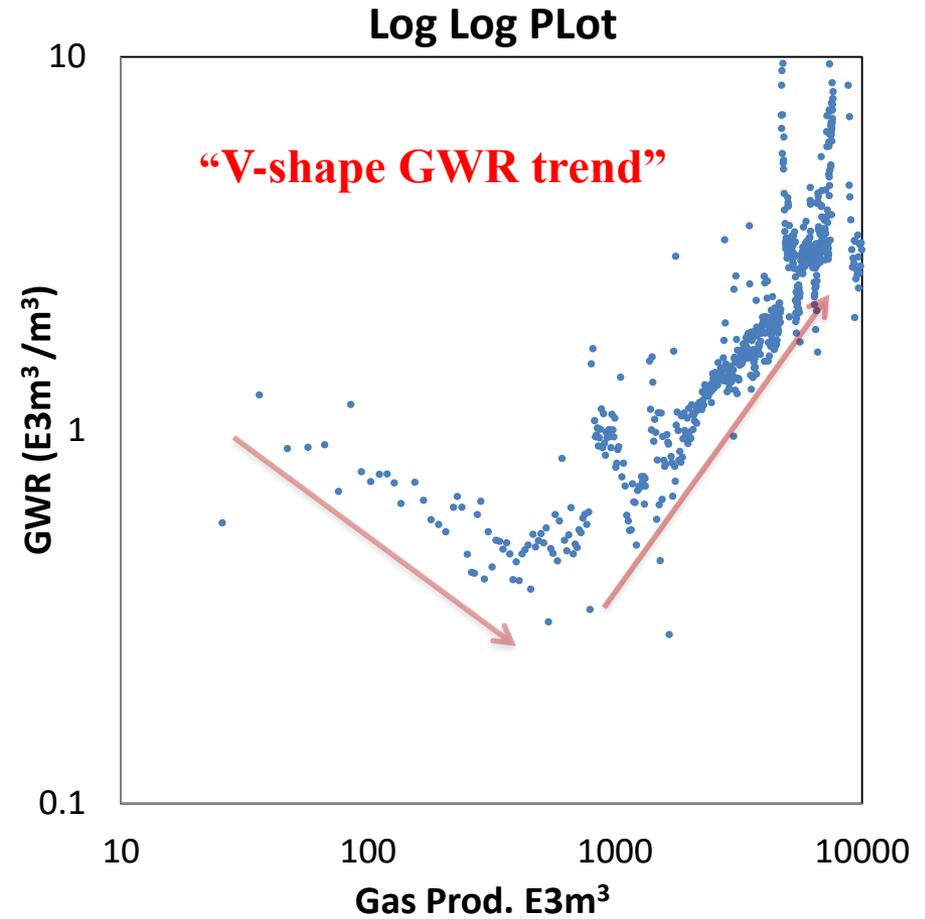
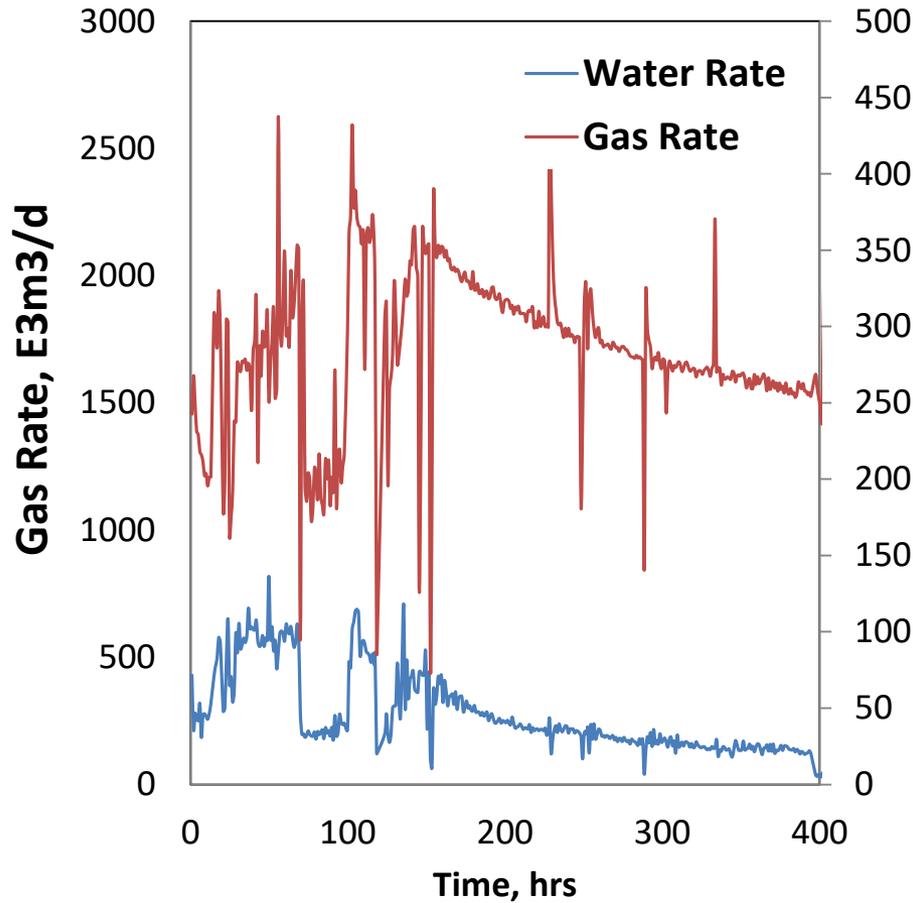
Field Observations

Horn River is a distant cousin to the Barnett Shale of Texas



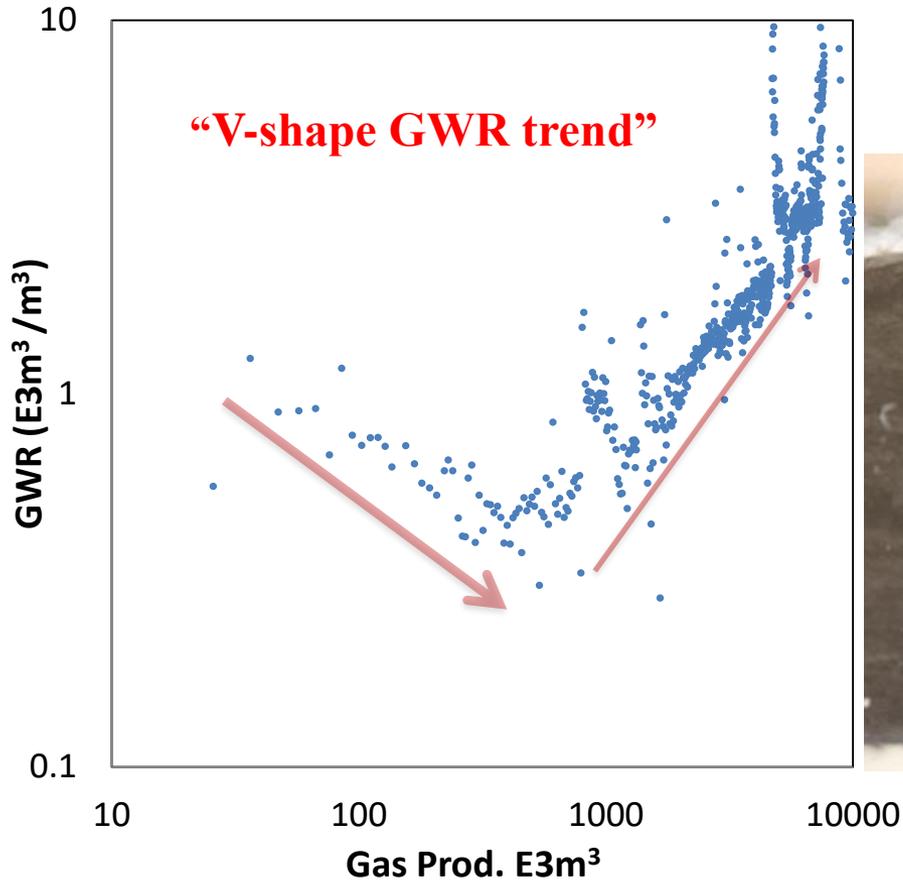
Source: National Energy Board

Field Observations from Horn River Shales



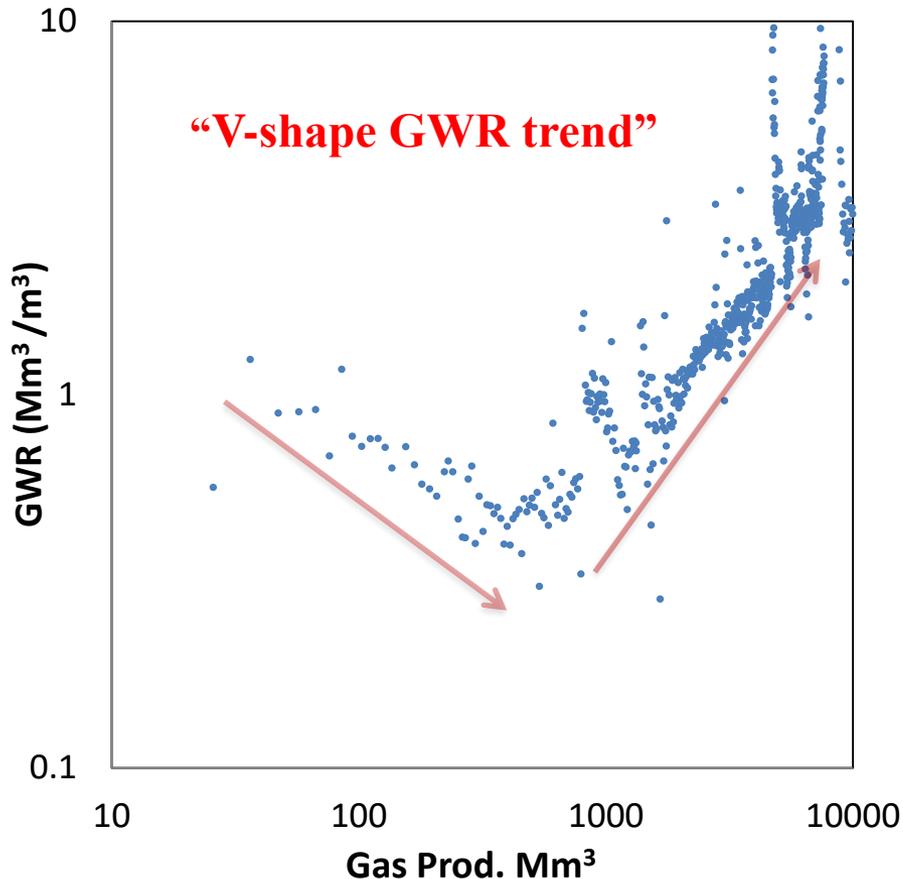
SPE 171636

Flowback Dynamics



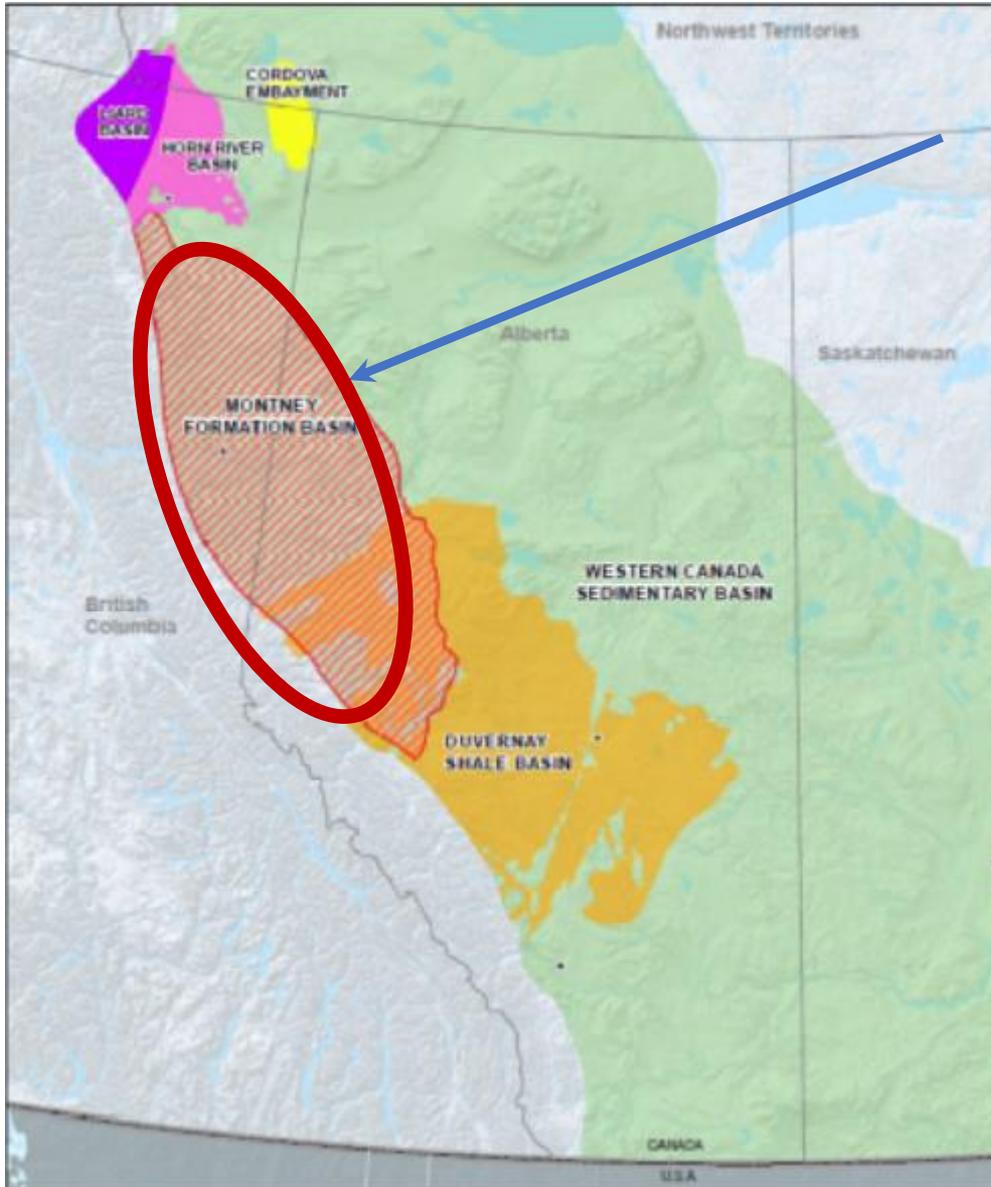
SPE 171636

Flowback Dynamics



- Early gas production is from free gas saturation within the primary fractures (spontaneous imbibition)
- The negative slope, is depletion of free gas from primary fracture network.
- The change in flow regimes signifies the onset of communication between matrix and natural fracture system.

SPE 171636



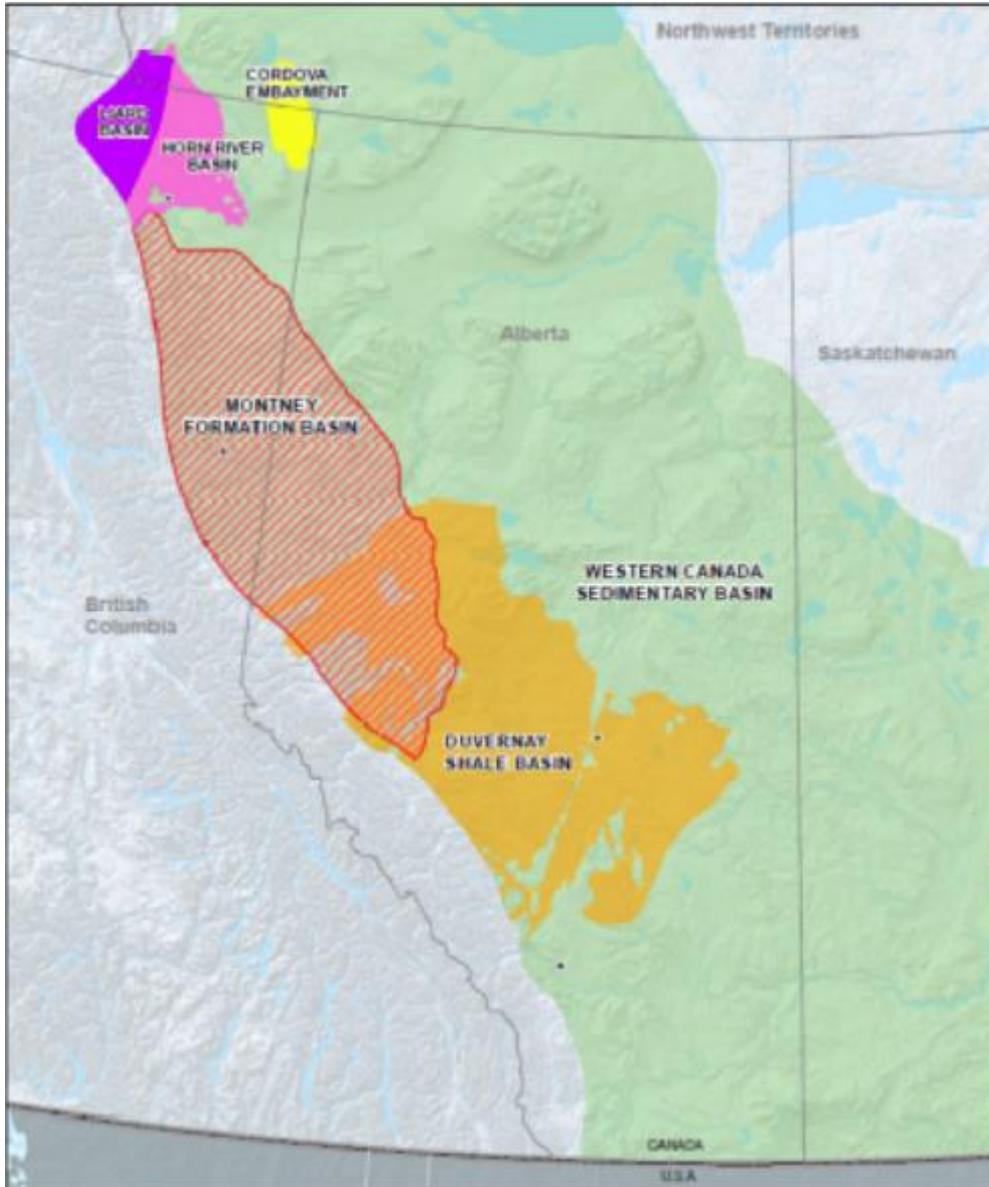
Montney Gas

Estimating
Ultimate Load
Fluid Recovery
using Early
Flowback
Diagnostics

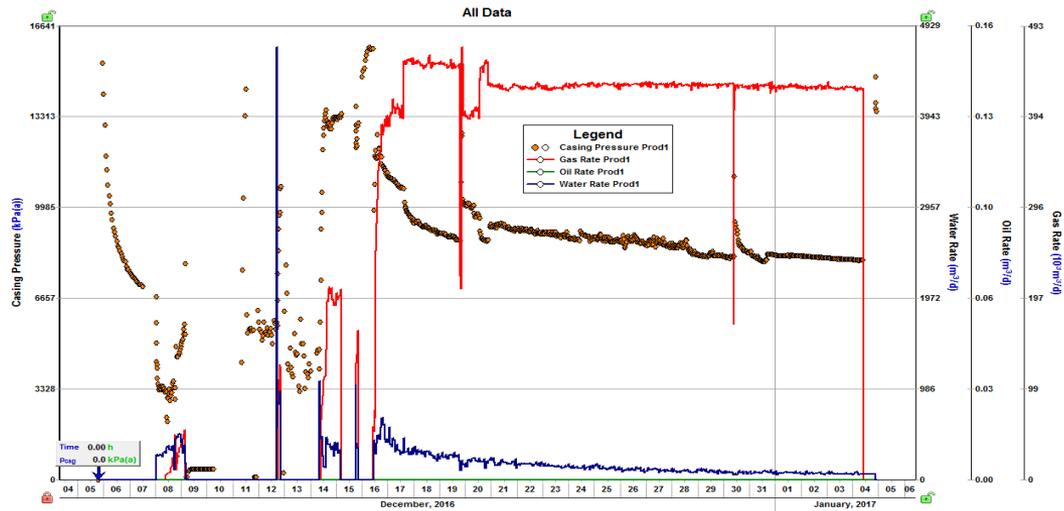
Definitions

LFTR: Load Fluid to Recover

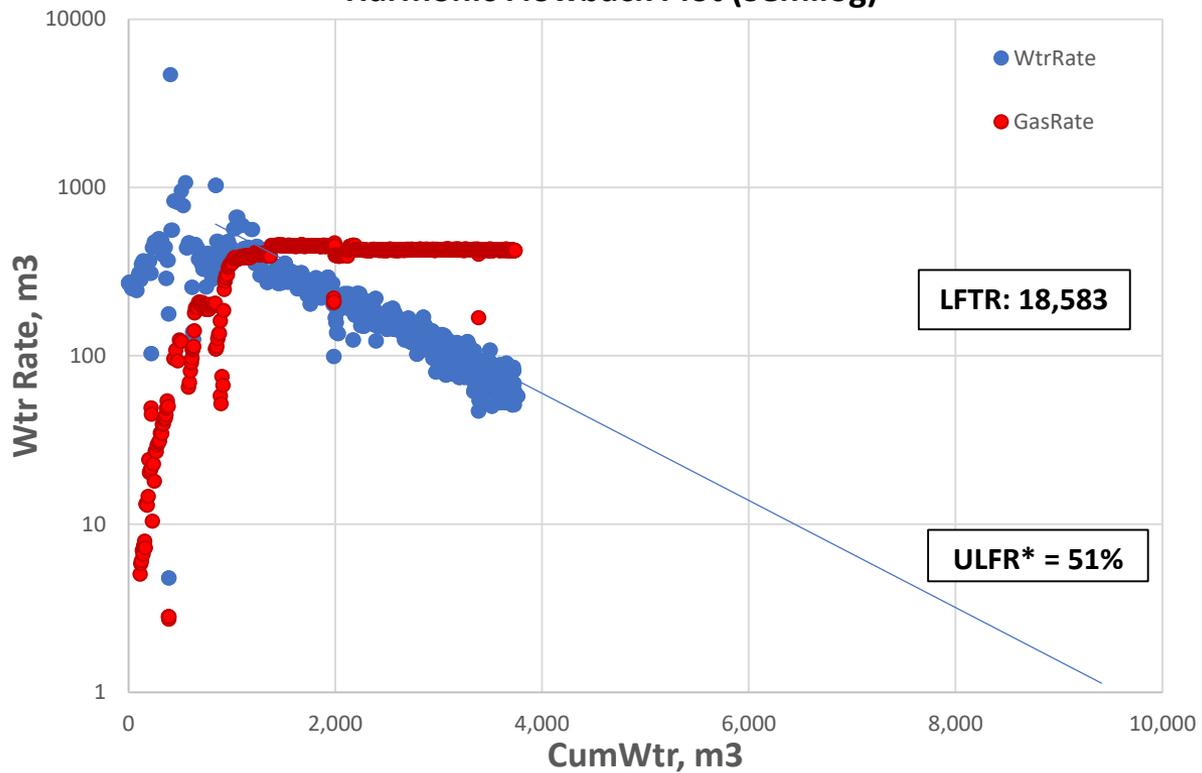
ULFR: Ultimate Load Fluid Recovered

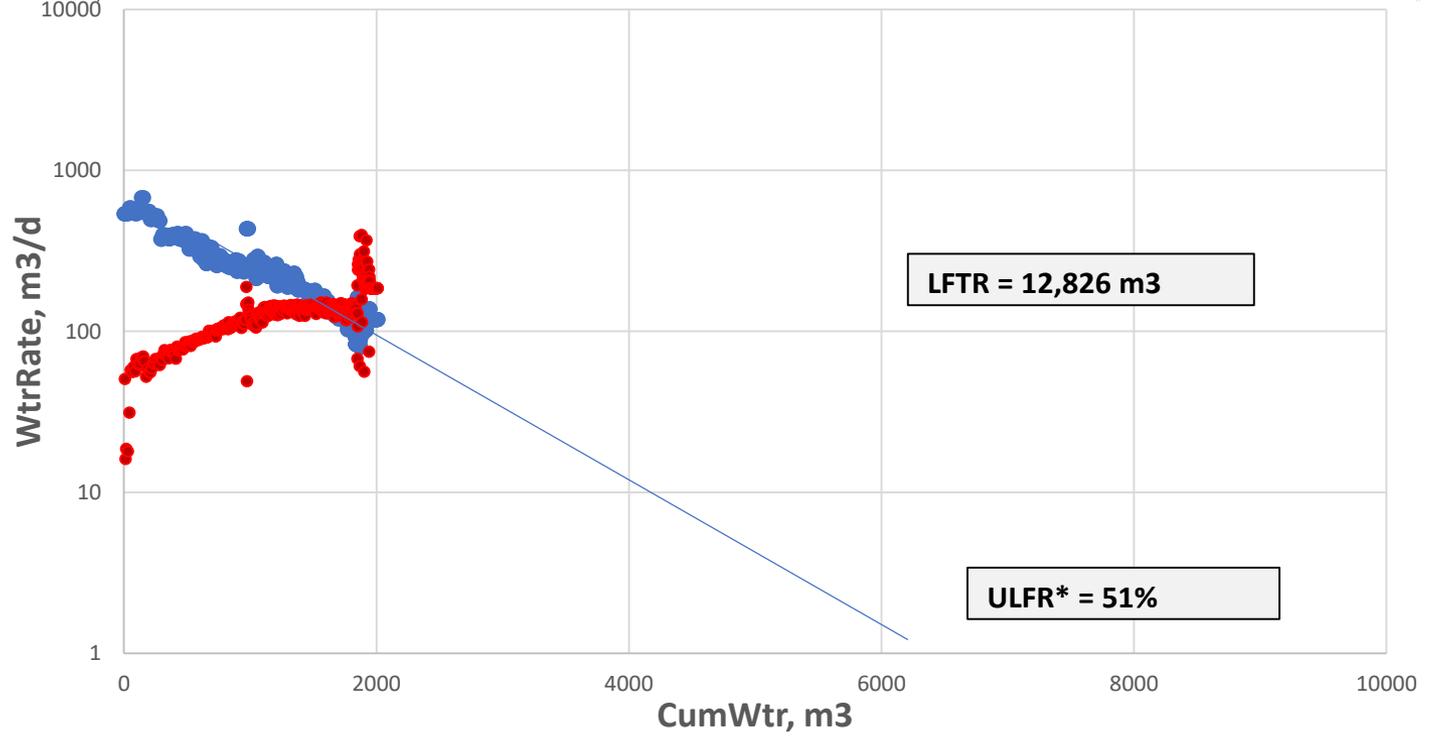
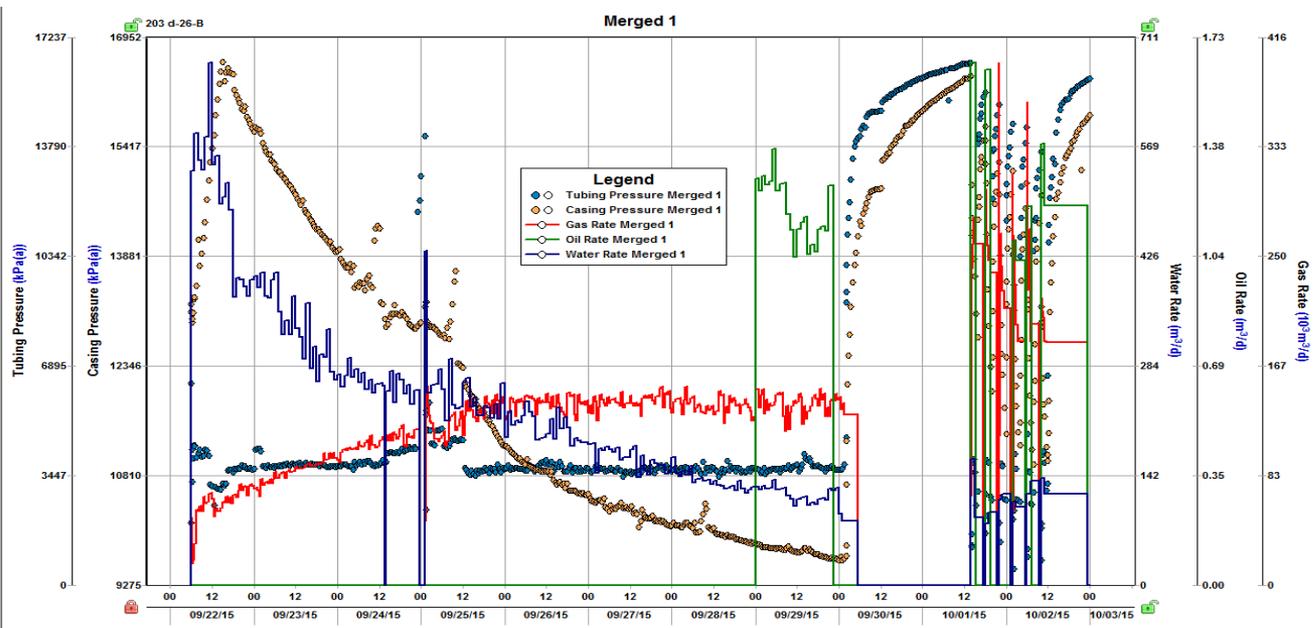


Source: National Energy Board

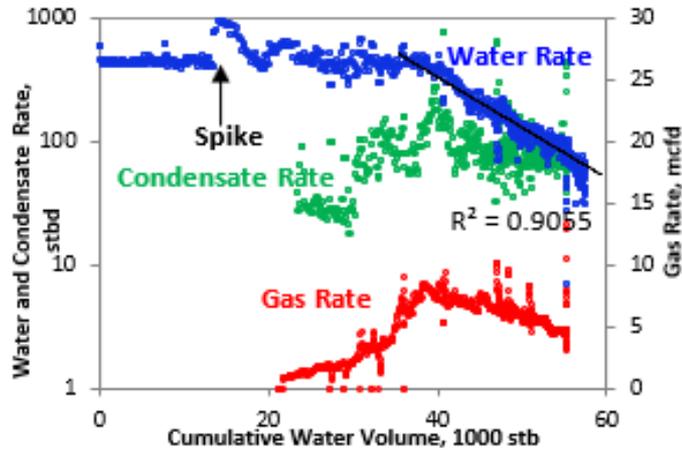


Harmonic Flowback Plot (Semilog)

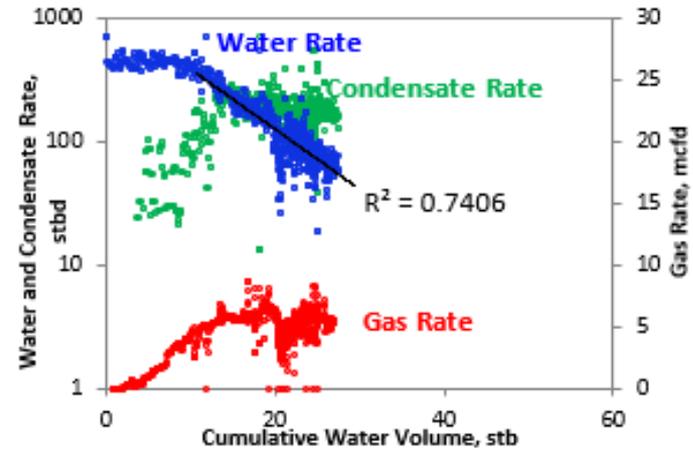




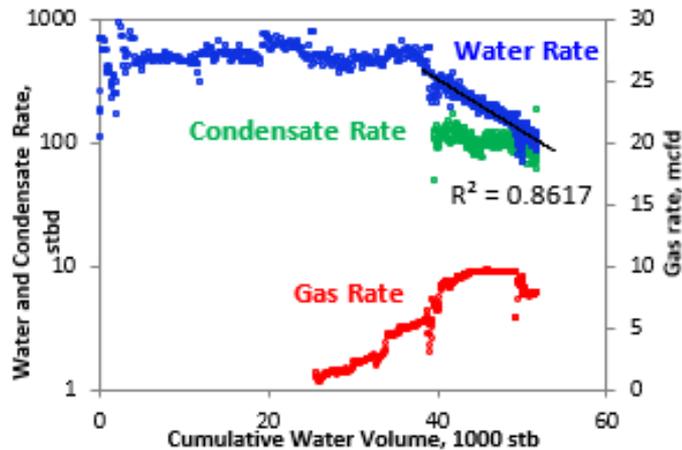
Rate-decline Analysis of 4 Gas-condensate Wells Completed in the Montney Formation



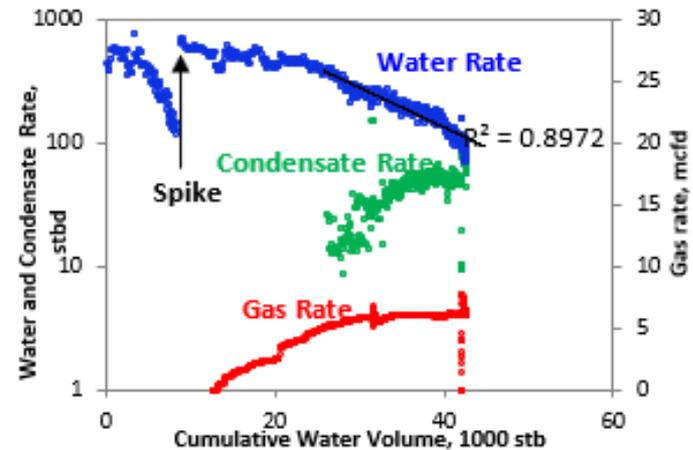
(a)



(b)



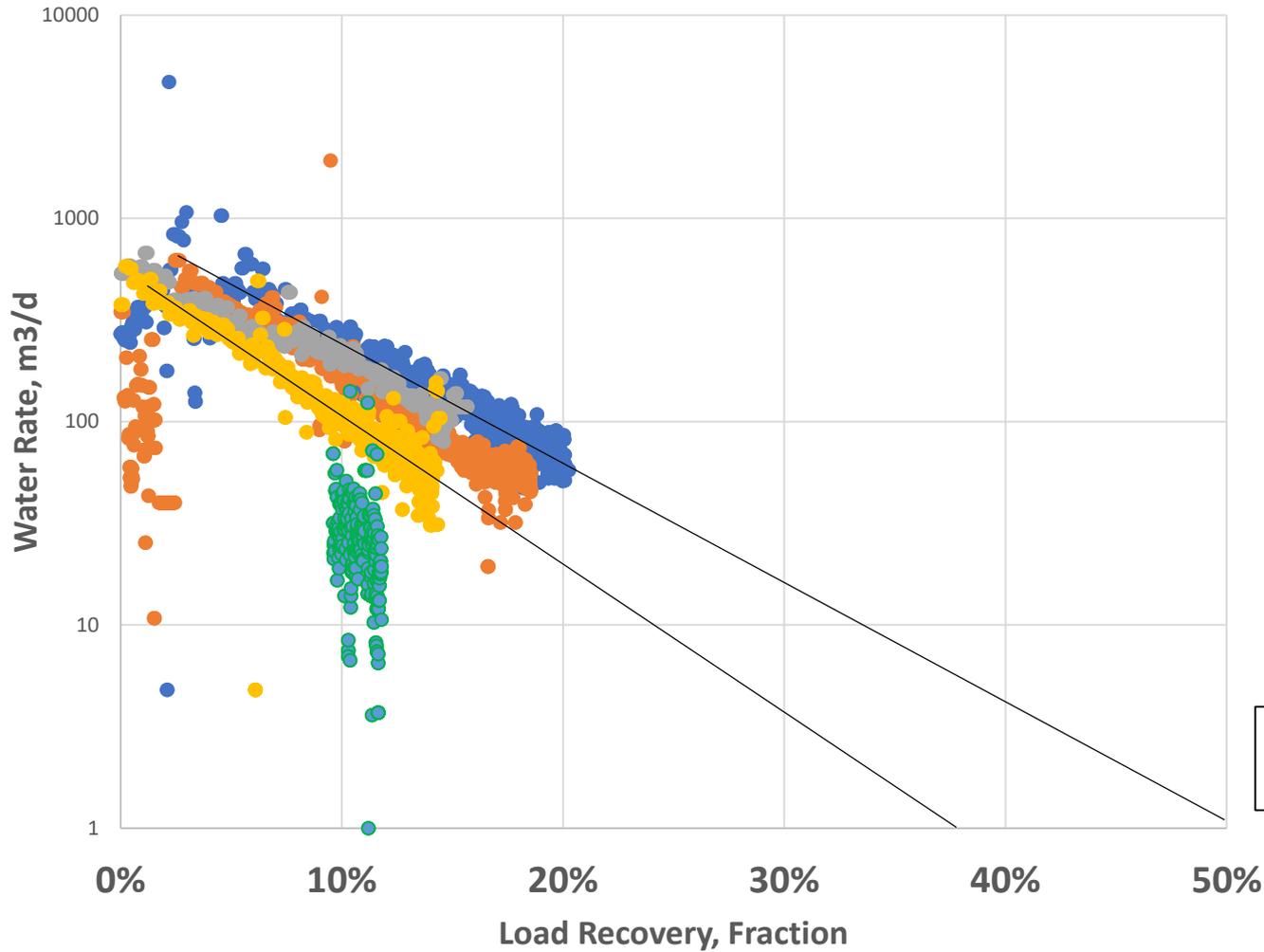
(c)



(d)

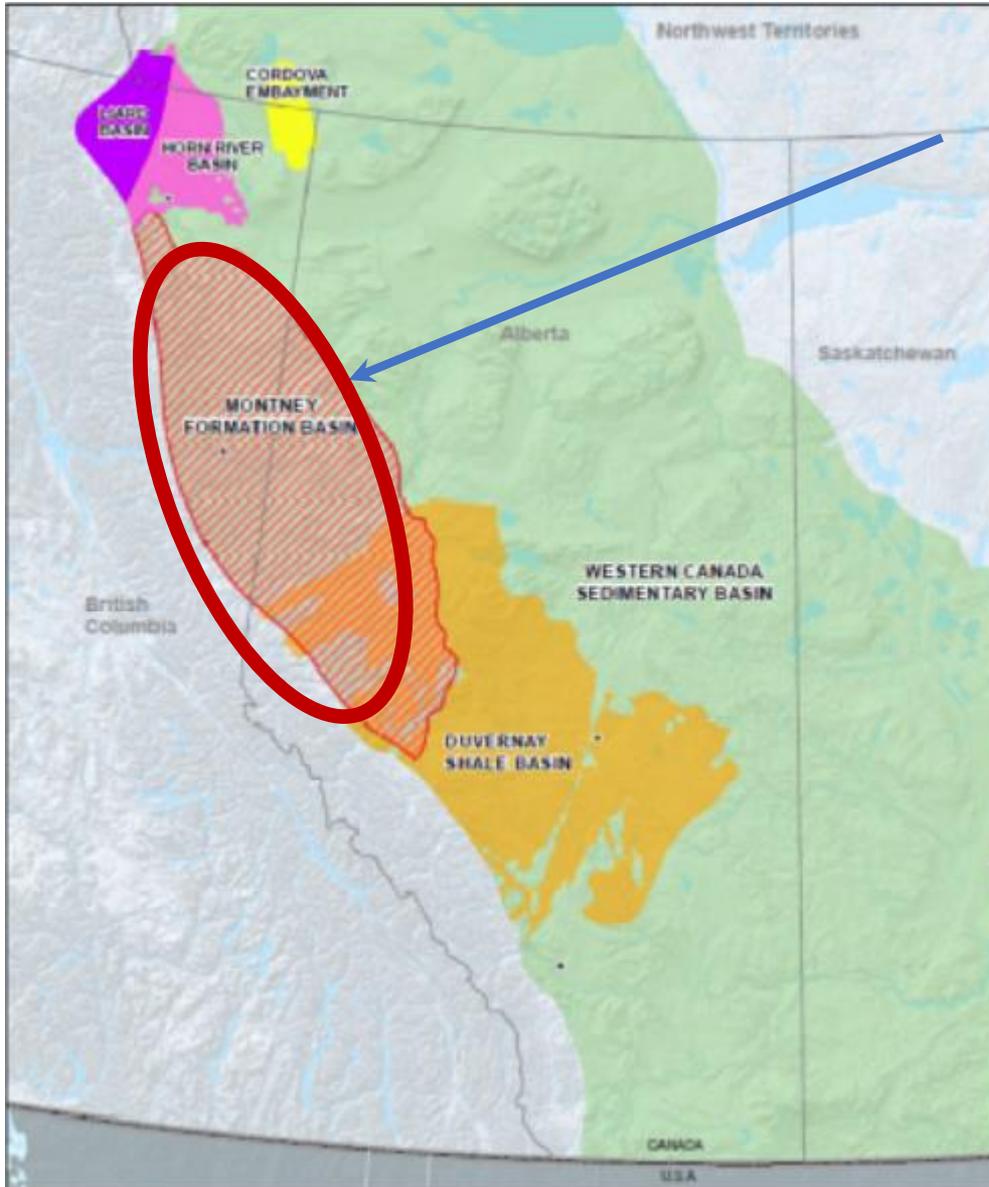
URTec 2903105

Uppr MNTN Well Review



A practical model for predicting Load Fluid Recovery.

F_L^* = Load Fluid Recovered / Injected Fluid Volume



Montney Tight Oil Field Observation

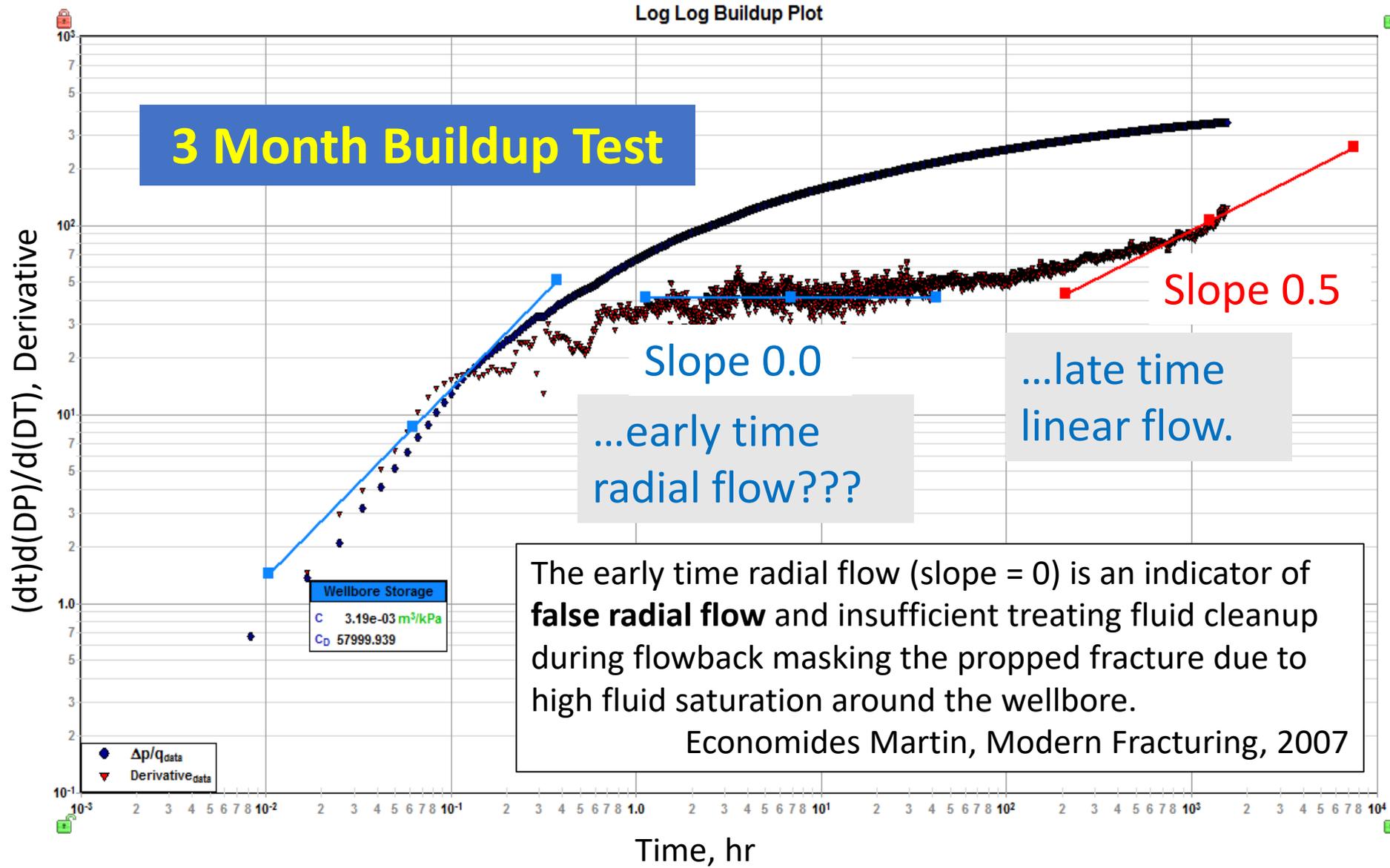
30 Stage N2 Slick Water

50m (165 ft spacing)

100 tonne/stage

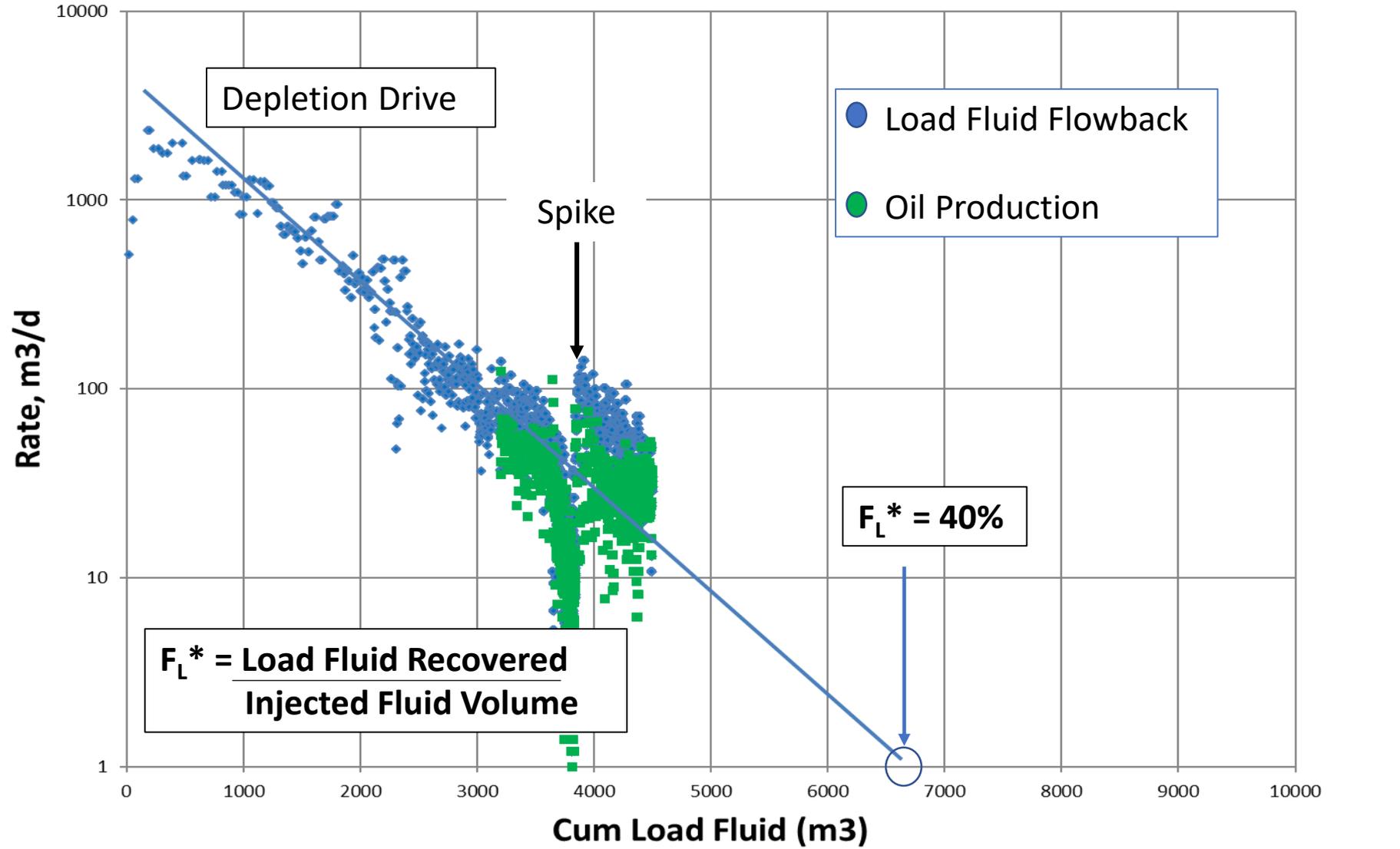
**Injected 16,390m³
(103,100 bbl) of water**

Montney Tight Oil



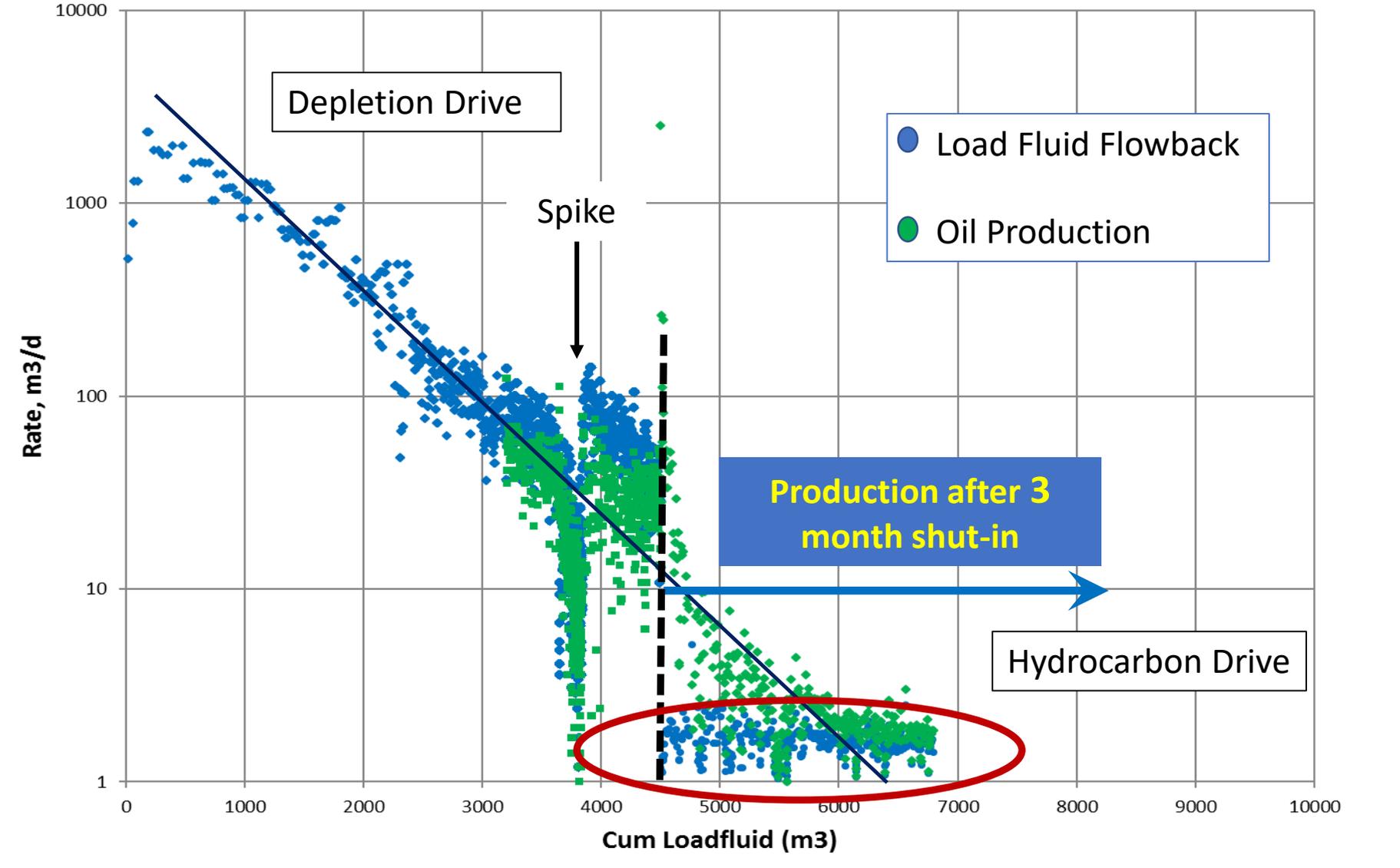
Montney Tight Oil

Load Fluid Recovery Plot



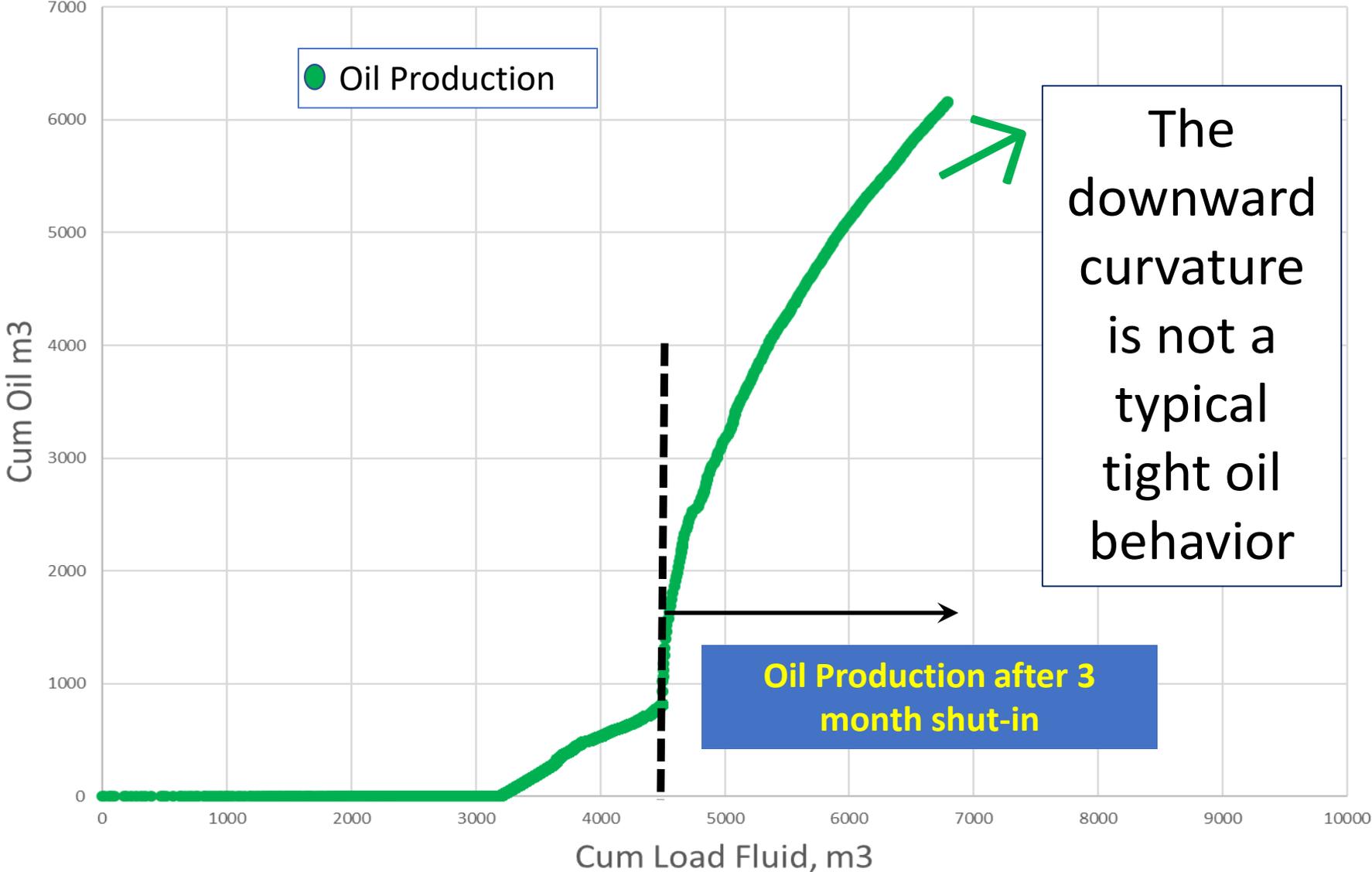
Montney Tight Oil

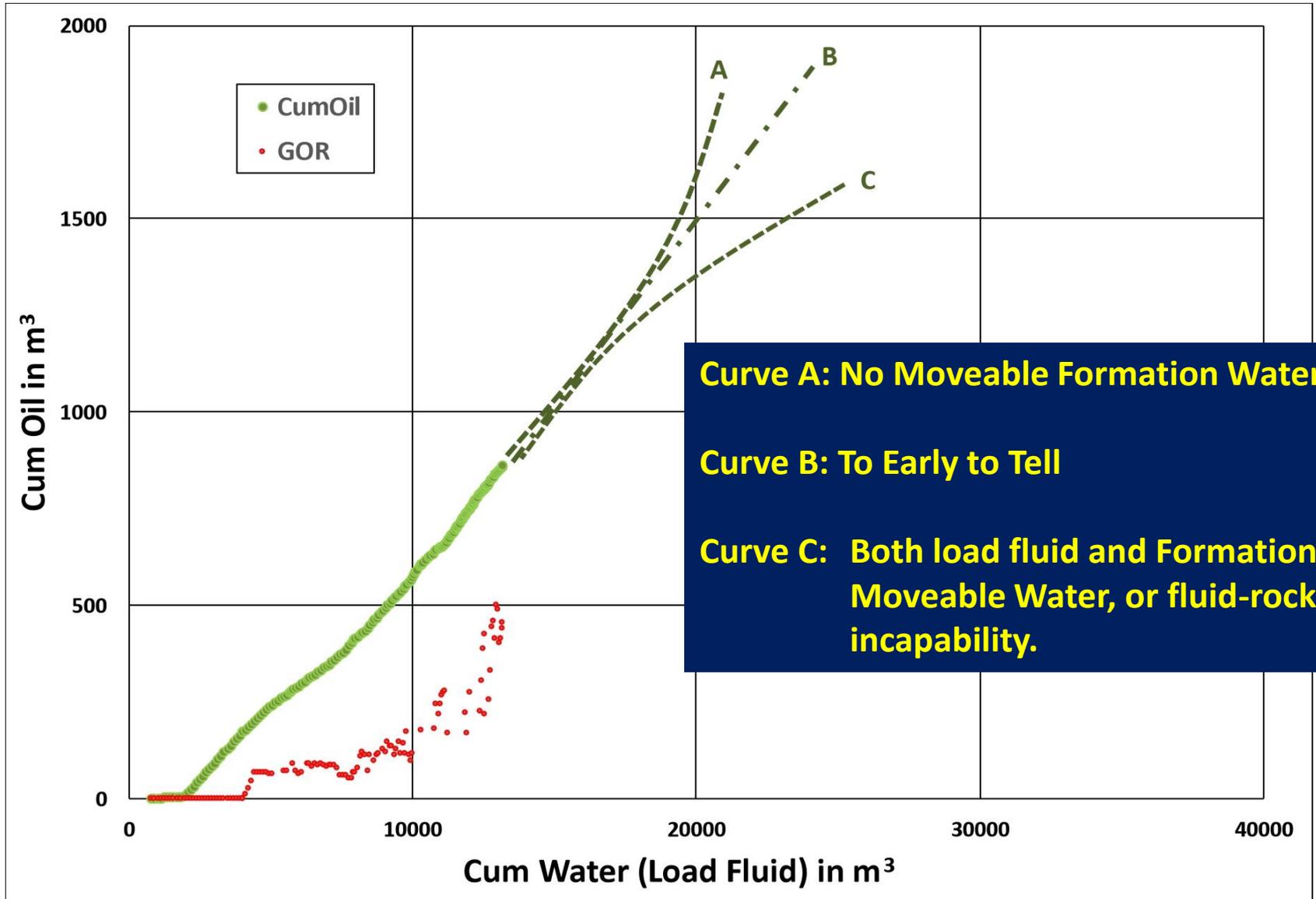
Loadfluid Recovery Plot

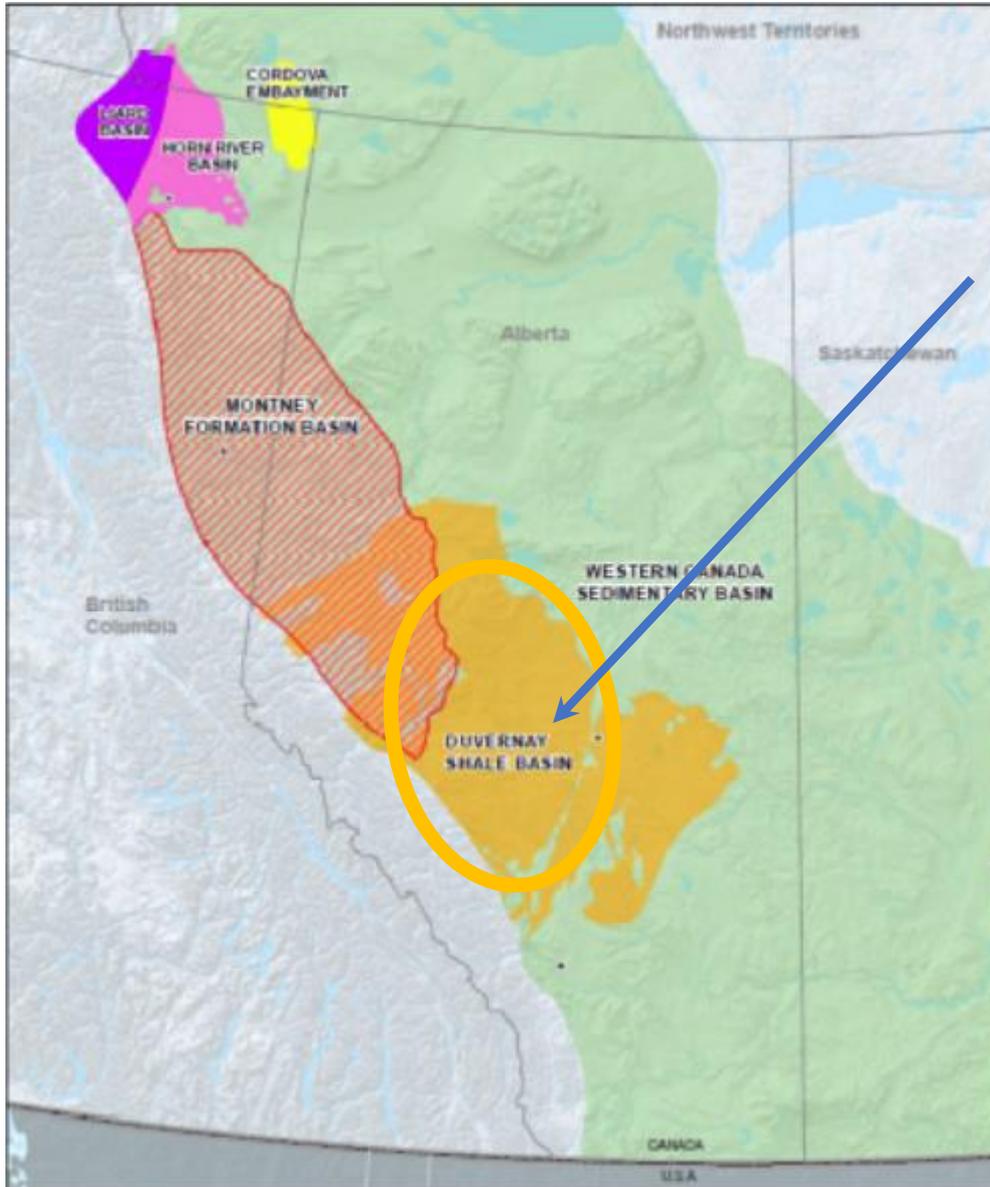


Montney Tight Oil

Cum Oil vs Cum Load Fluid







West Duvernay Shale

Field Observation

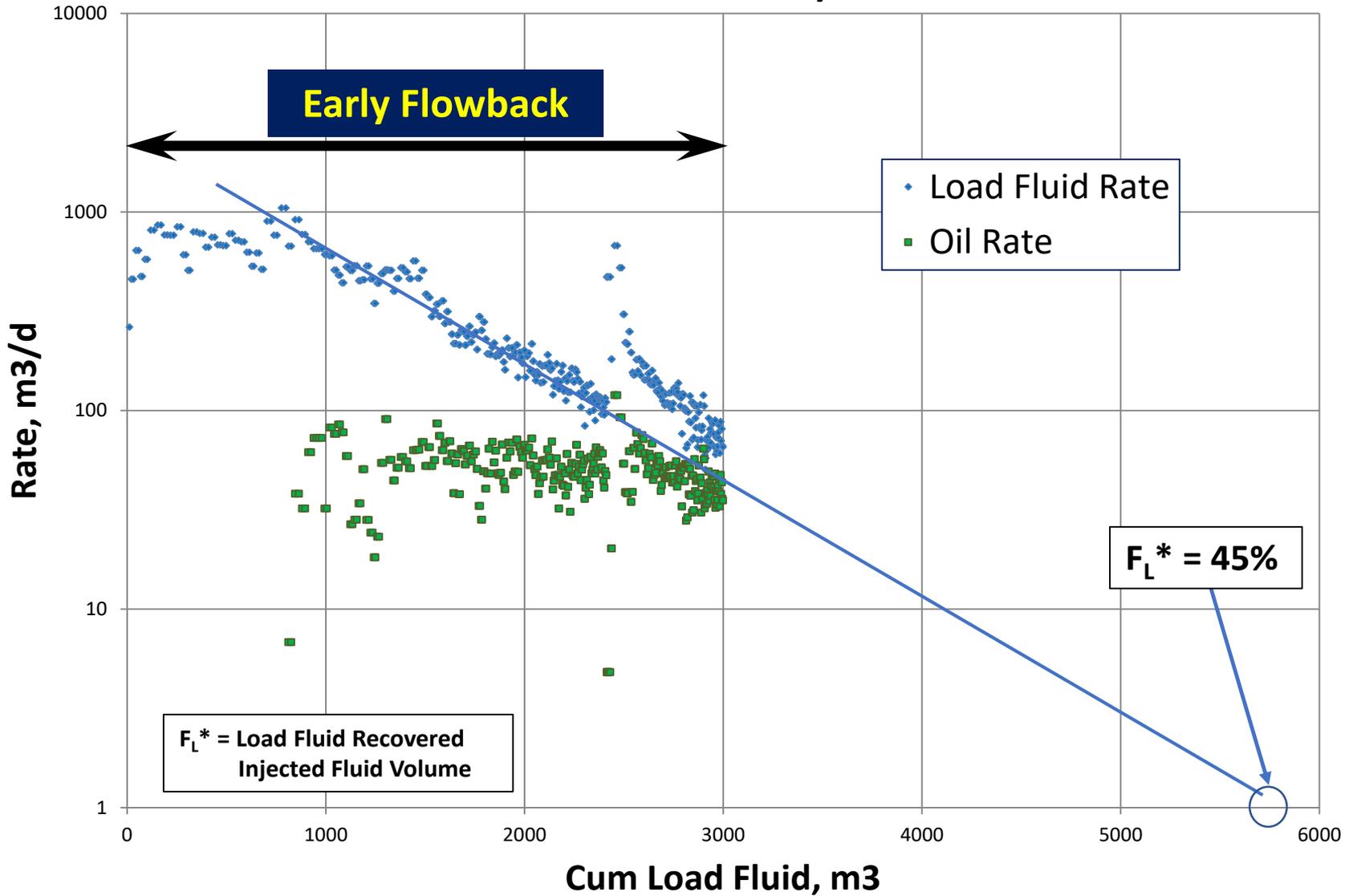
The Duvernay Shale is a distant cousin to the Utica Shale of NE USA



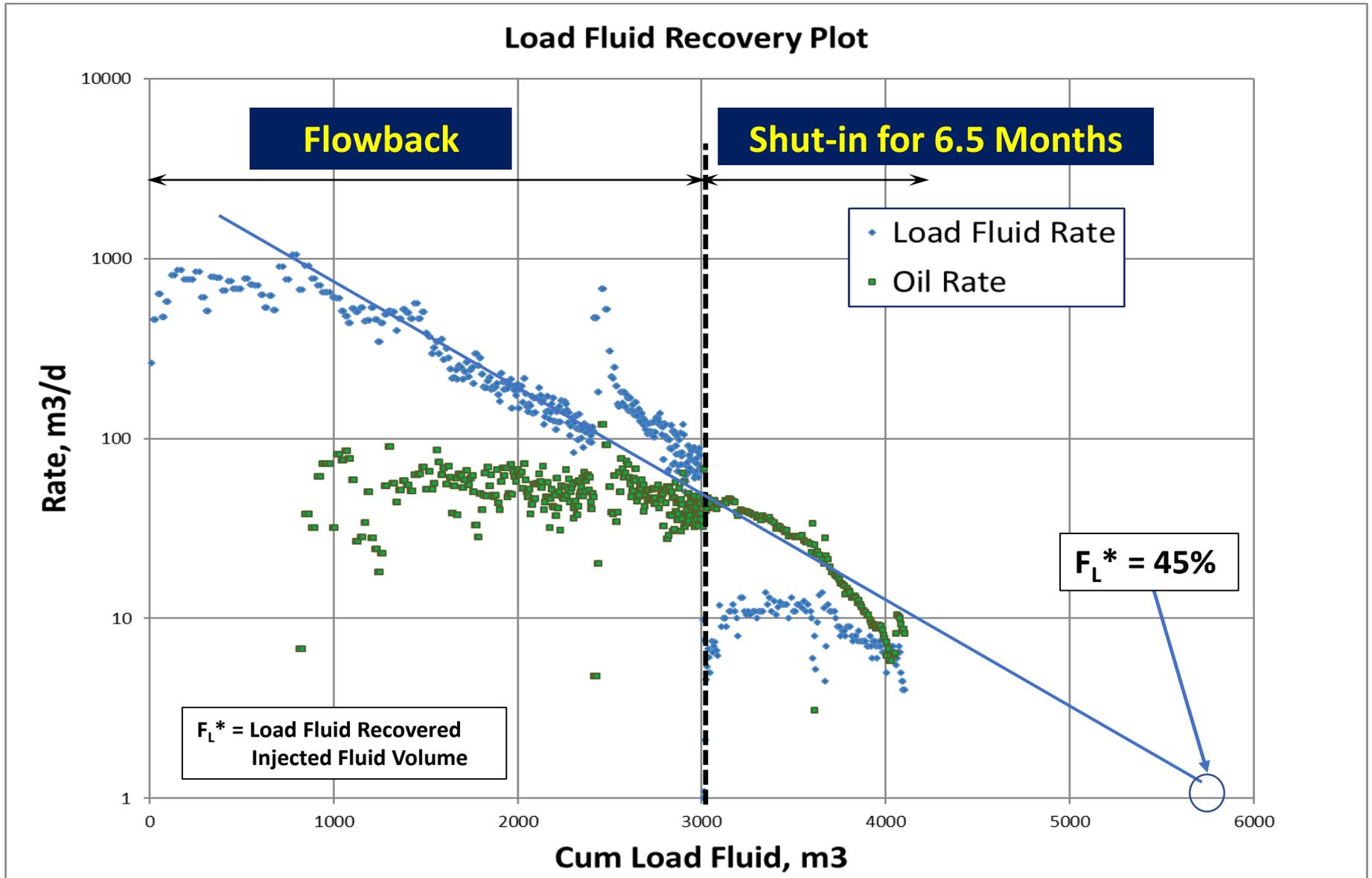
Source: National Energy Board

West DUVERNAY EXAMPLE

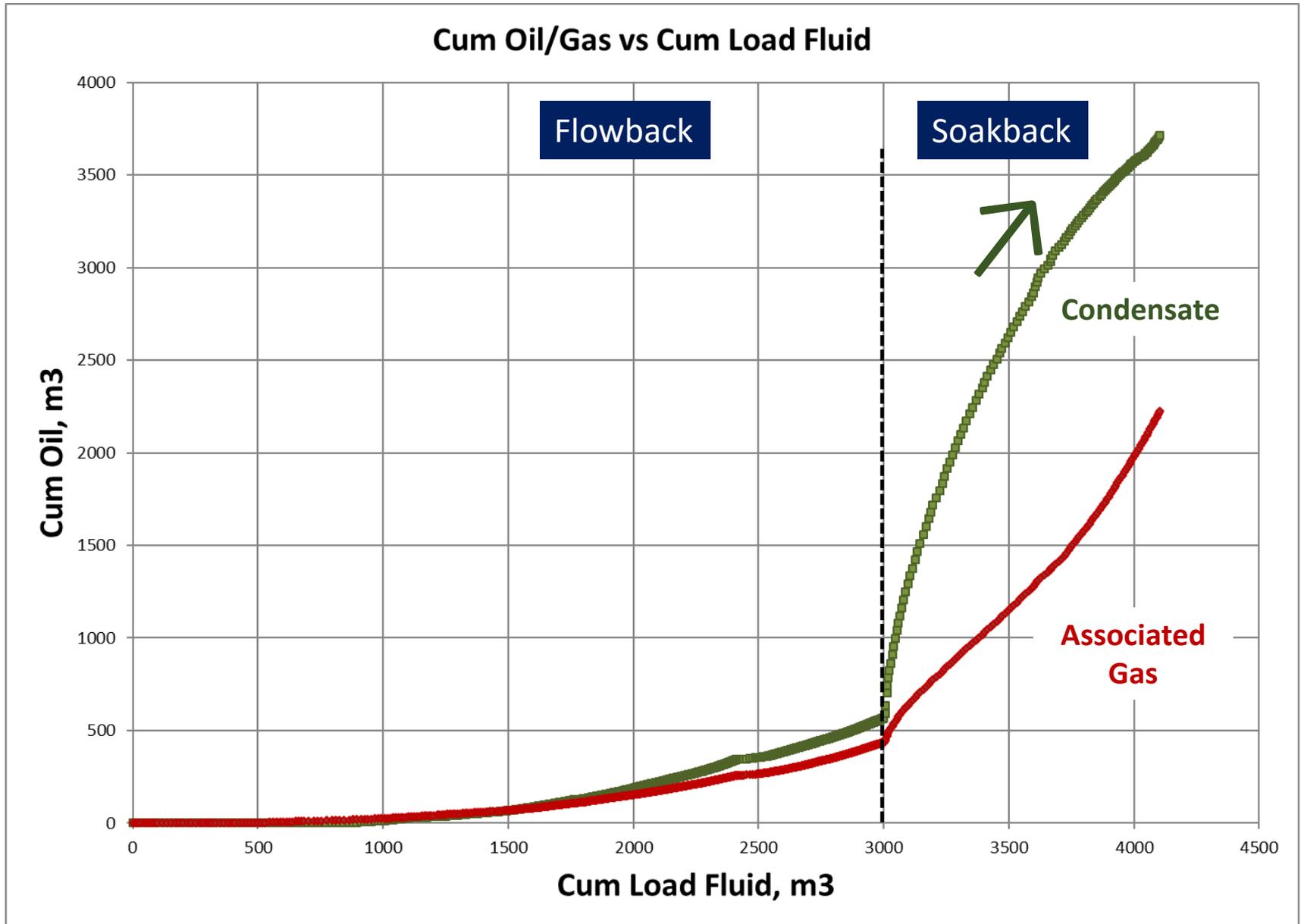
Load Fluid Recovery Plot

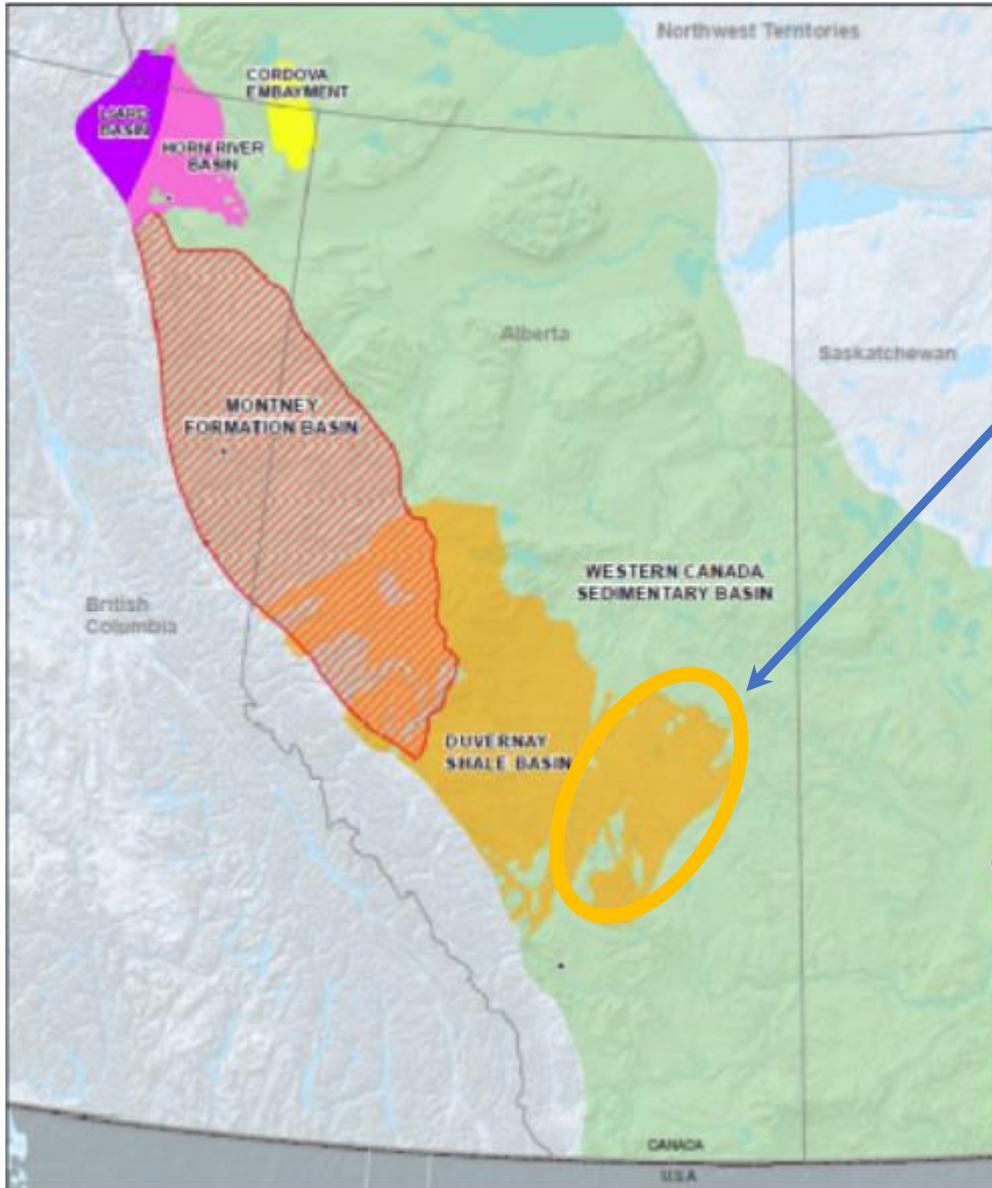


West DUVERNAY EXAMPLE



West DUVERNAY EXAMPLE





**East Duvernay
Oil Shale**

**Analogous to
Eagleford**

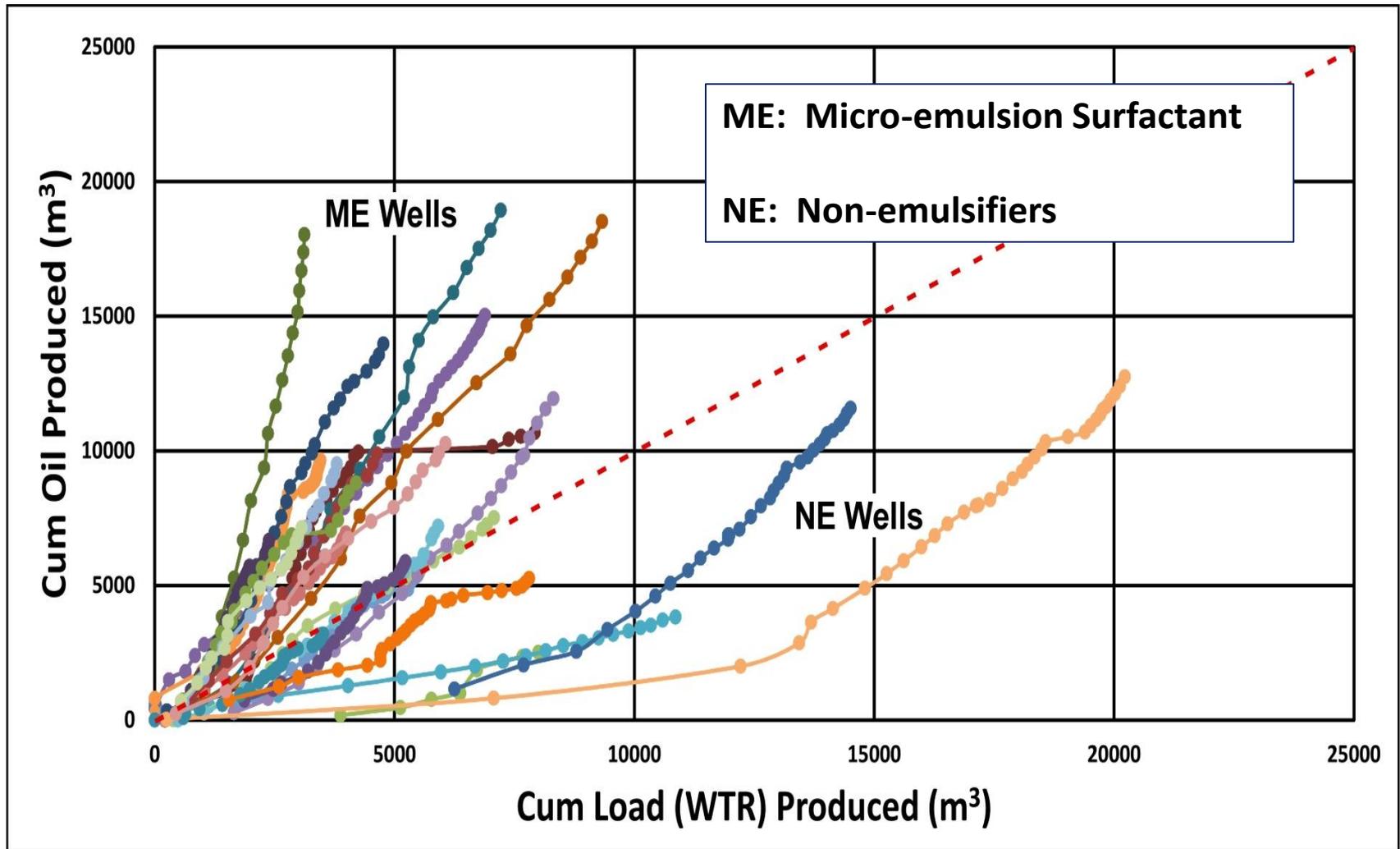
Field Observation

East Duvernay Oil Shale Completion

Hz Multi-Stage Fractured Wells

Construction	Cased Hole –5.5” Csg
TVD	7,200 ft
Lateral Length	8,200 ft
# of Stages	Early on 12 now > 55
Frac Method	Plug ‘n’ Perf
Fluid Type	Slick Water/Hybrid
Typical Fluid Vol	310,000 early on now >500,000 bbls
Typical Proppant	40/70, 1 – 2 lb/gal

Cum Oil vs Cum Load Fluid Recovery

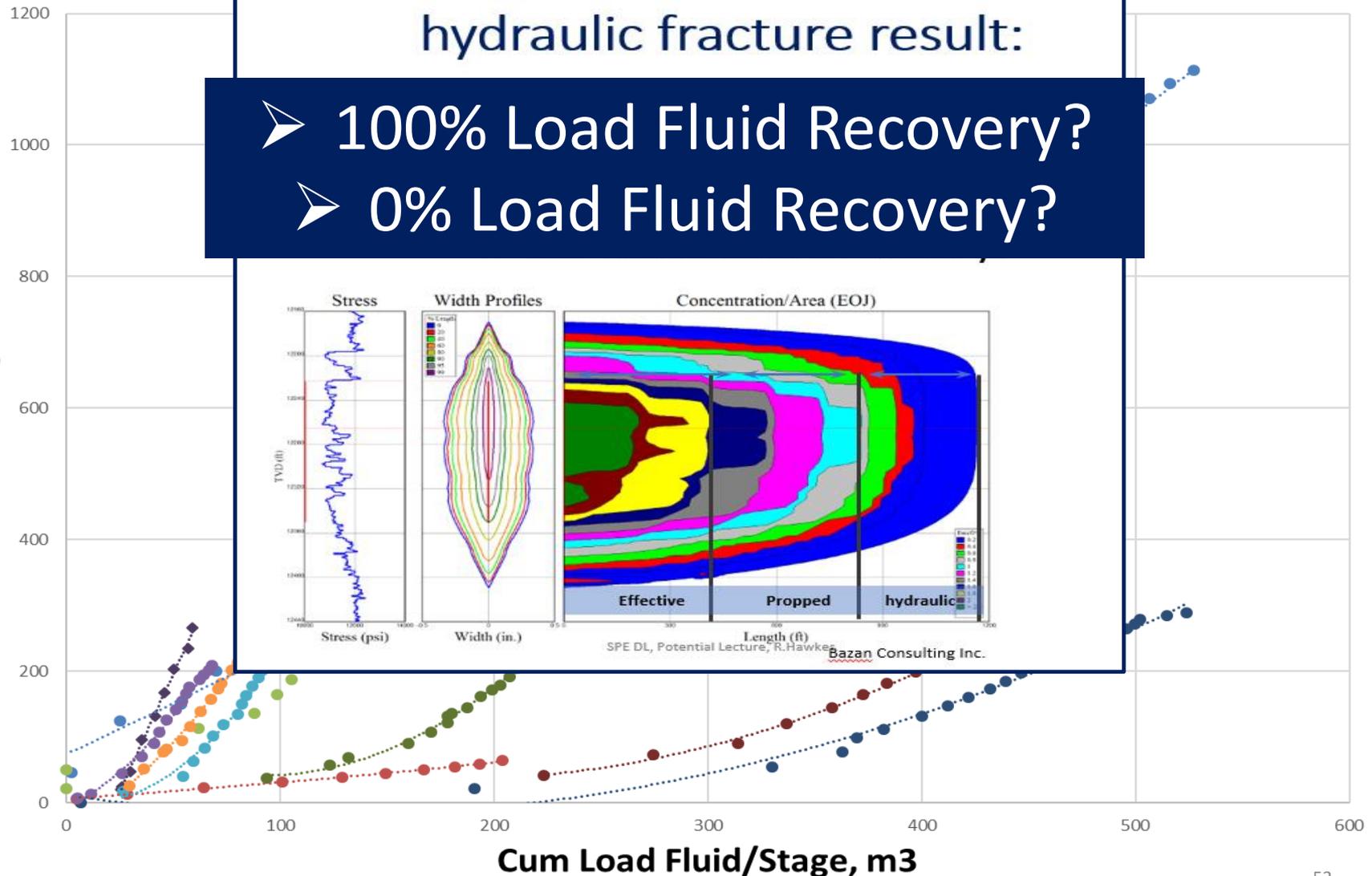


Cum Oil/Stage vs Cum Load Fluid Recovery

What is *YOUR* idealized hydraulic fracture result:

- 100% Load Fluid Recovery?
- 0% Load Fluid Recovery?

Cum Oil/Stage, m3



Summary Comments



1. Flowback analysis can either be quantitative or qualitative, depending on your a) tool box, b) assumptions and c) data set.
2. Soaking allows for dissipation of water into the matrix and unpropped fractures to help “suck-in” the water and (can) allow for higher peak hydrocarbon rates.
3. Construction of Load Fluid Recovery diagnostic plots helps in understanding fluid-rock interaction in unconventional reservoirs.



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ATCE

SPE Calgary Section

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