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Fluid Imbibition - Hydraulic Fracture Flowback Dynamics

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TRICAN

Buenos Aires
Thursday, Nov 21,2018

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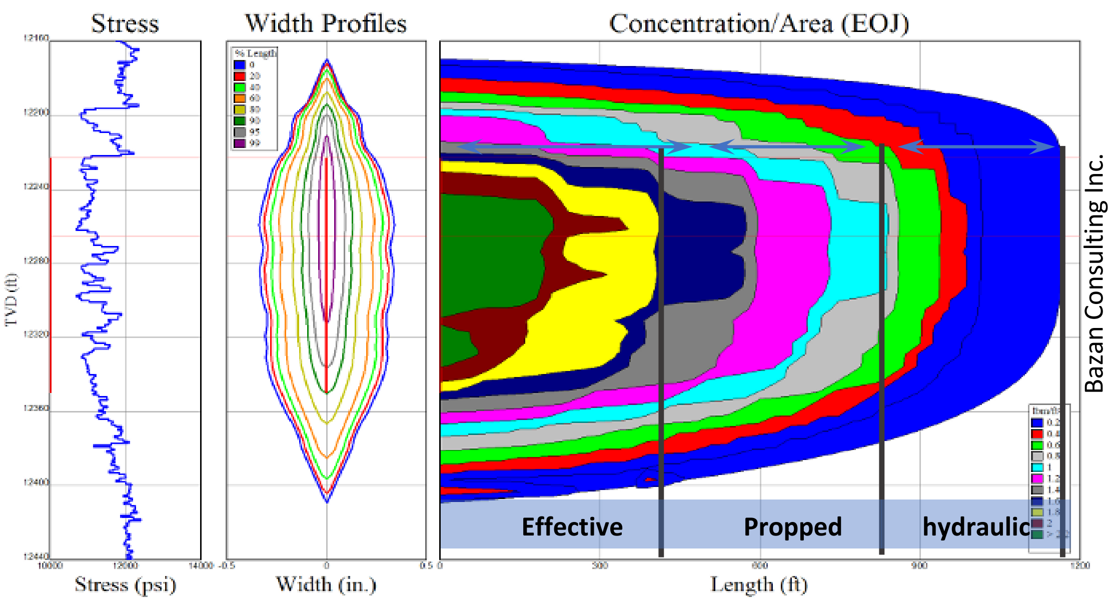
What is *YOUR* idealized hydraulic fracture result:

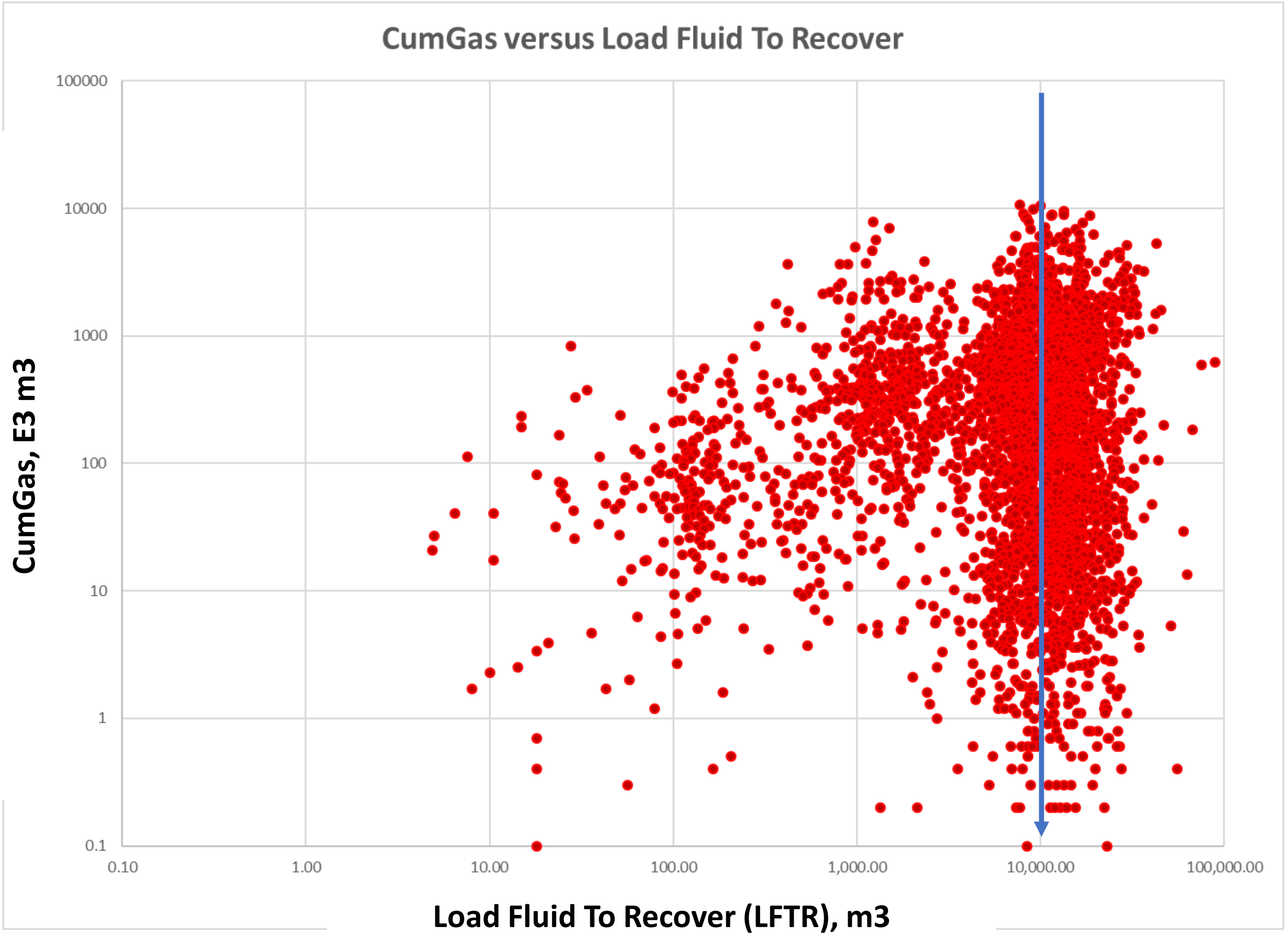
- 100% Load Fluid Recovery?

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?

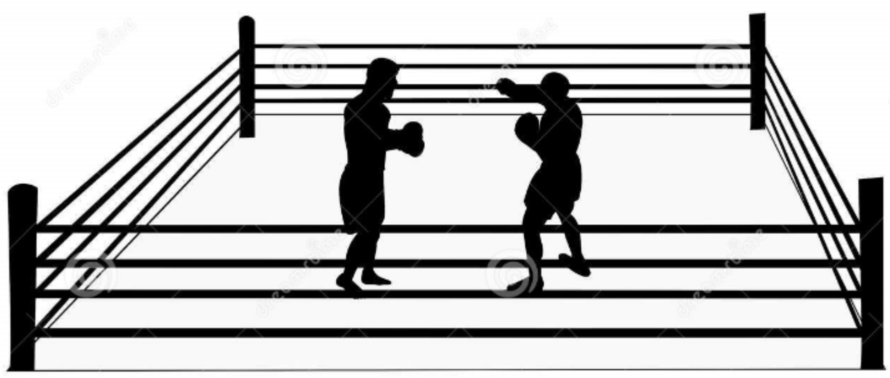
Does extended shut-in time improve hydrocarbon productivity?

Where did all the Frac water go?

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

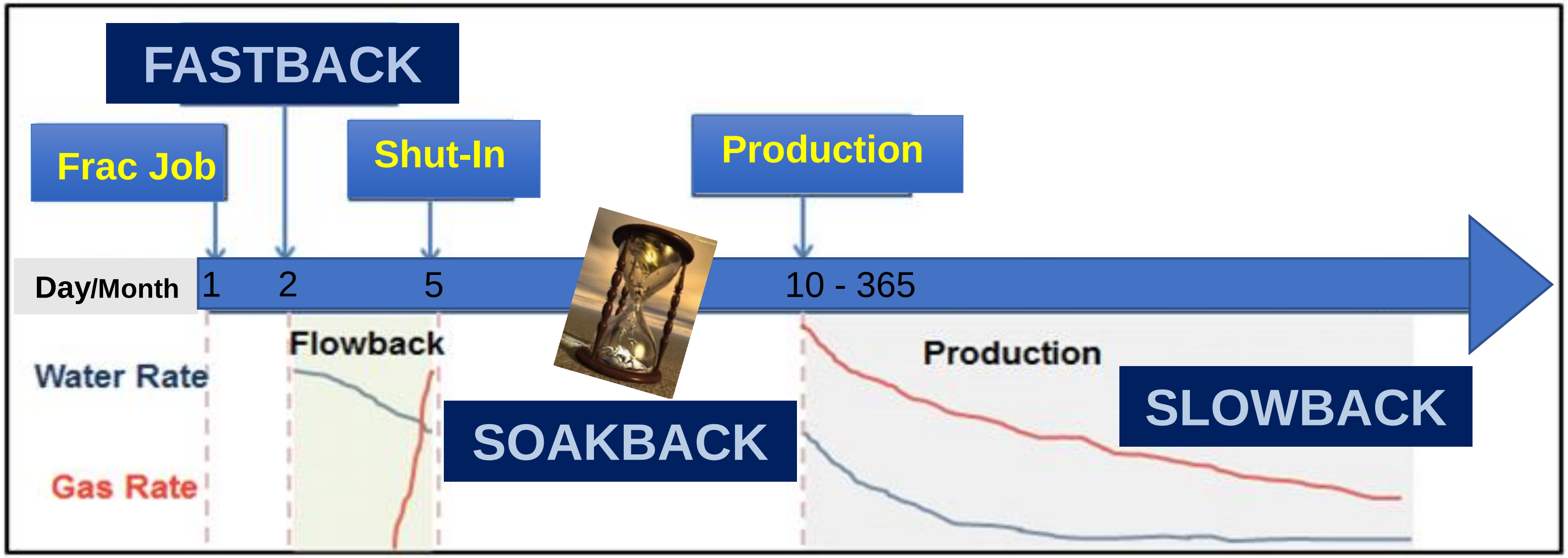
Production Delays and Extended Shut-ins
What is an engineer to do?

Flowback as
soon as possible



Take your Time

Hydraulic Fracture Flowback Dynamics



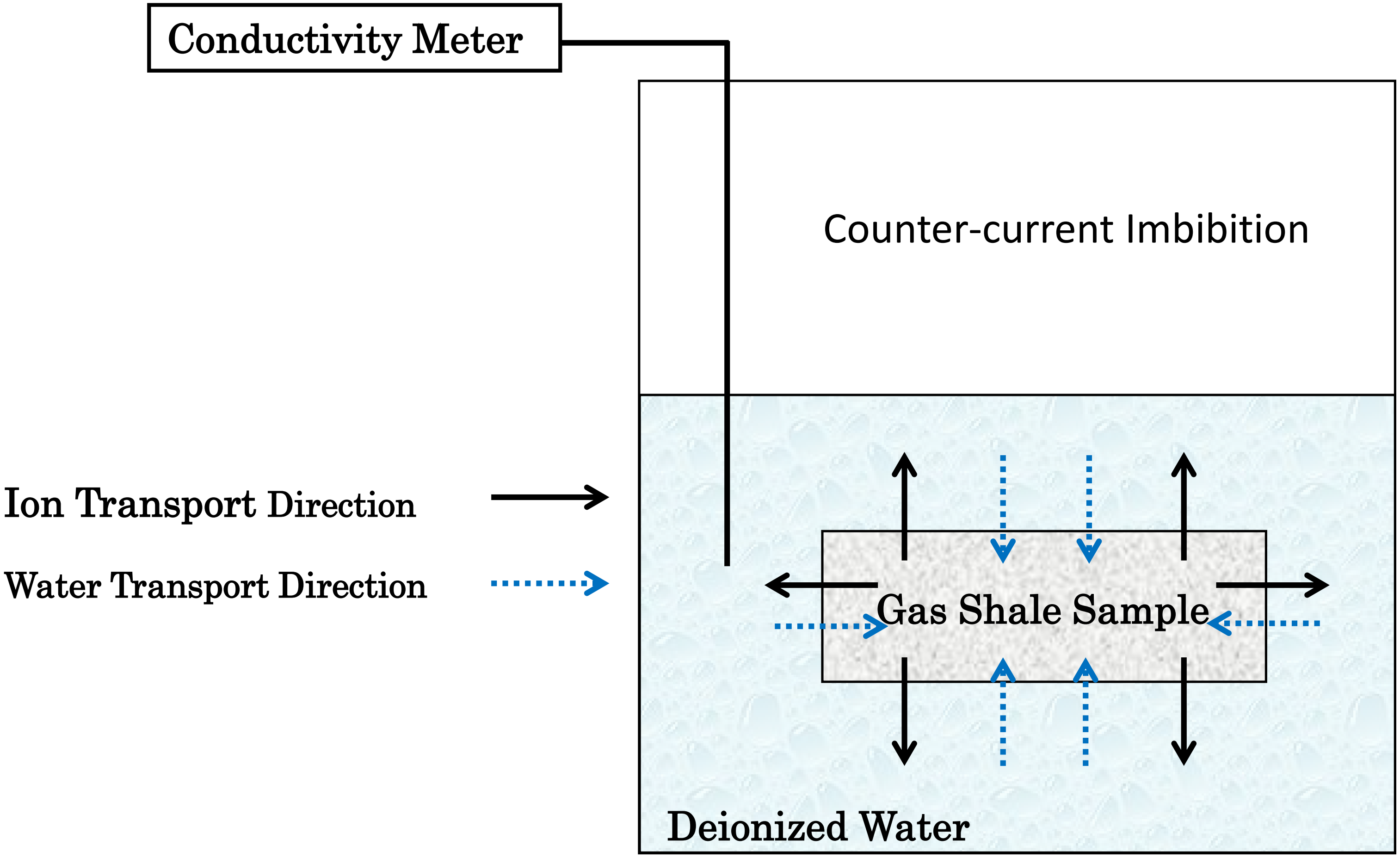
Modified from SPE 166279

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

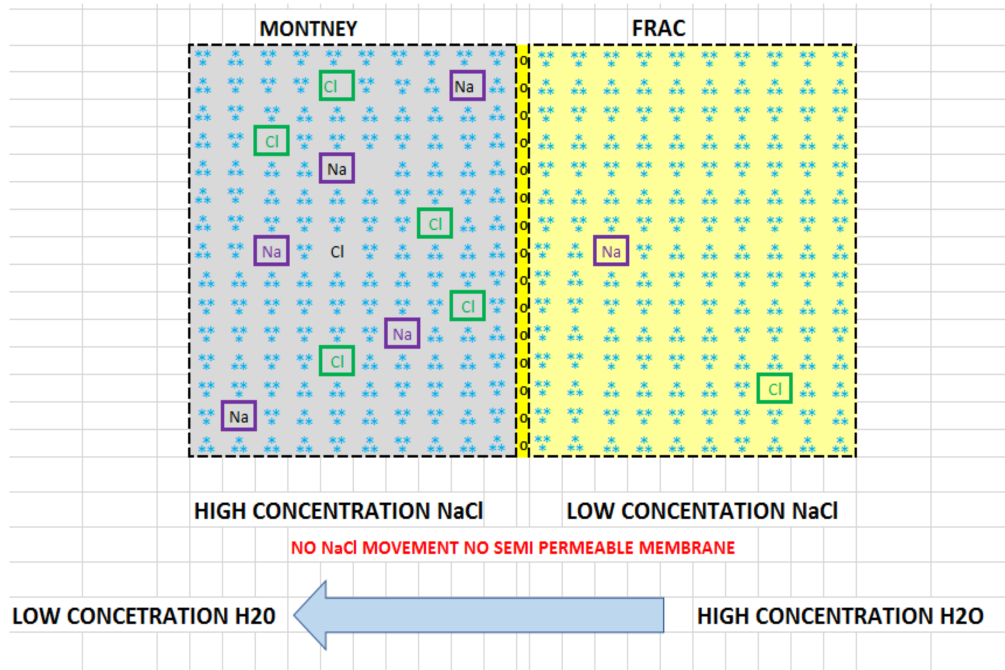


SPE-167165

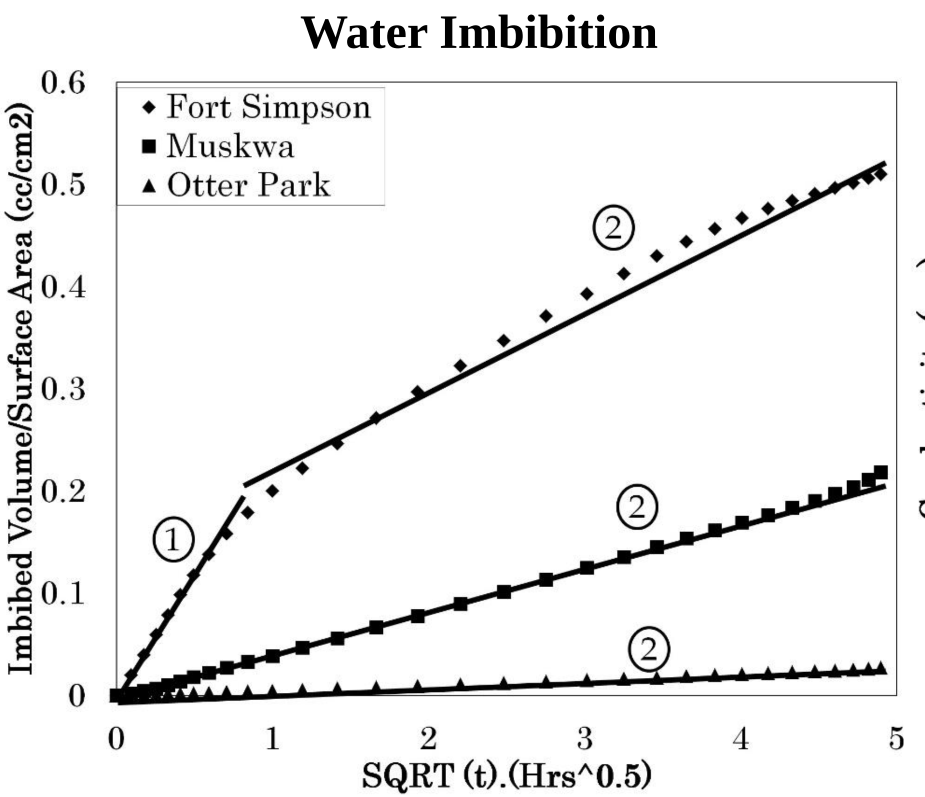
Obs 1: Water Imbibition and Salt Diffusion

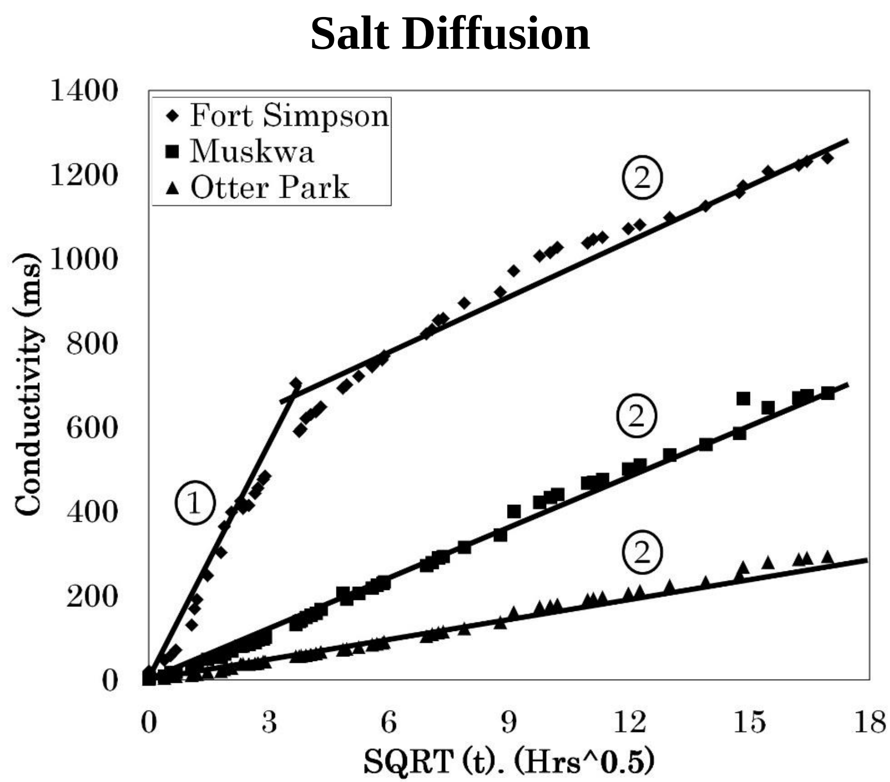
Chemical Osmosis

- 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.)





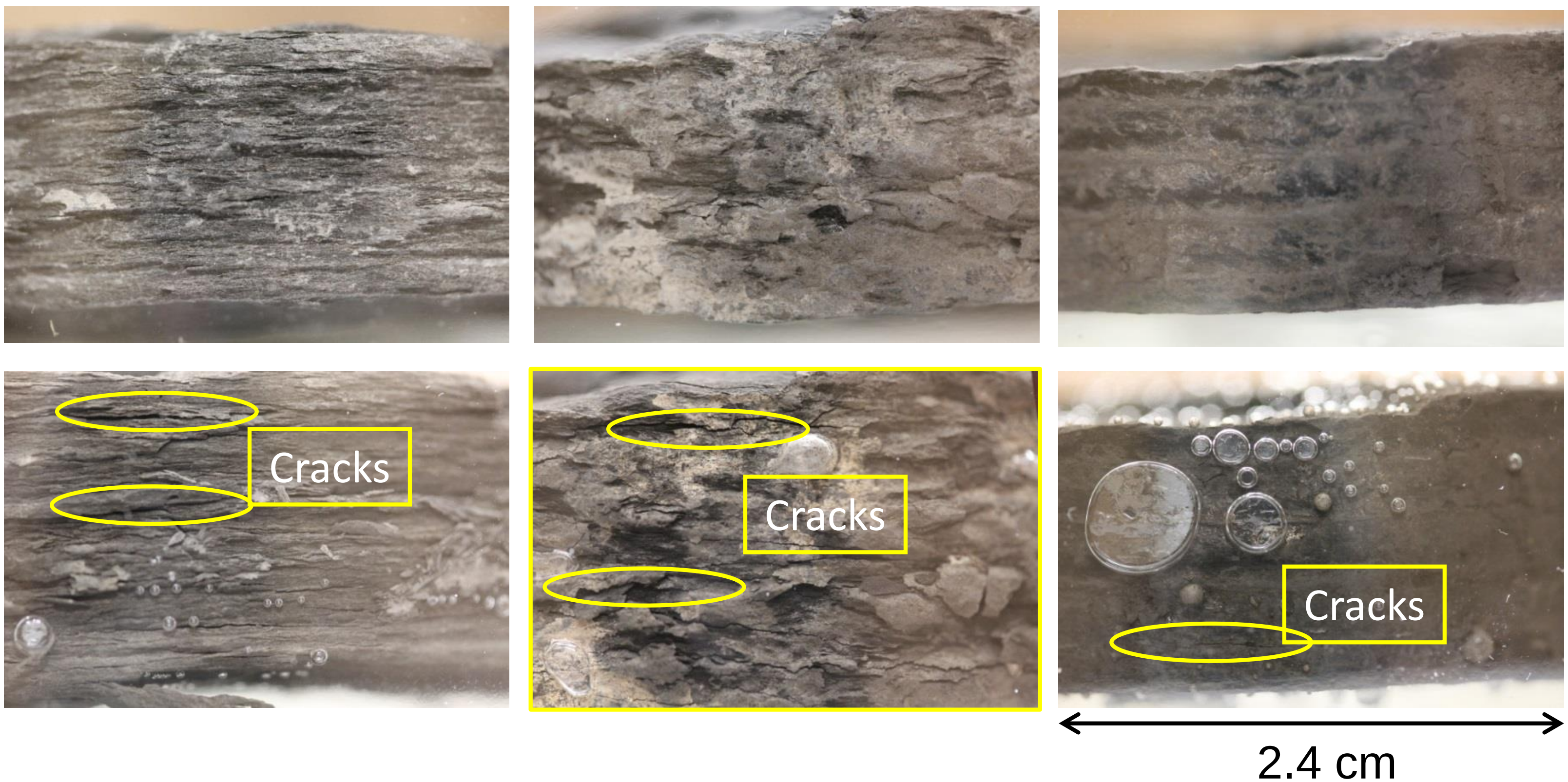
SPE-167165

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

Fort Simpson | Muskwa | Otter Park

0 Hours

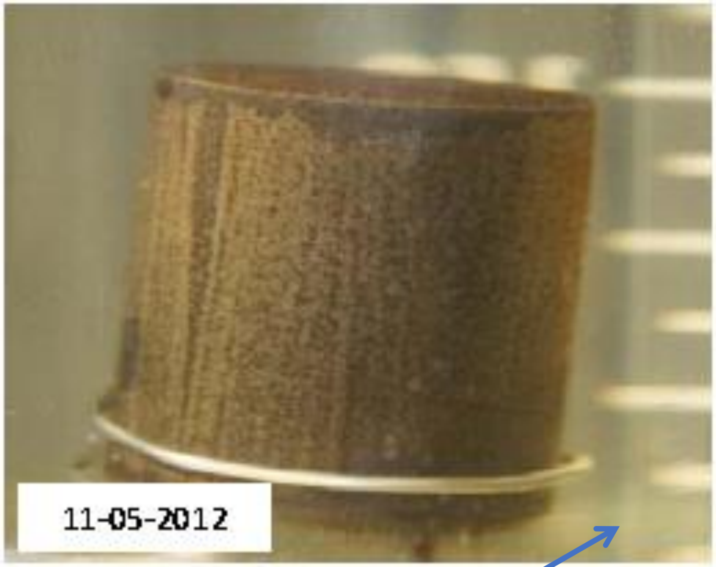
52 Hours



SPE-167165

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

Soak Time: 5 d



Soak Time: 6 d

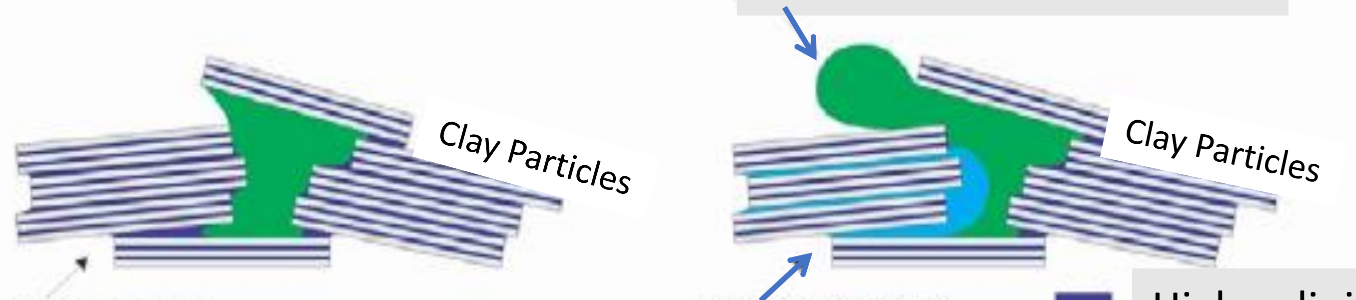
High-salinity solution

Low-salinity solution

SPE-168998

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

3) Oil is expelled due to osmotic-pressure increase



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.

High-salinity solution

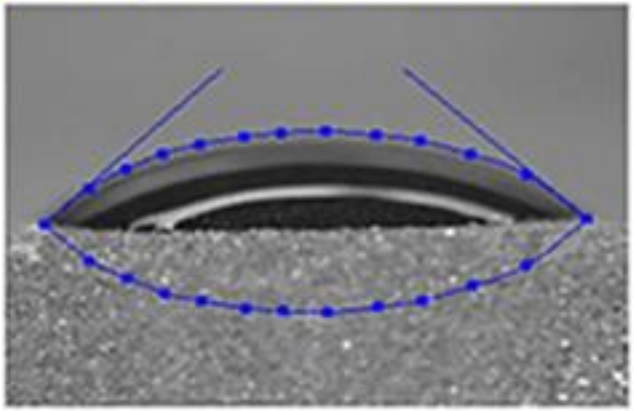
Low-salinity solution

Oil

SPE-168998

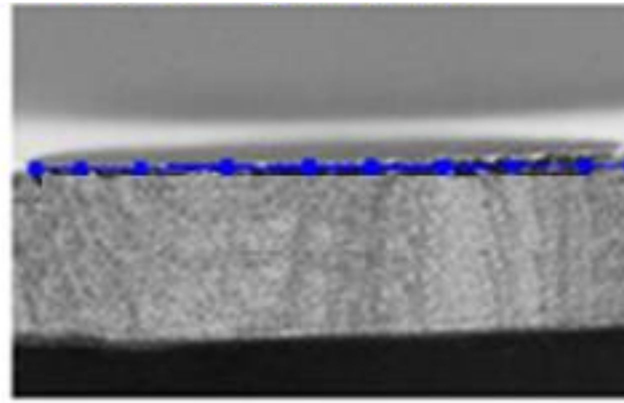
Obs 3: Mixed Wettability (Montney Core)

Water



Time

Oil

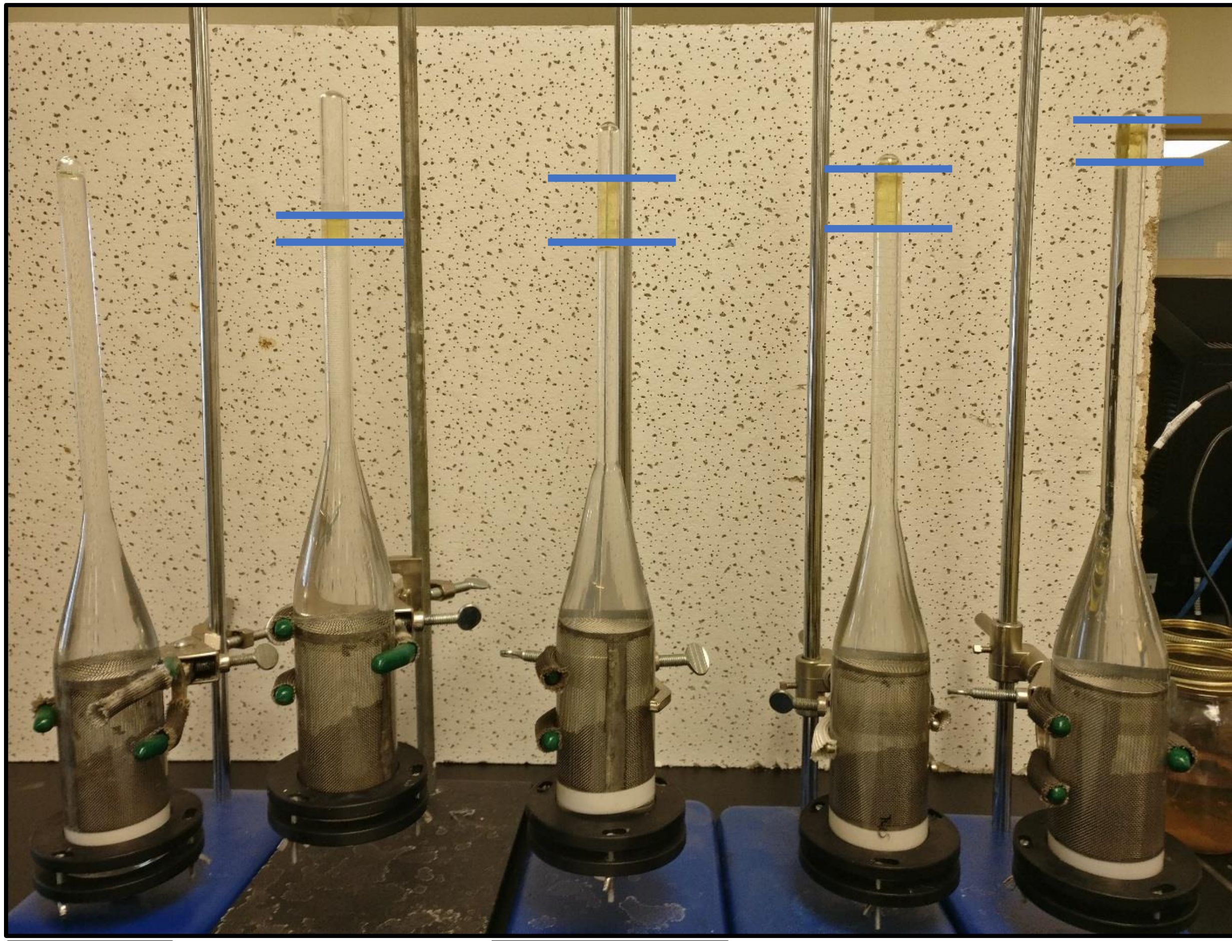


Time

University of Alberta

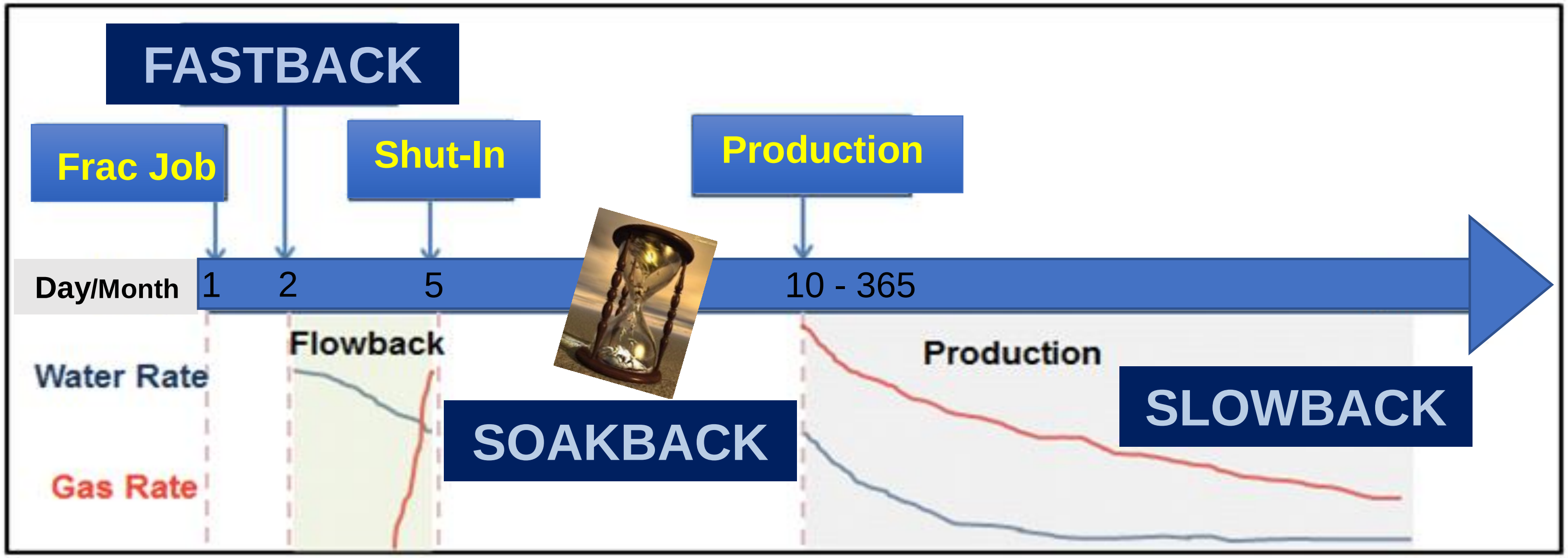
Obs 4: Amott Cell Testing

- 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

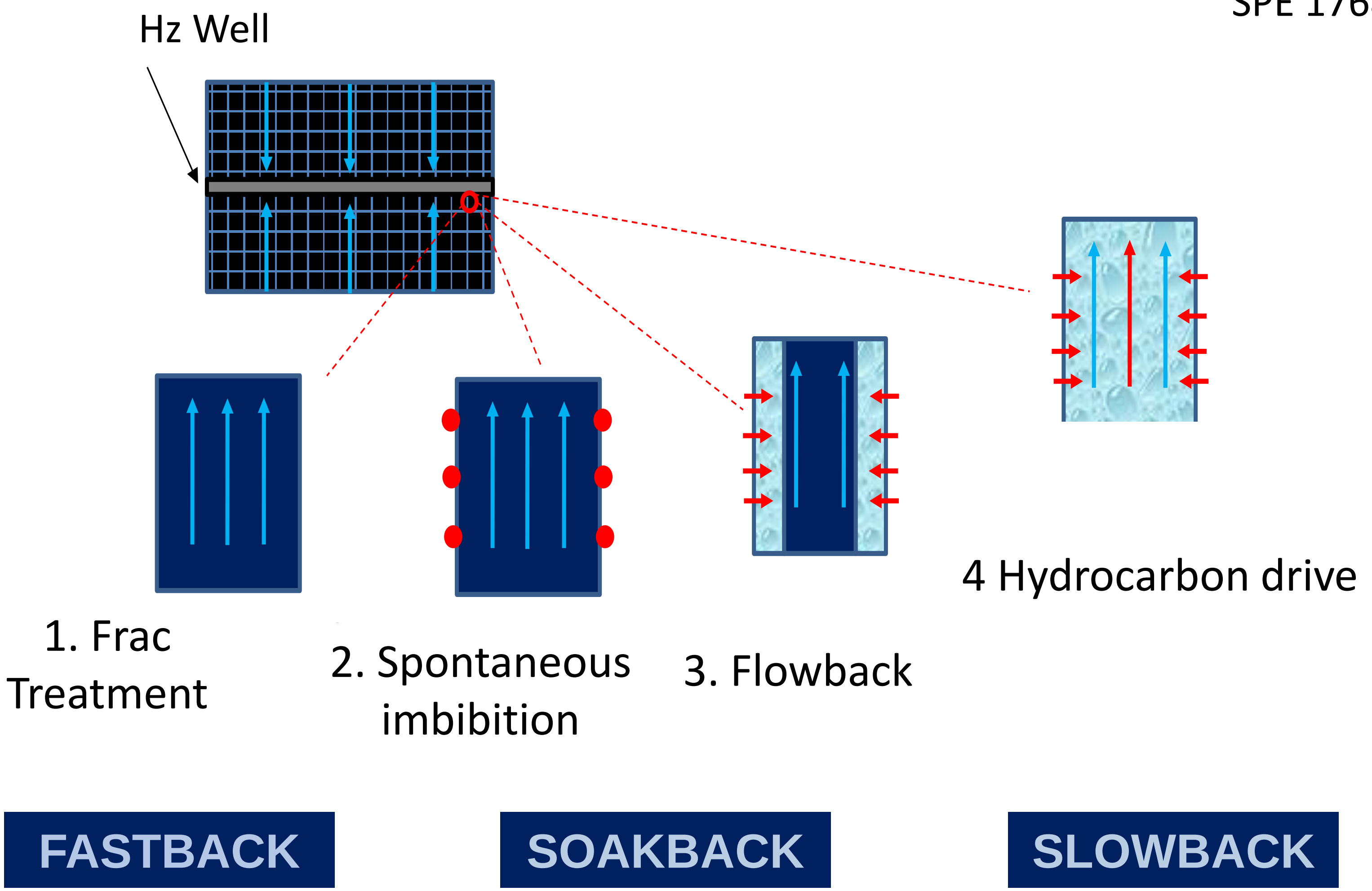
2. **DEPLETION DRIVE**
   - *Depletion drive* represents the portion of flowback recovery <u>due to water</u> drainage

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



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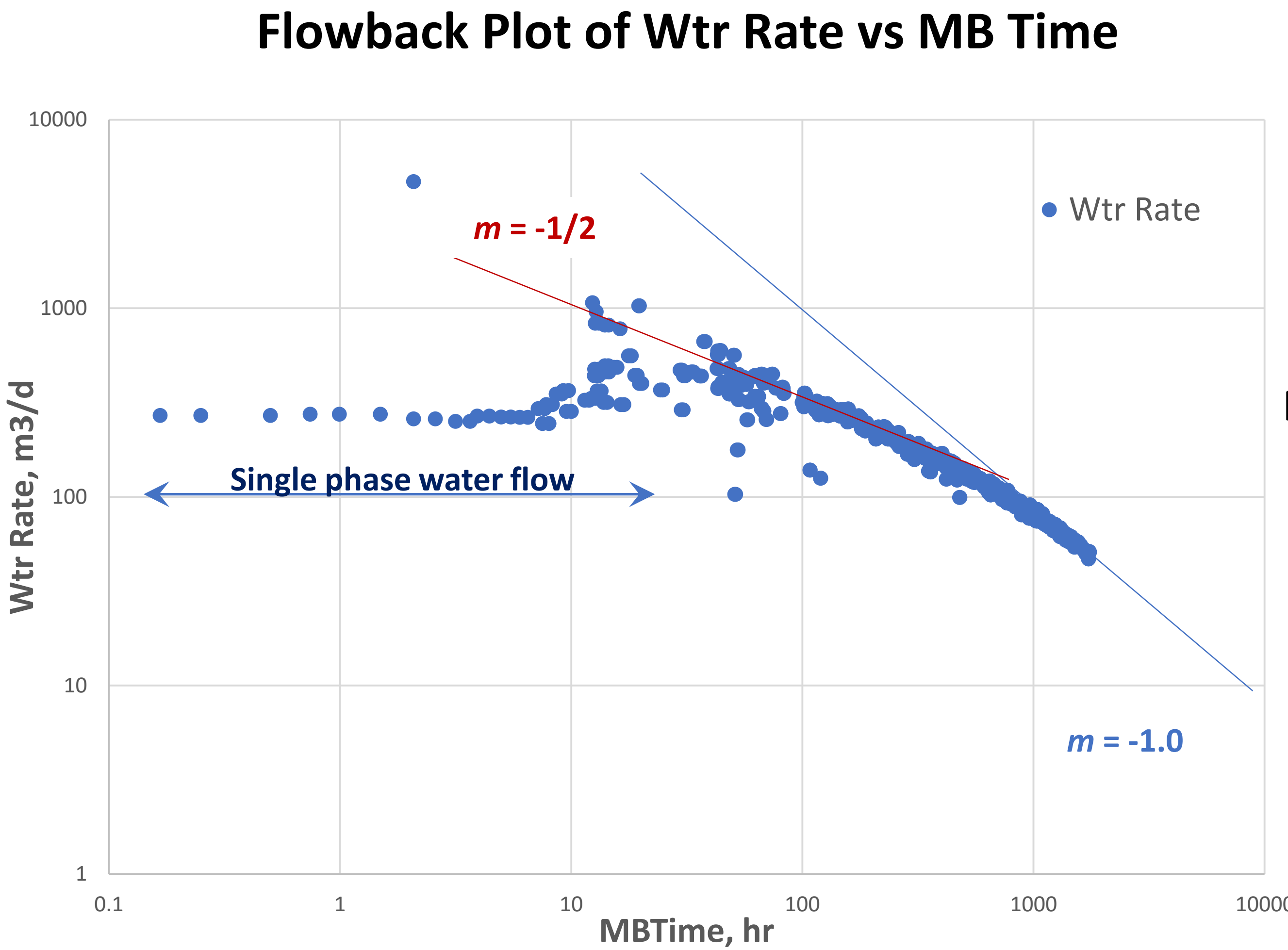
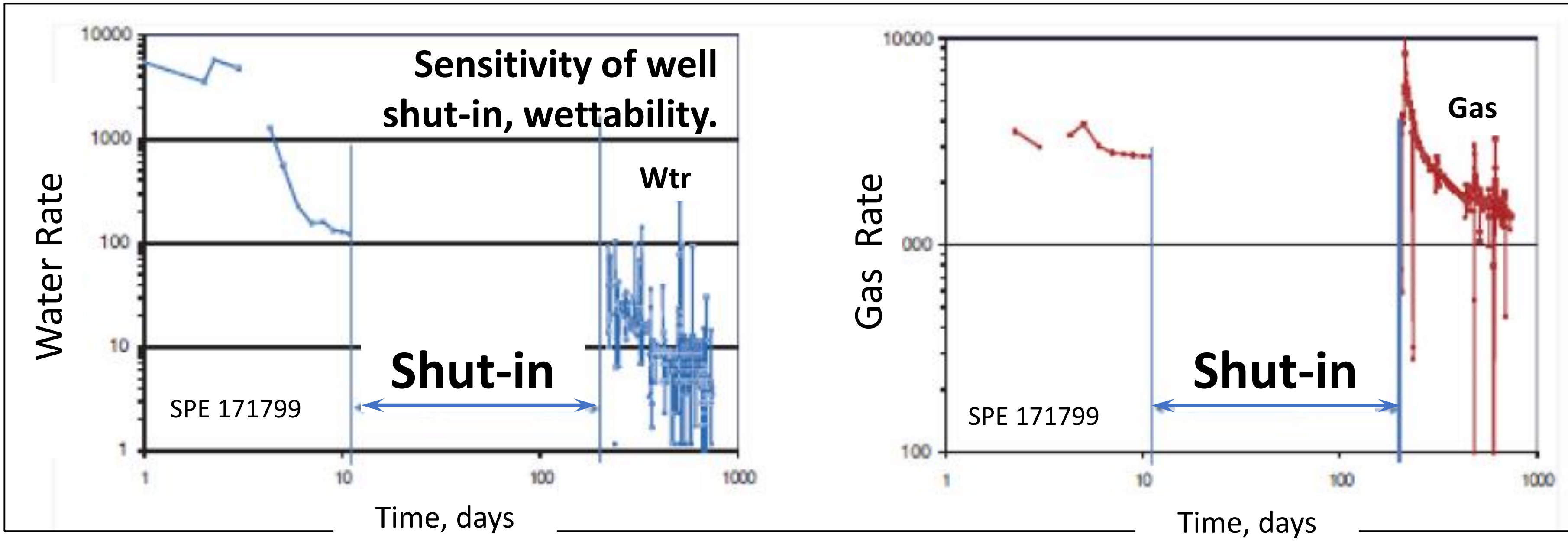
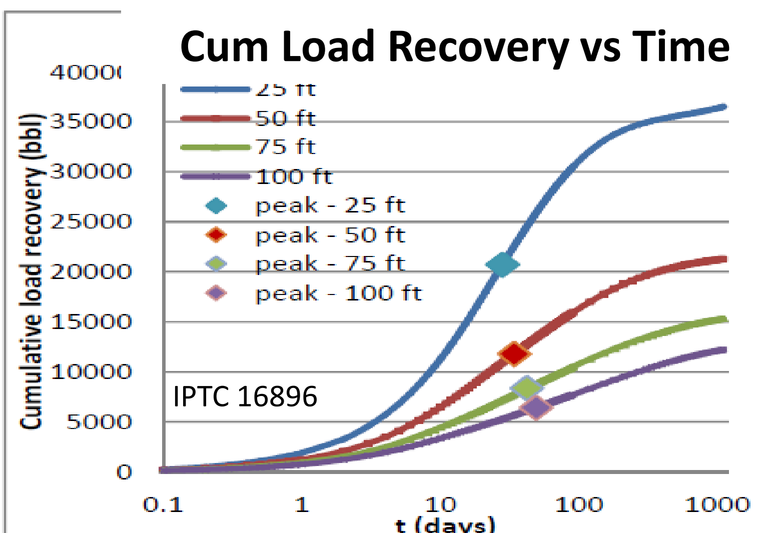
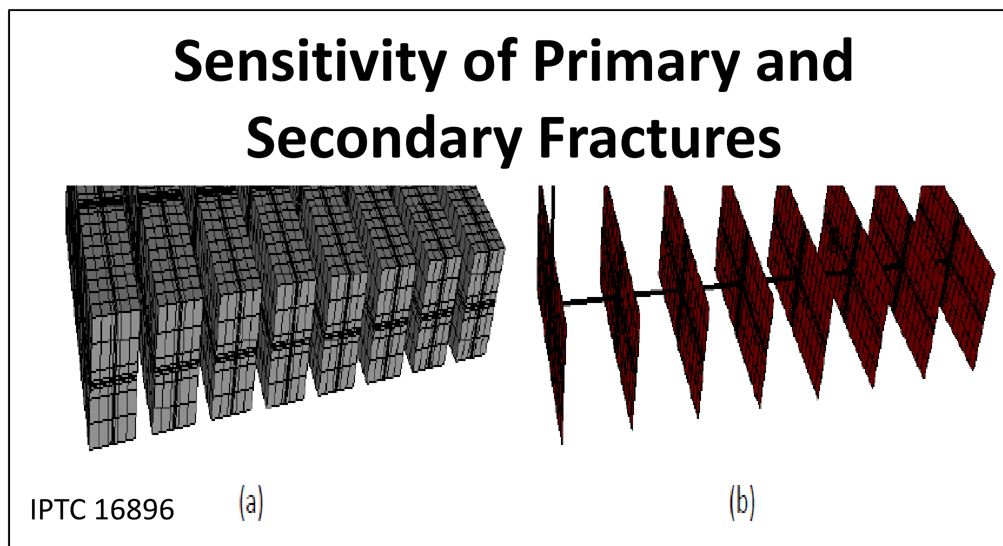


$$MBTime = \frac{WtrCum}{WtrRate}$$

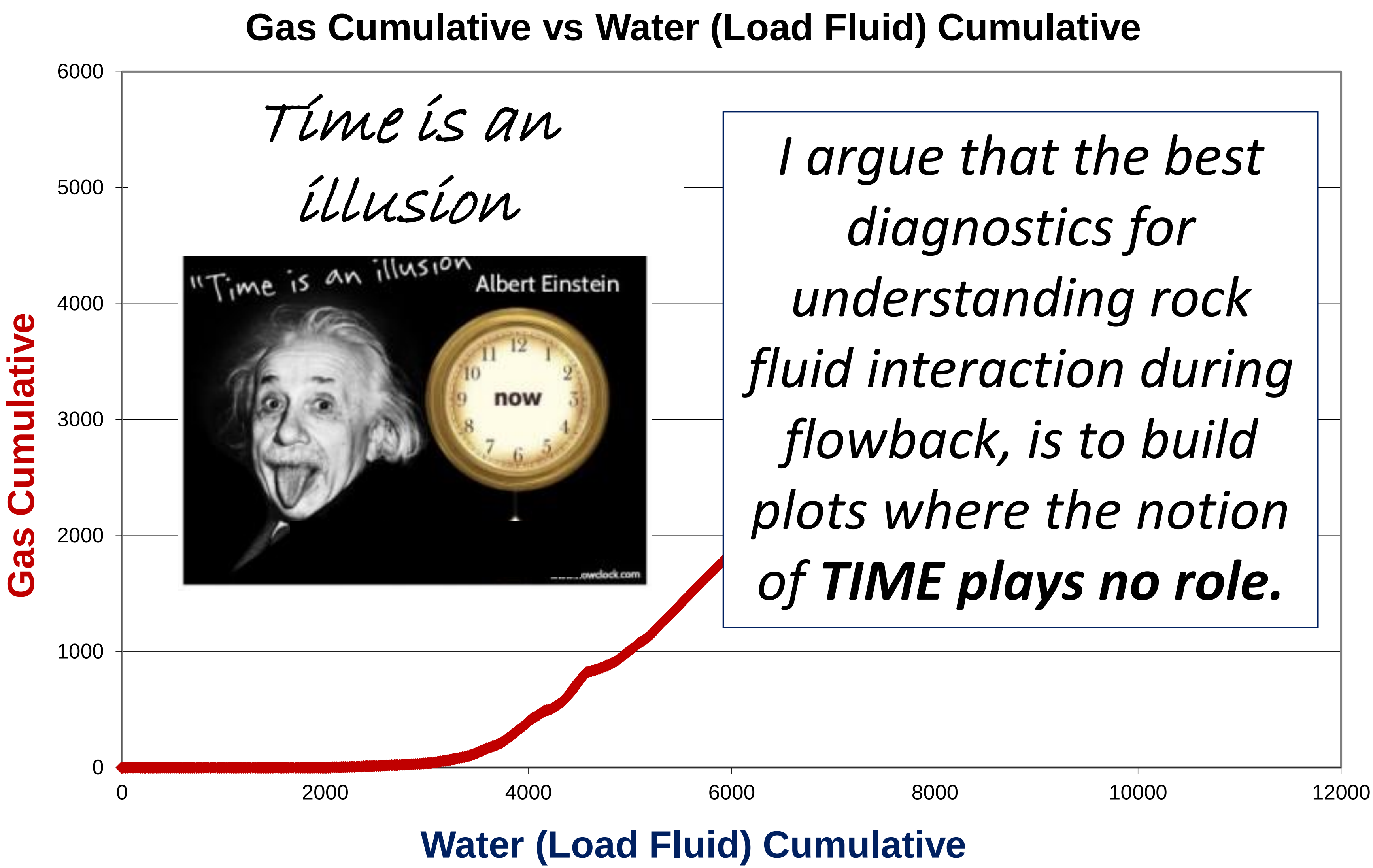
Flowback Dynamics – A Reservoir Simulation Perspective



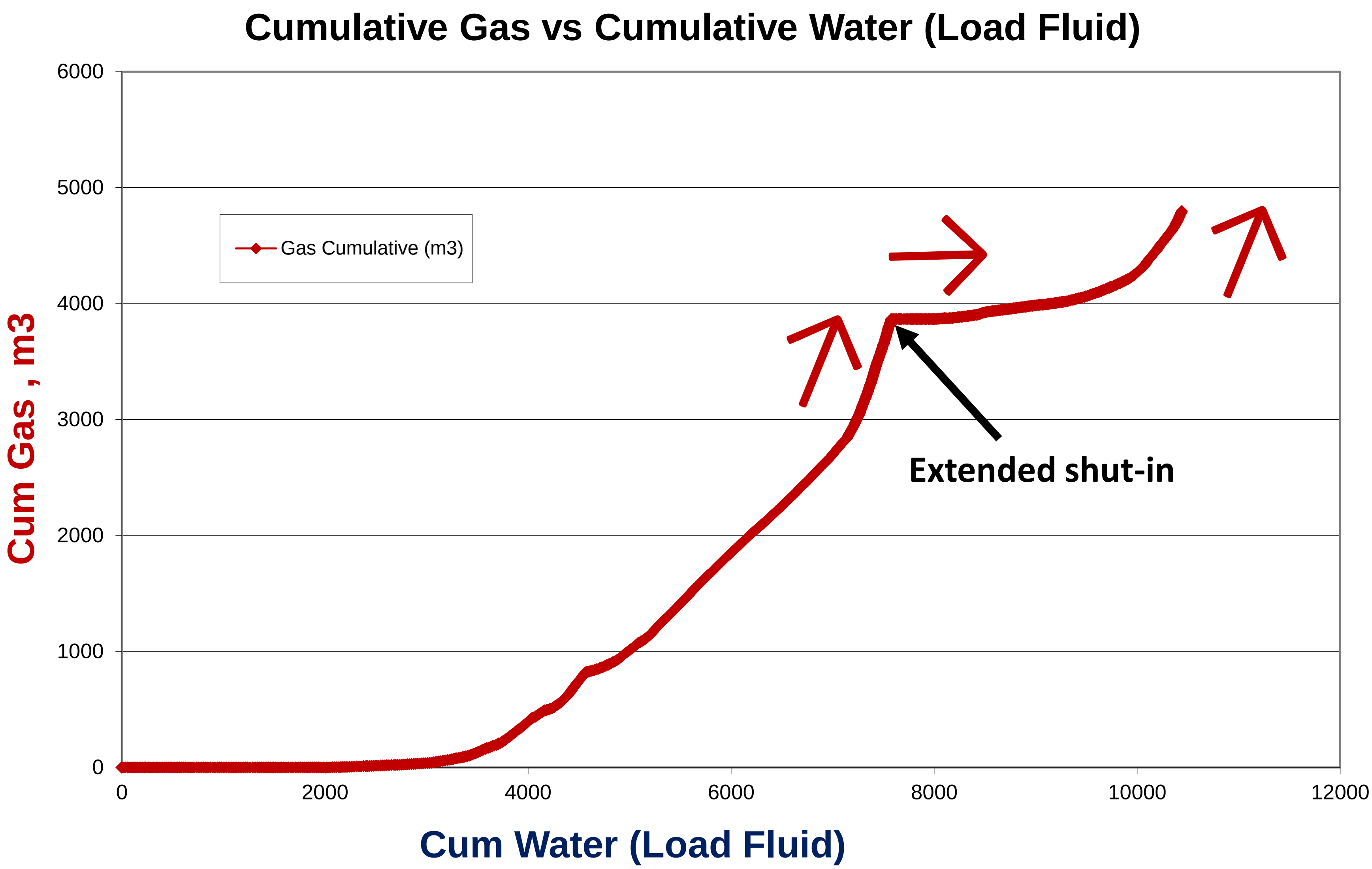


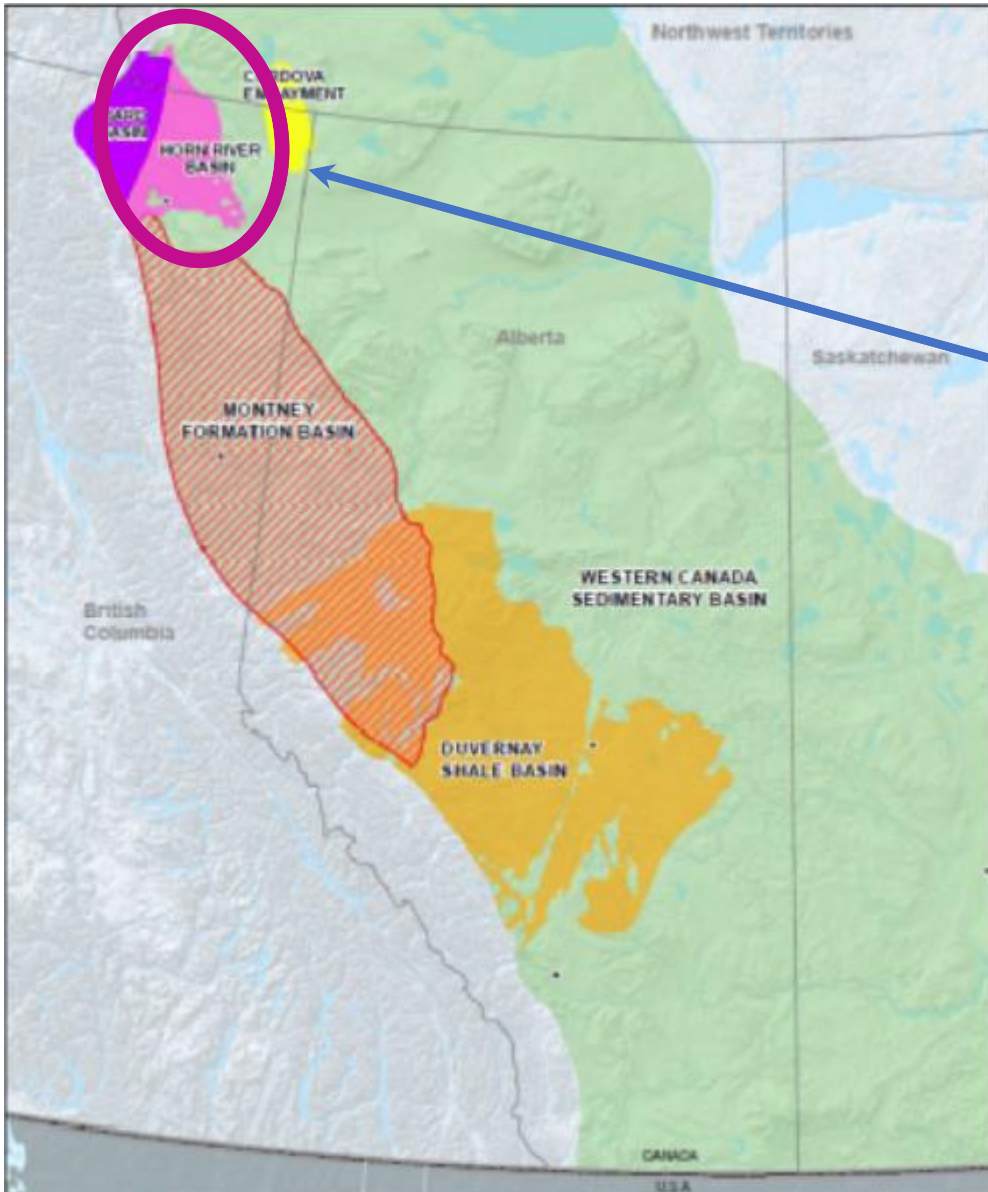


Flowback Dynamics – A *Diagnostics* Perspective



Flowback Dynamics – A *Diagnostics* Perspective





Source: National Energy Board

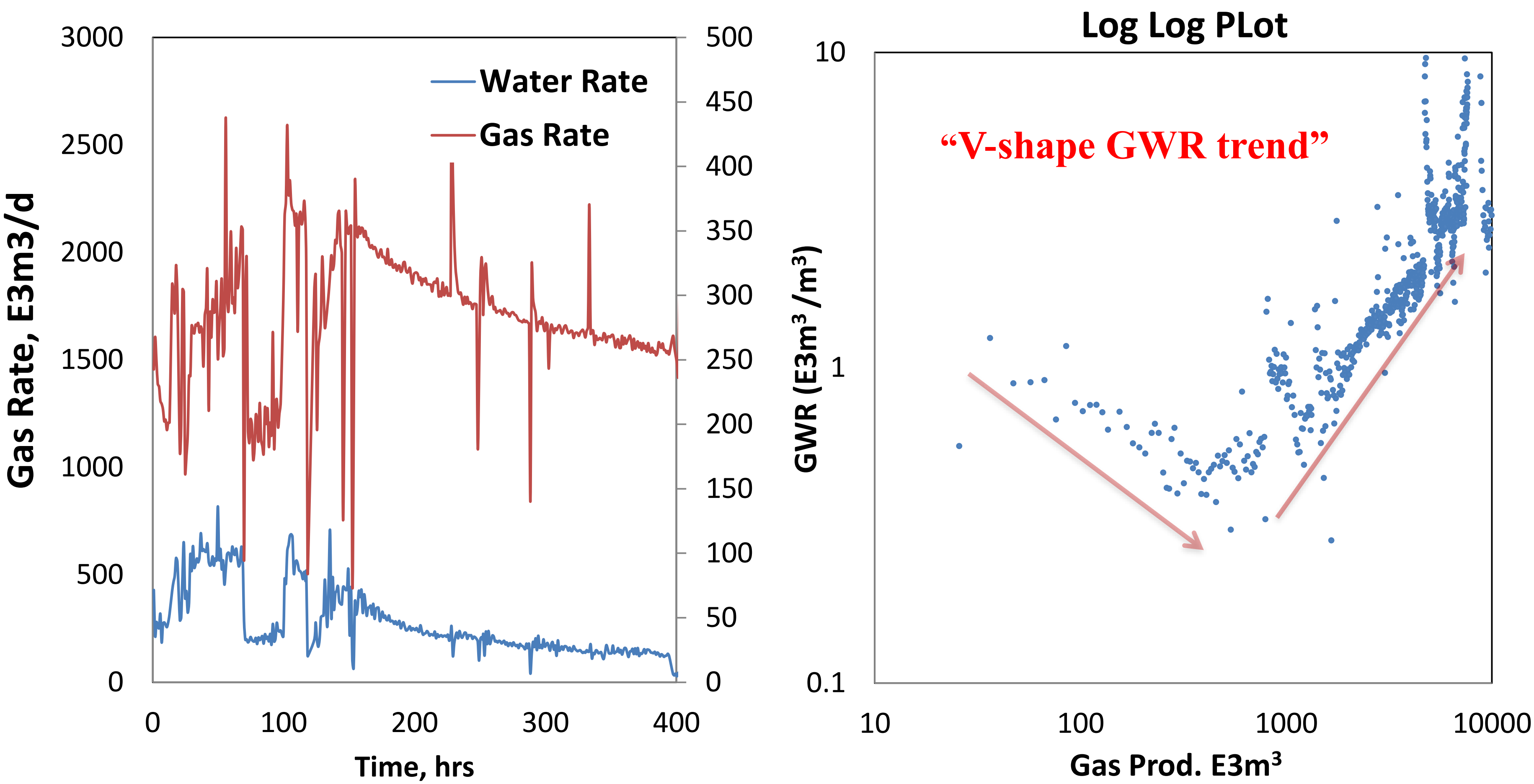
Shale Gas

Horn River Basin

Field Observations

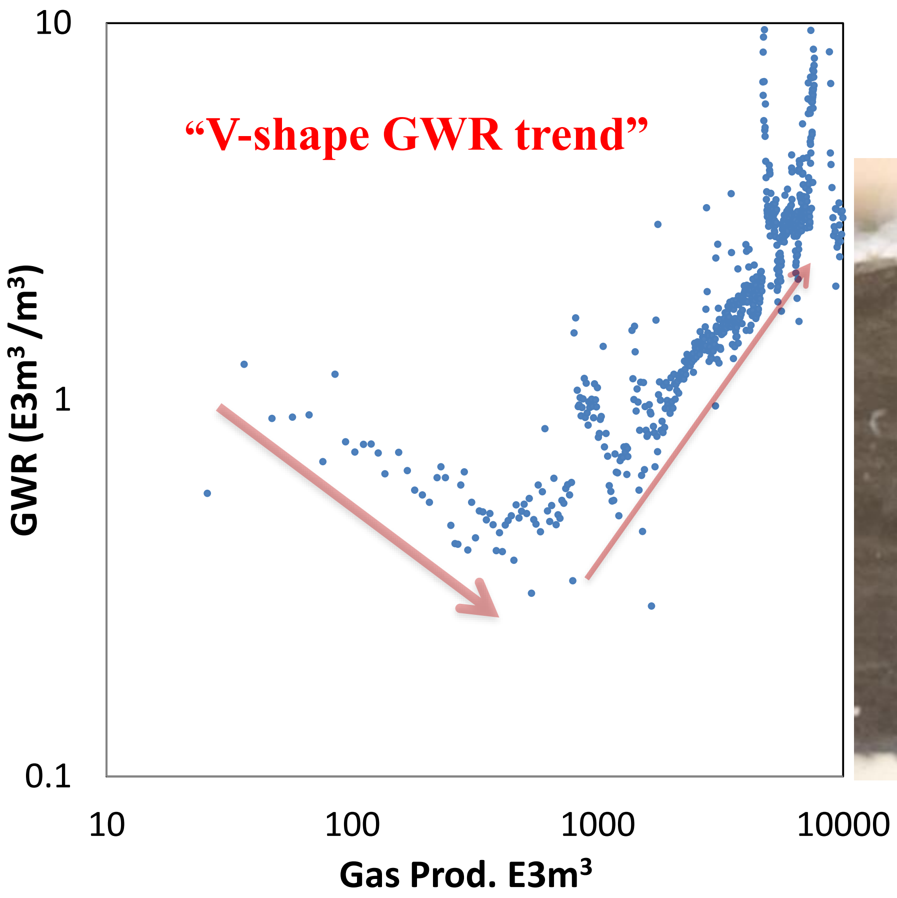
Horn River is a distant cousin to the Barnett Shale of Texas

Field Observations from Horn River Shales



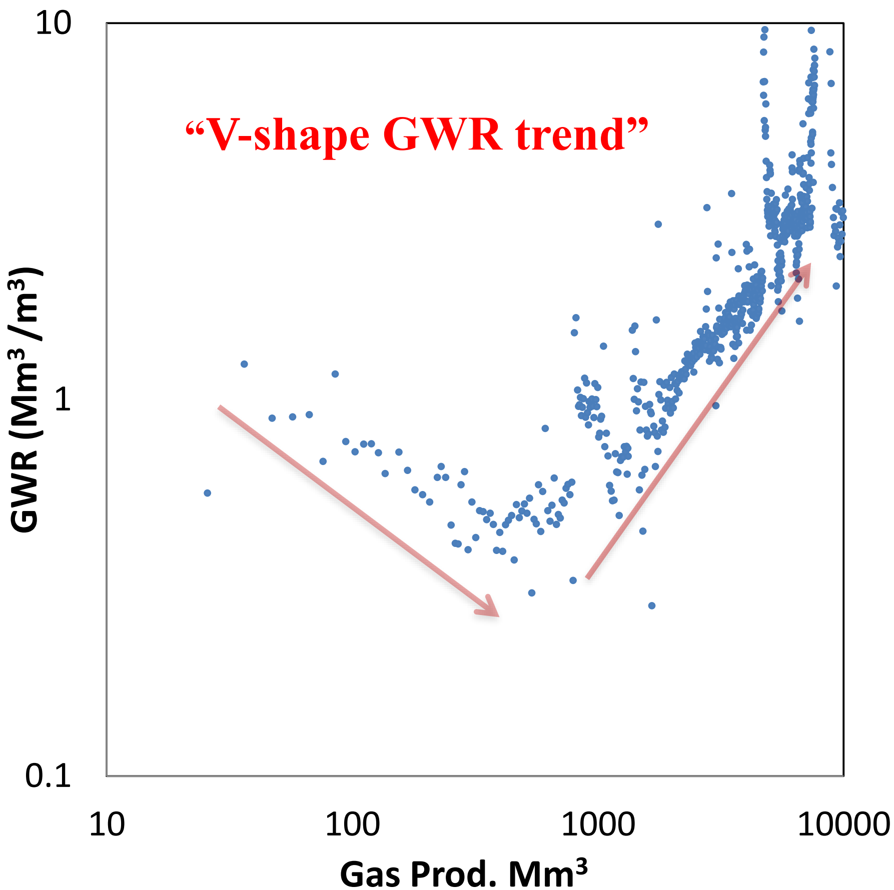
SPE 171636

Flowback Dynamics



SPE 171636

Flowback Dynamics

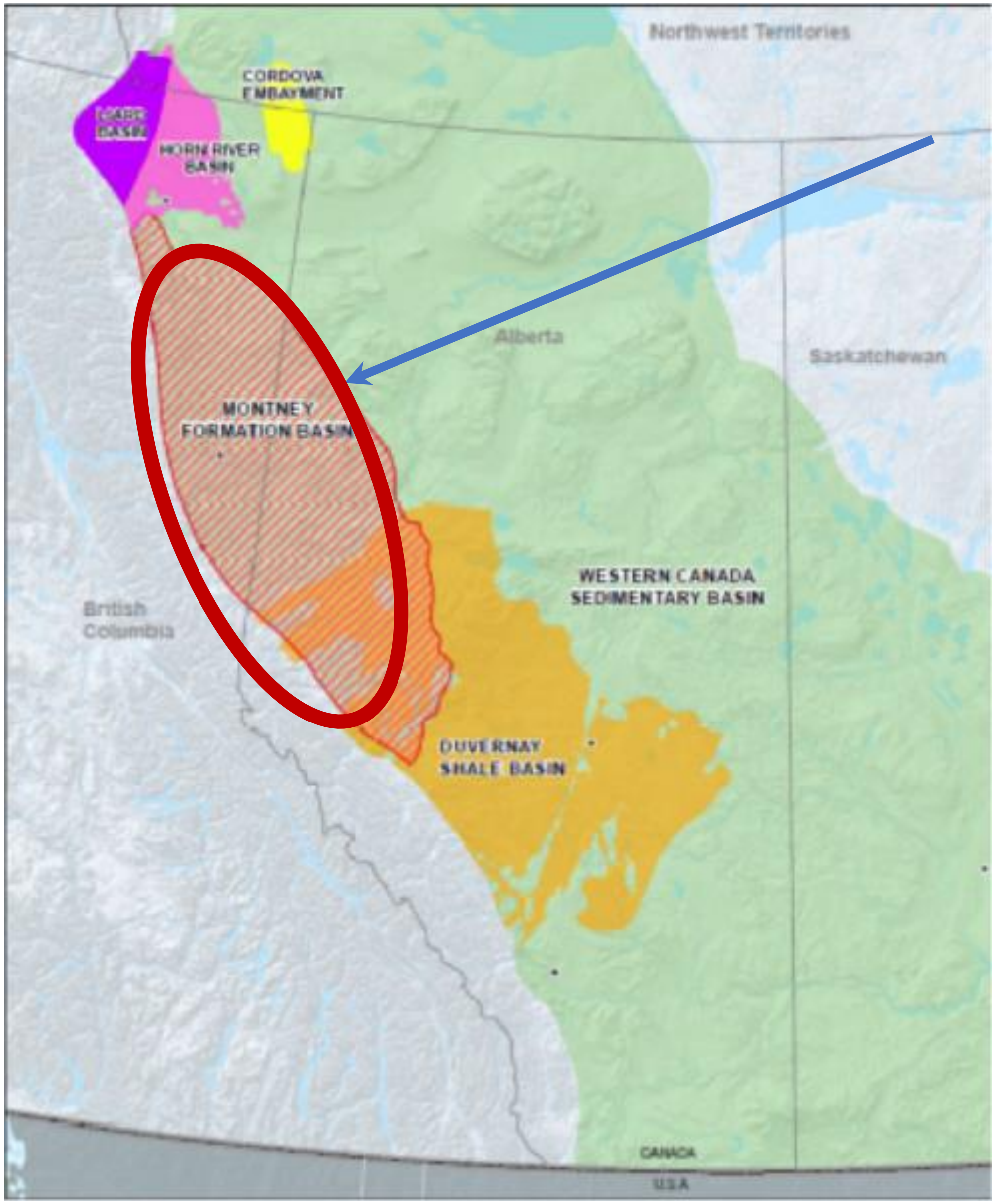


- Early gas production is from free gas saturation within the primary fractures (spontaneous imbibition)
- The negative slope, is depletion of free gas from primary fracture network.
- The change in flow regimes signifies the onset of communication between matrix and natural fracture system.

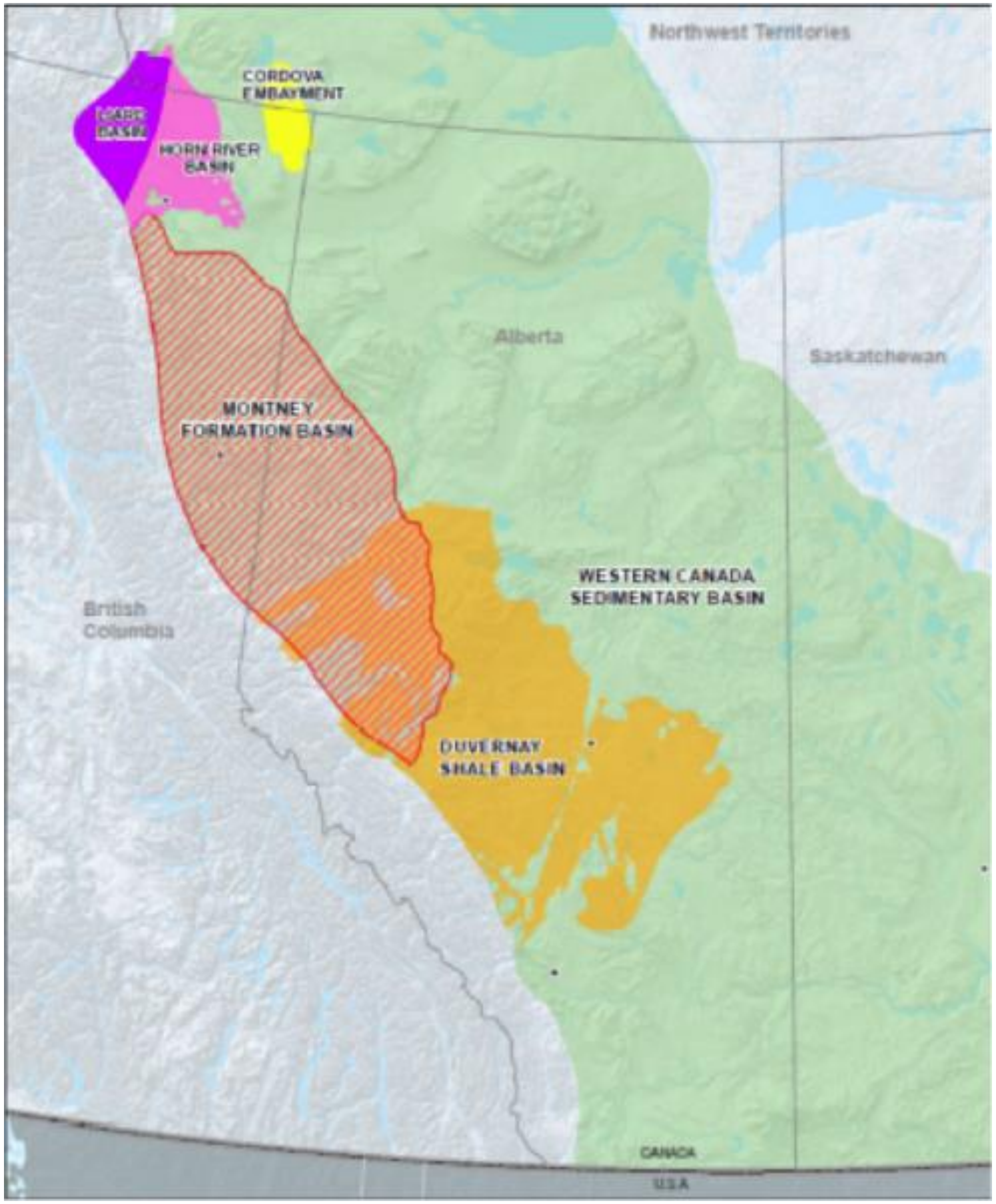
SPE 171636

Montney Gas

Estimating Ultimate Load Fluid Recovery using Early Flowback Diagnostics



Source: National Energy Board

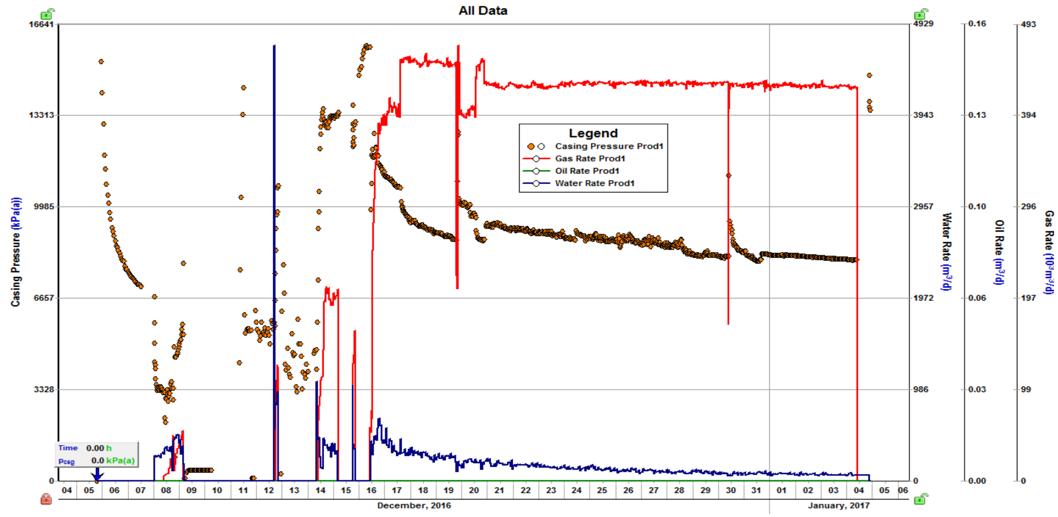


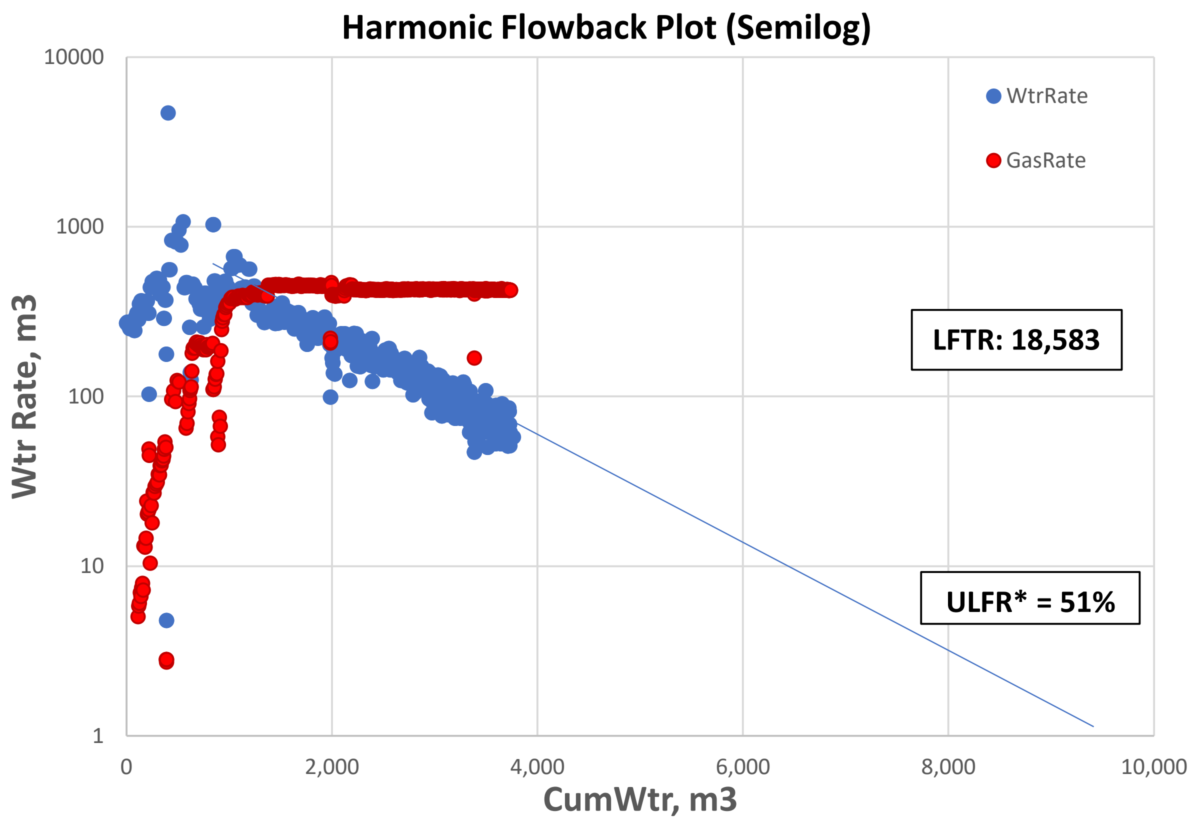
Source: National Energy Board

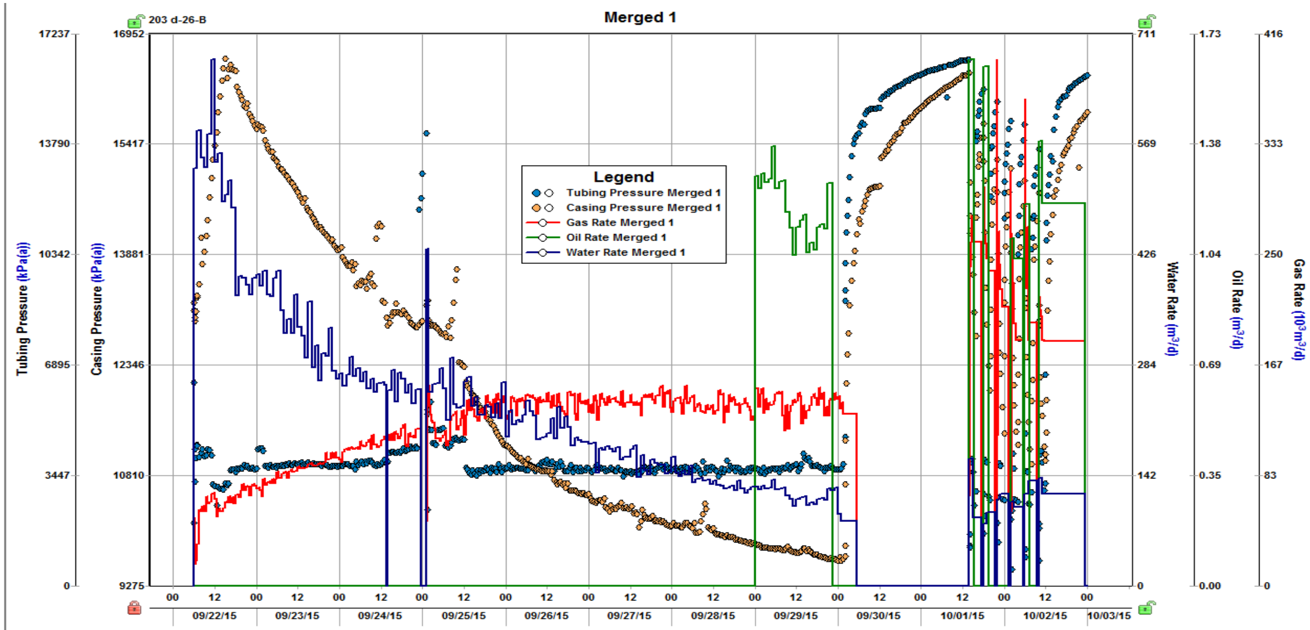
Definitions

<u>LFTR</u>: Load Fluid to Recover

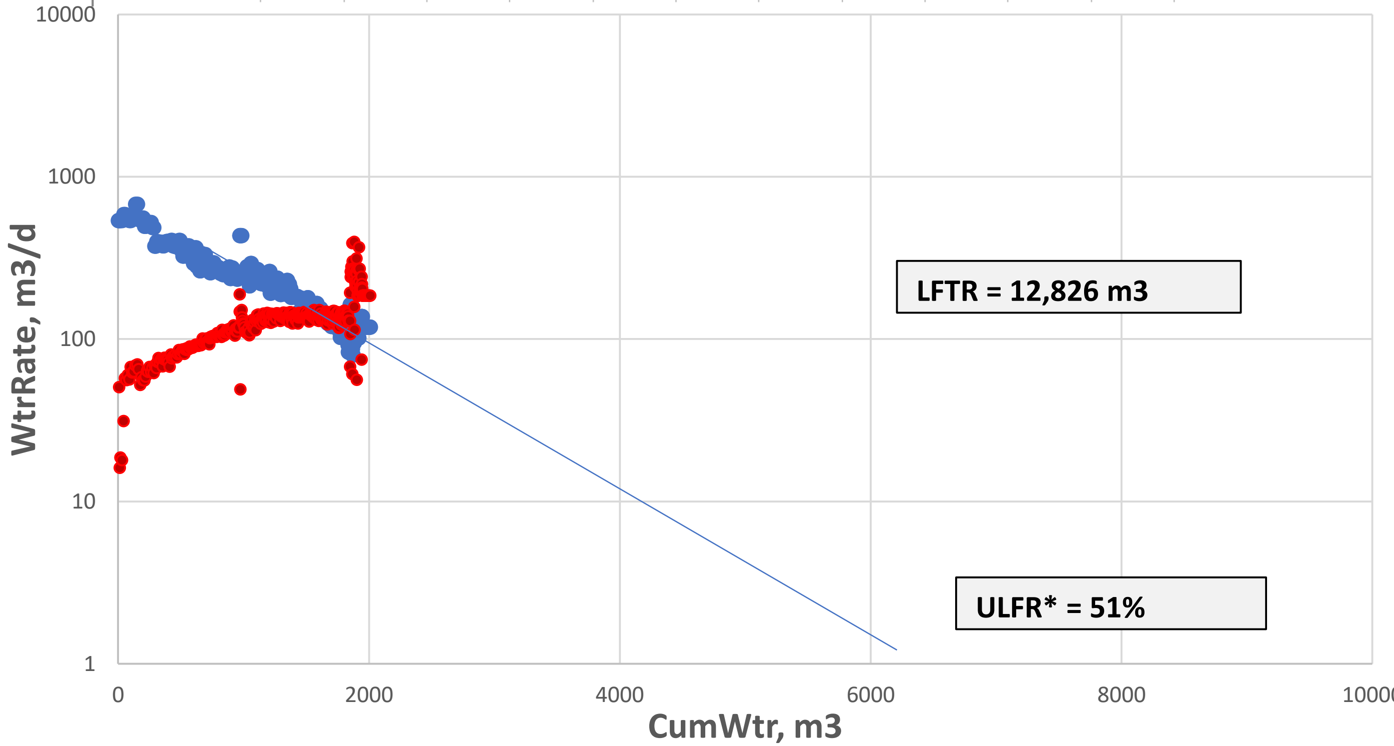
<u>ULFR</u>: Ultimate Load Fluid Recovered


All Data
Legend
Casing Pressure Prod1
Gas Rate Prod1
Oil Rate Prod1
Water Rate Prod1
Casing Pressure (kPa(a))
Water Rate (m³/d)
Oil Rate (m³/d)
Gas Rate (10³m³/d)
December, 2016
January, 2017


Harmonic Flowback Plot (Semilog)
WtrRate
GasRate
LFTR: 18,583
ULFR* = 51%
Wtr Rate, m3
CumWtr, m3

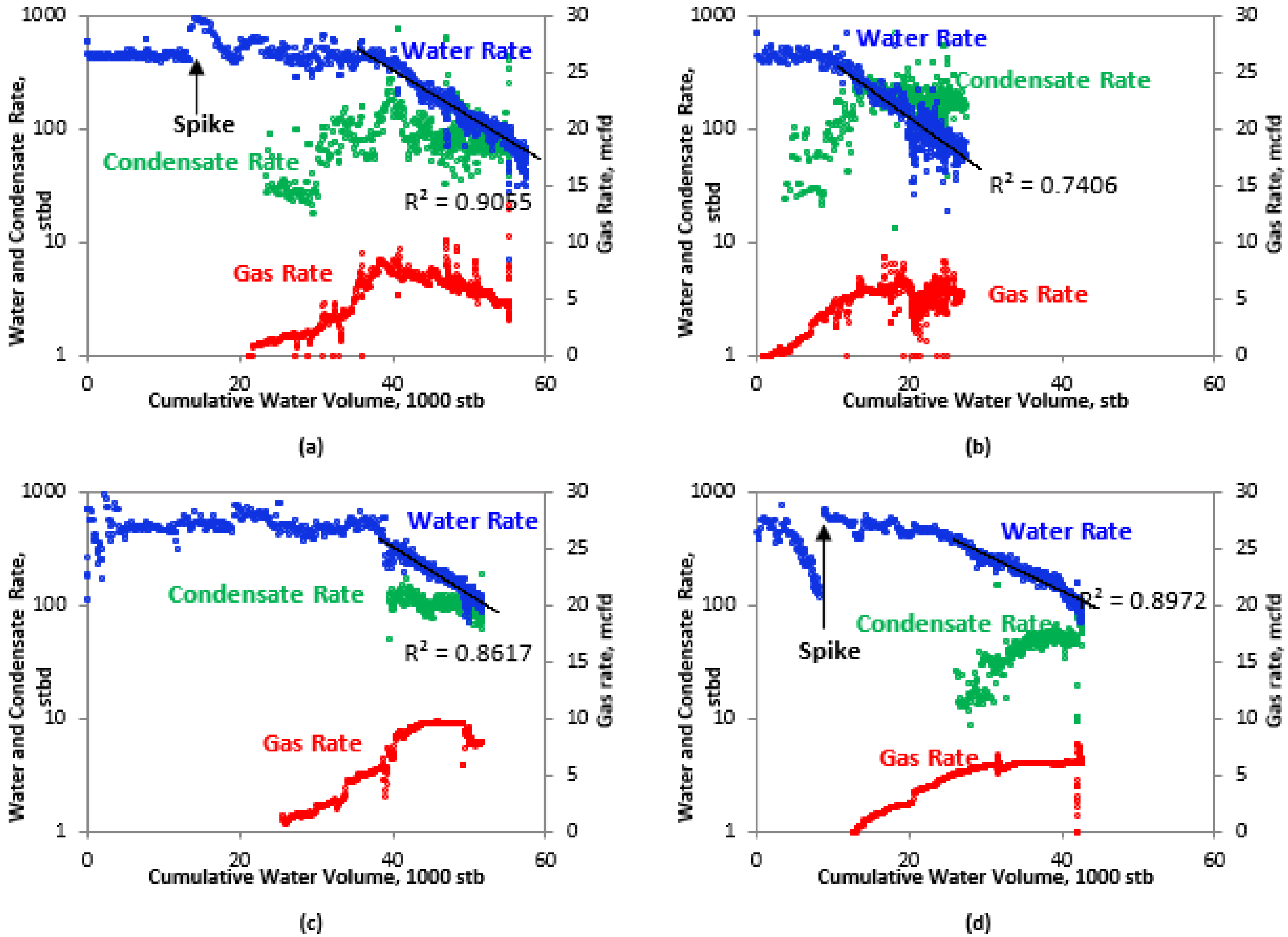


Merged 1
203 d-26-B
Legend
Tubing Pressure Merged 1
Casing Pressure Merged 1
Gas Rate Merged 1
Oil Rate Merged 1
Water Rate Merged 1
Tubing Pressure (kPa(a))
Casing Pressure (kPa(a))
Water Rate (m3/d)
Oil Rate (m3/d)
Gas Rate (10³m³/d)
09/22/15
09/23/15
09/24/15
09/25/15
09/26/15
09/27/15
09/28/15
09/29/15
09/30/15
10/01/15
10/02/15
10/03/15

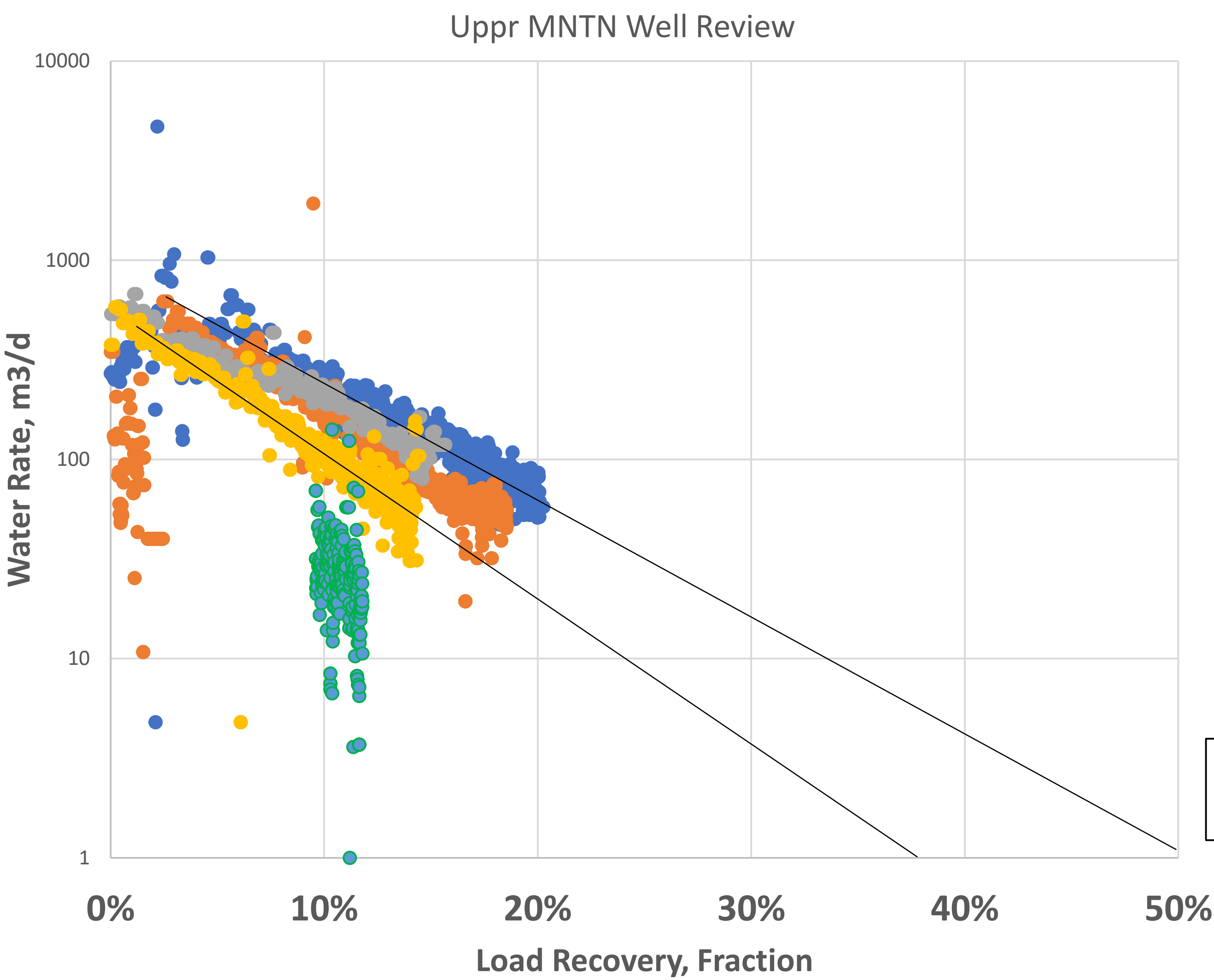


WtrRate, m3/d
CumWtr, m3
LFTR = 12,826 m3
ULFR* = 51%
10000
1000
100
10
1
0
2000
4000
6000
8000
10000

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



URTec 2903105

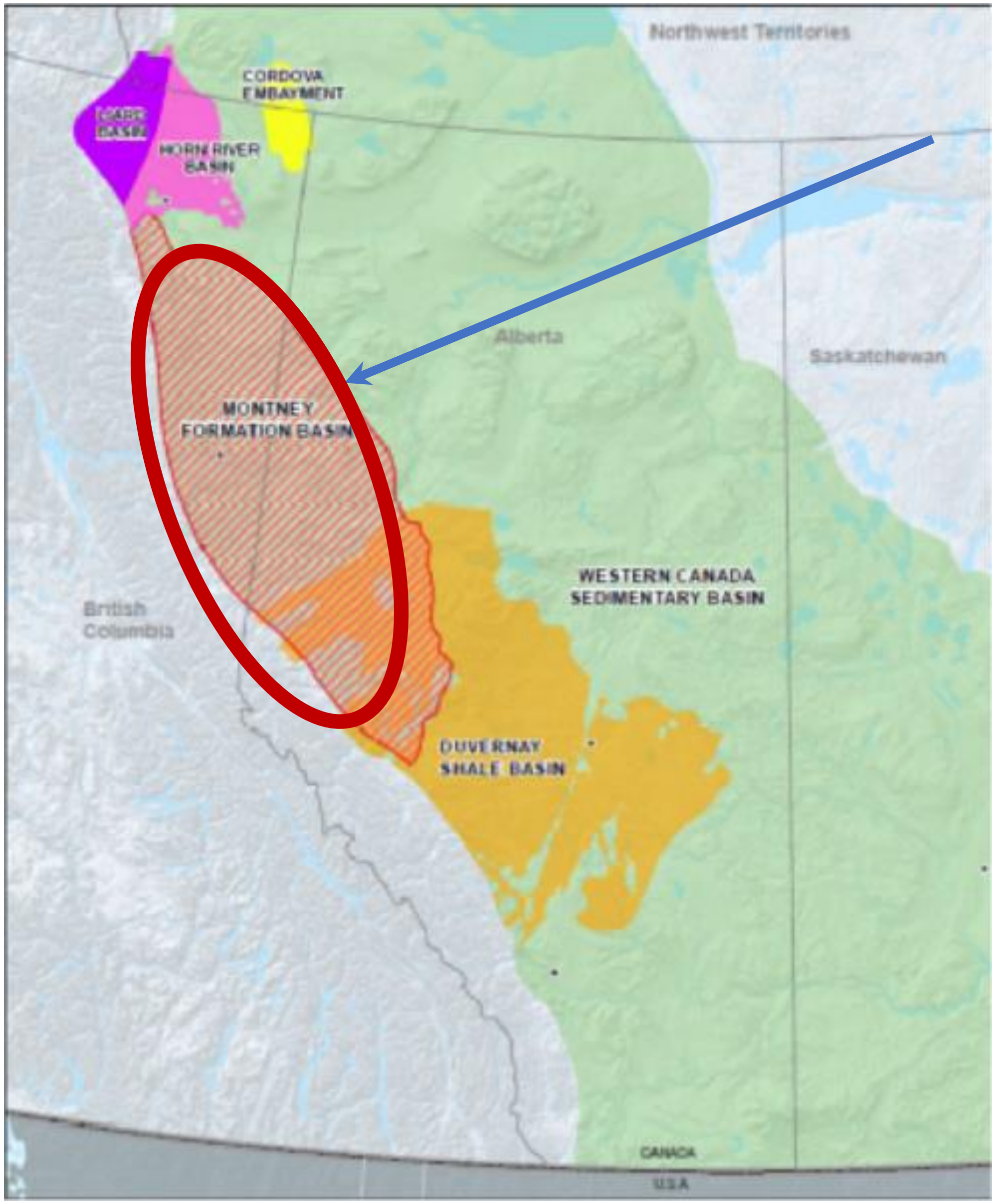


A practical model for predicting Load Fluid Recovery.

F_L^* = Load Fluid Recovered / Injected Fluid Volume

Montney Tight Oil

Field Observation



Source: National Energy Board

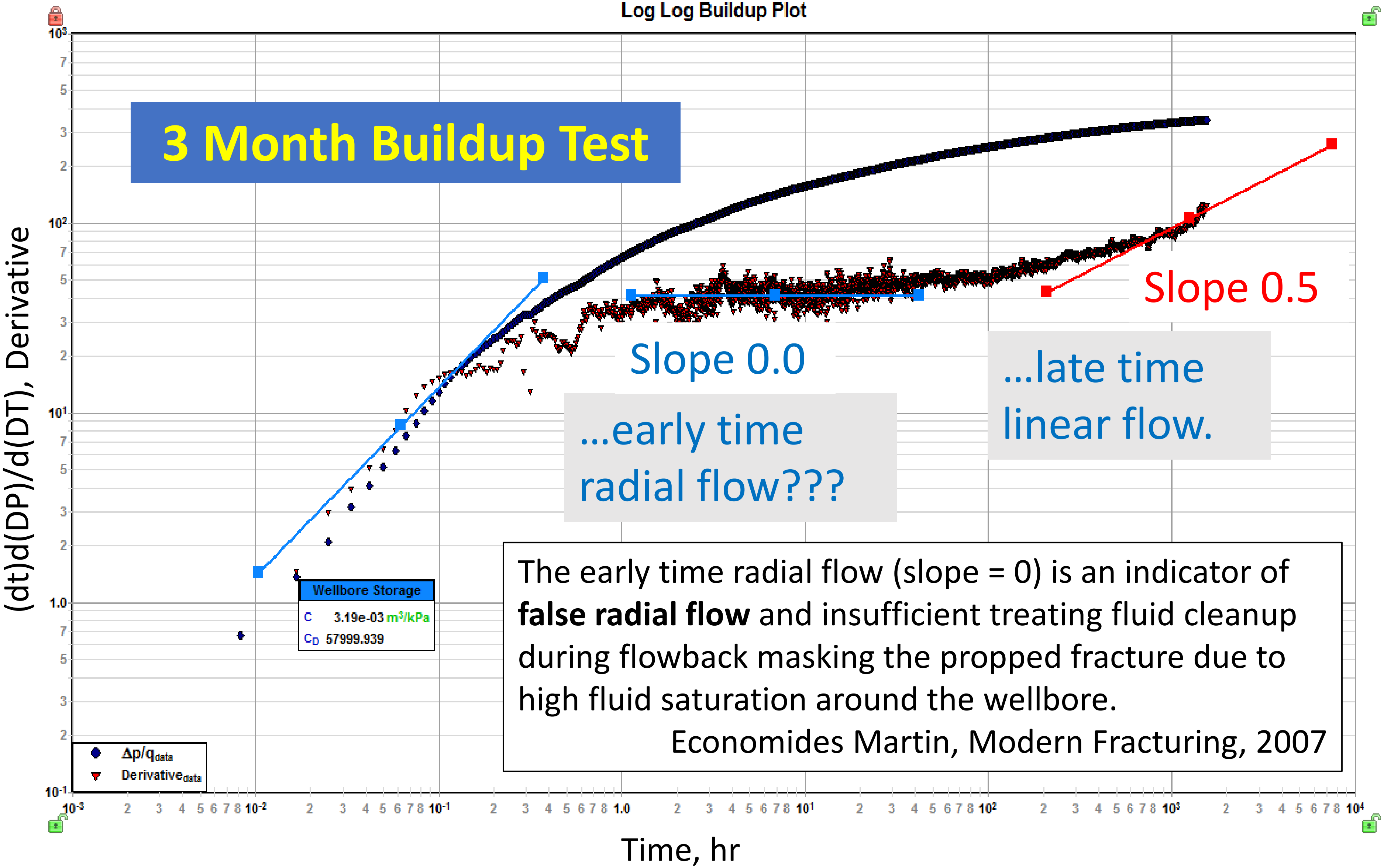
30 Stage N2 Slick Water

50m (165 ft spacing)

100 tonne/stage

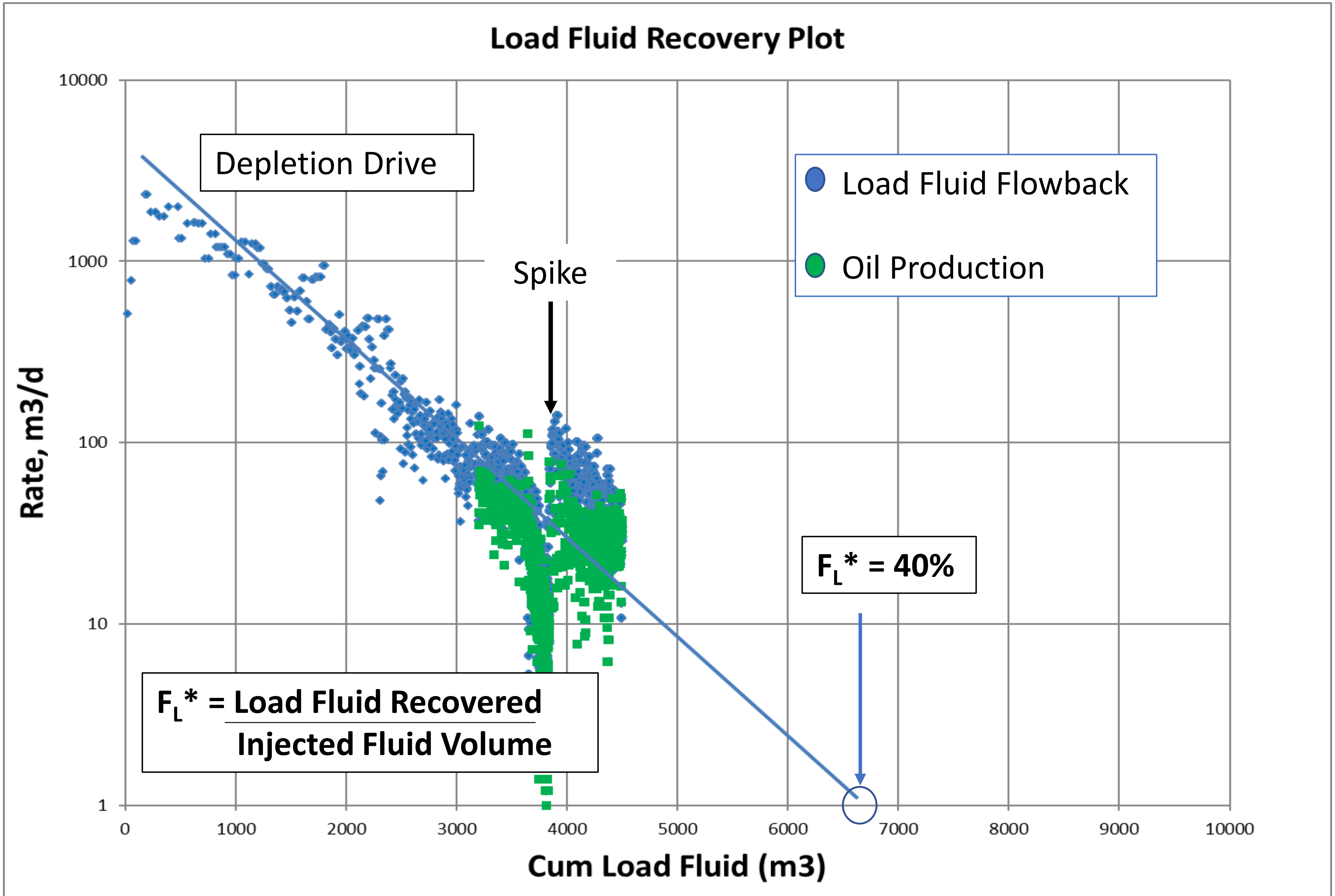
Injected 16,390m3 (103,100 bbl) of water

Montney Tight Oil

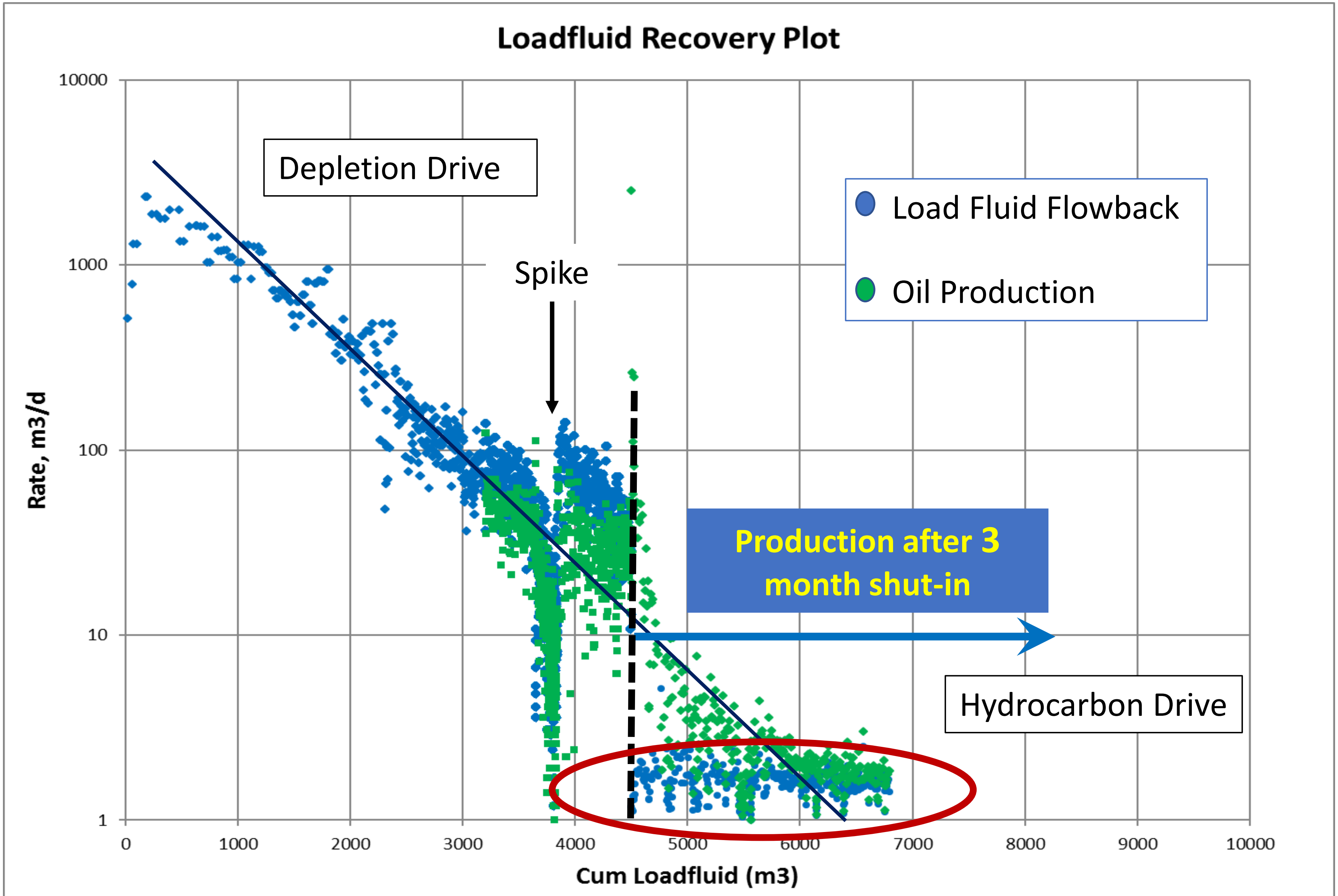


The early time radial flow (slope = 0) is an indicator of **false radial flow** and insufficient treating fluid cleanup during flowback masking the propped fracture due to high fluid saturation around the wellbore.
Economides Martin, Modern Fracturing, 2007

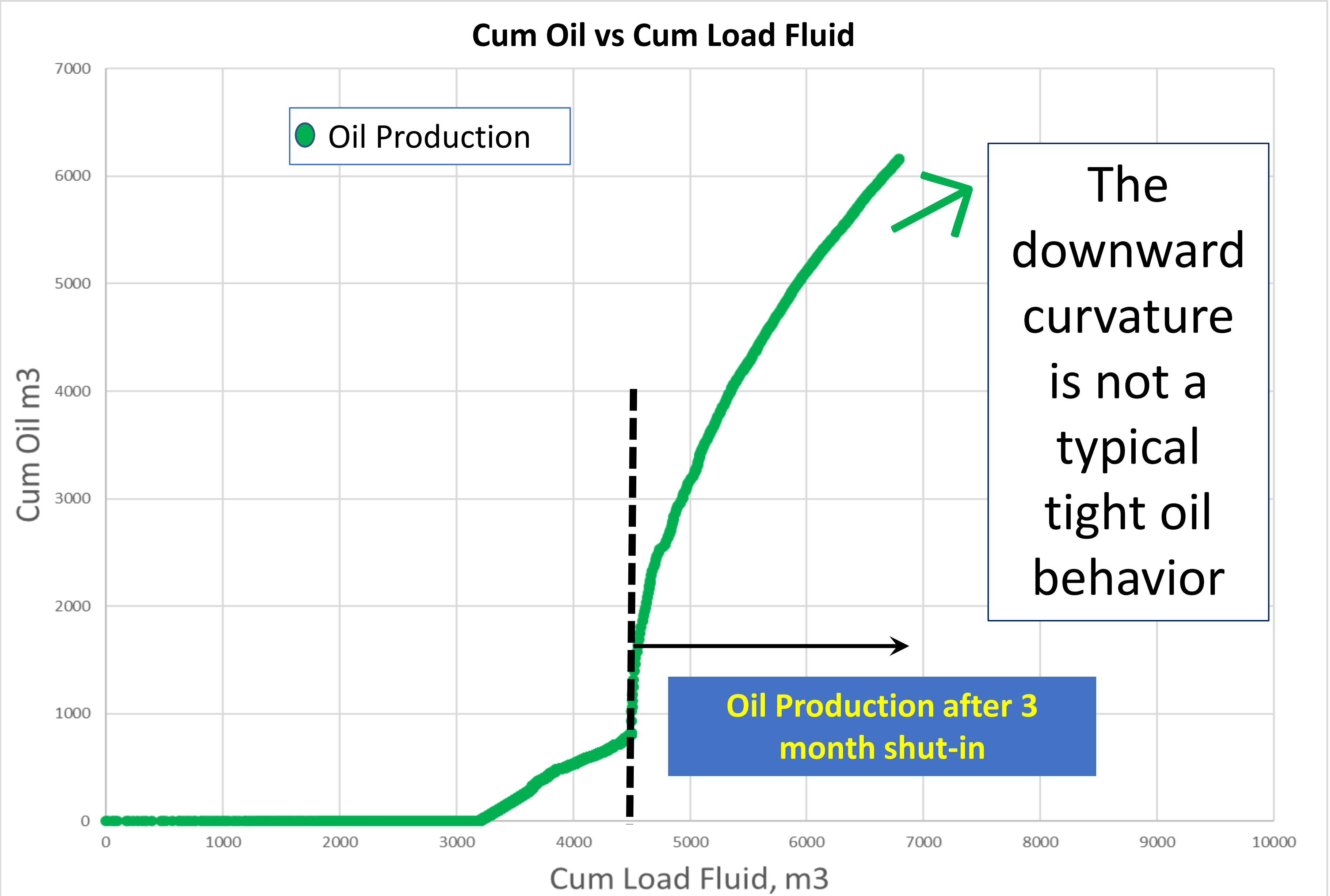
Montney Tight Oil

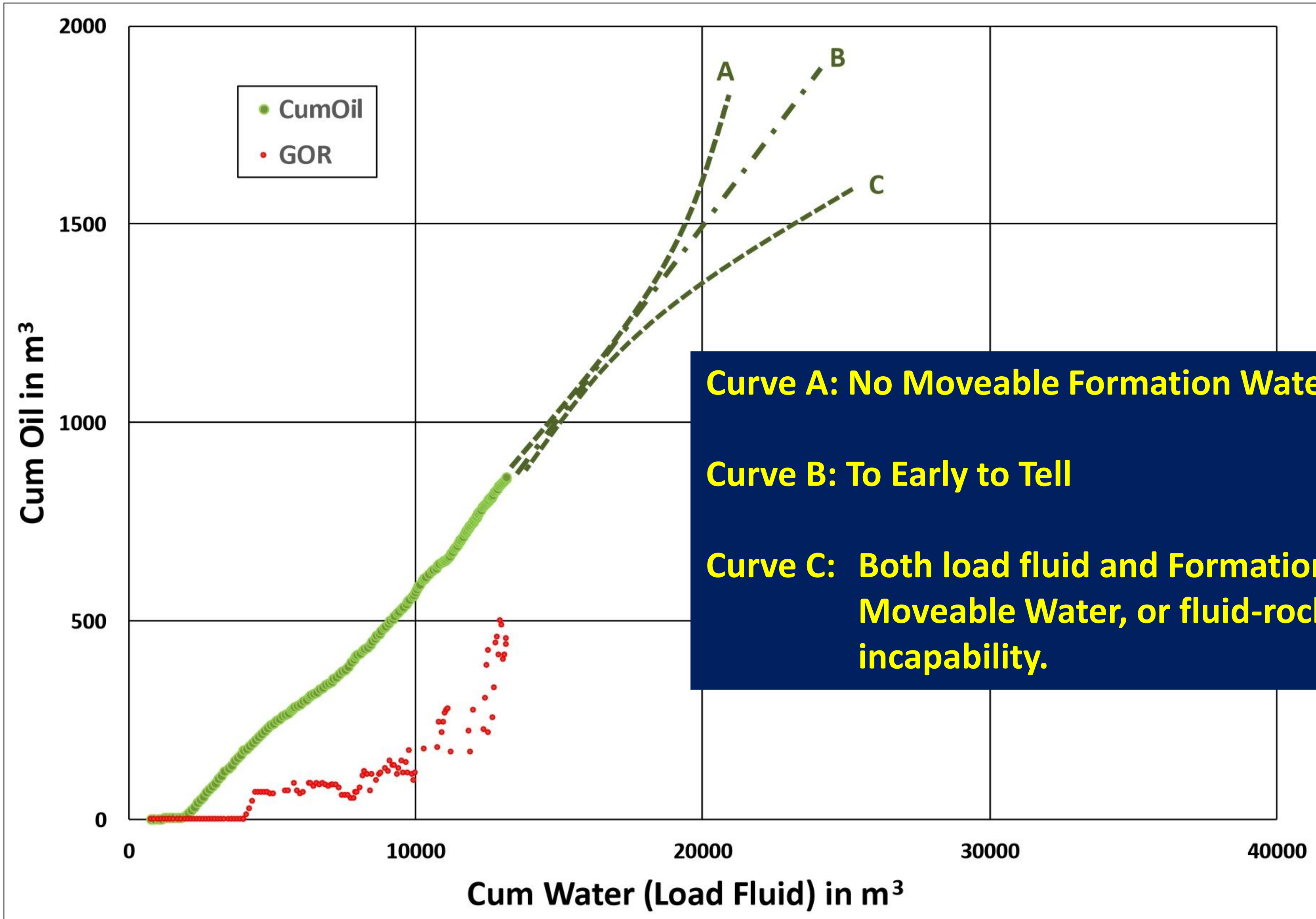


Montney Tight Oil



Montney Tight Oil

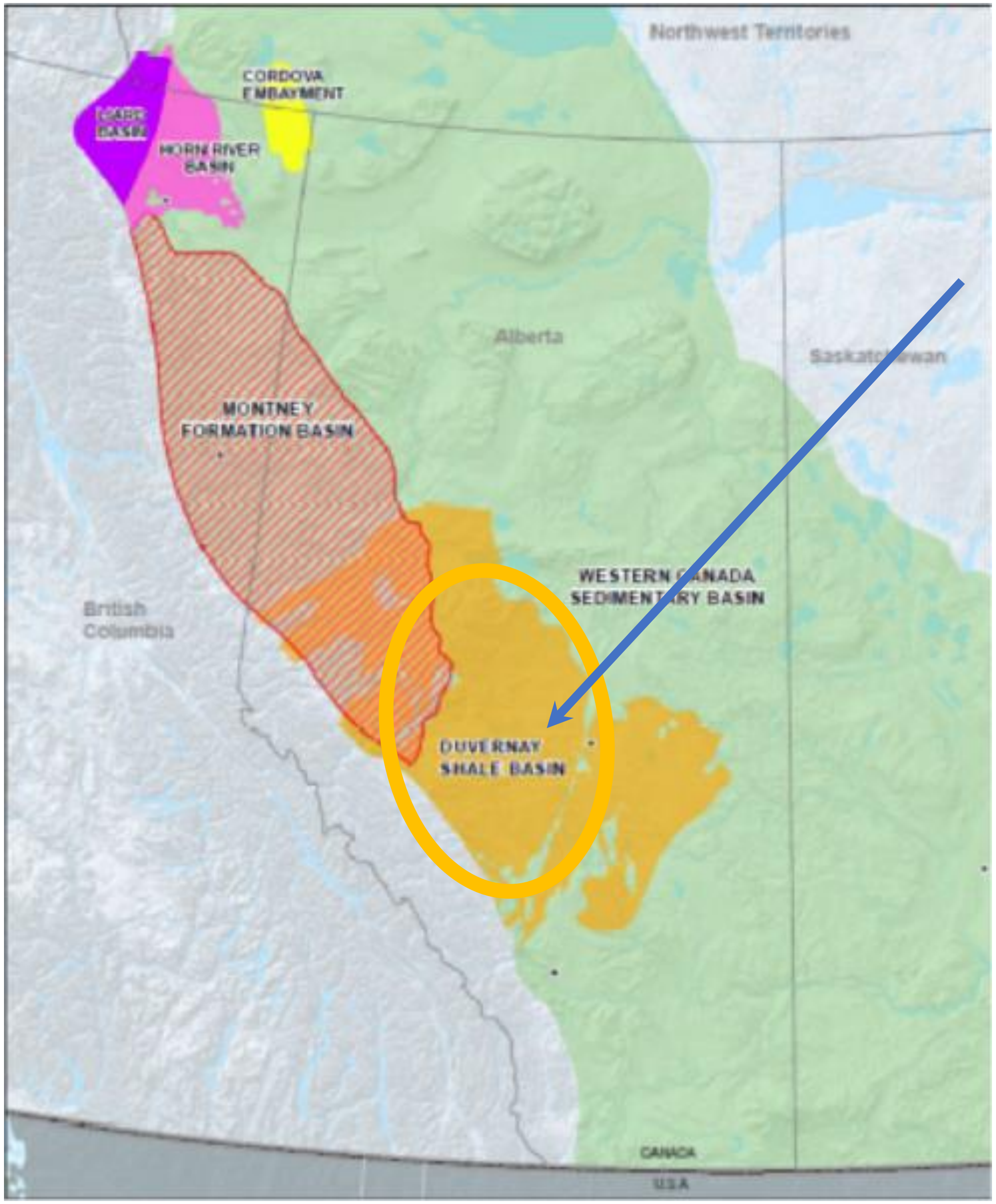




Curve A: No Moveable Formation Water

Curve B: To Early to Tell

Curve C: Both load fluid and Formation Moveable Water, or fluid-rock incapability.



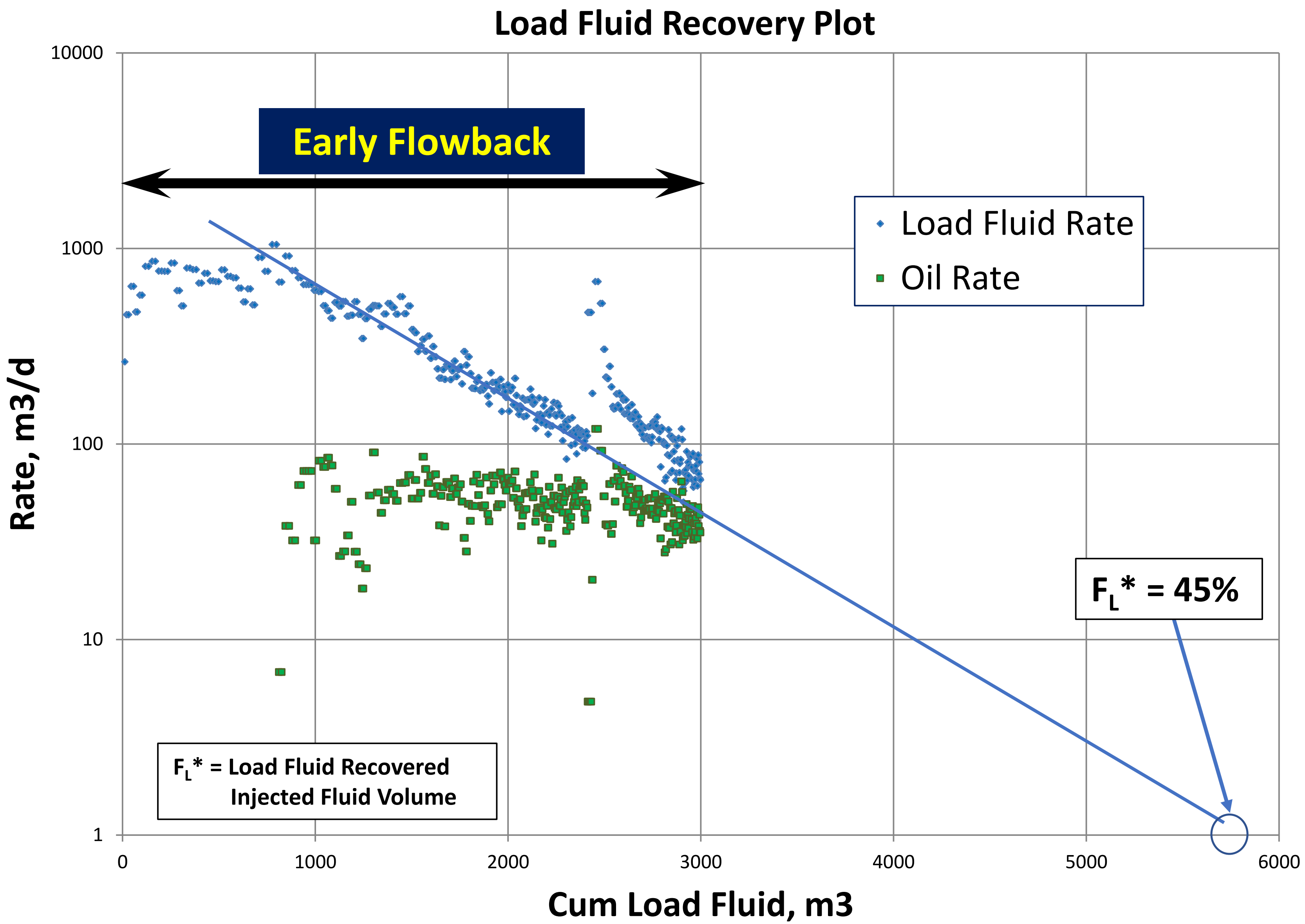
Source: National Energy Board

West Duvernay Shale

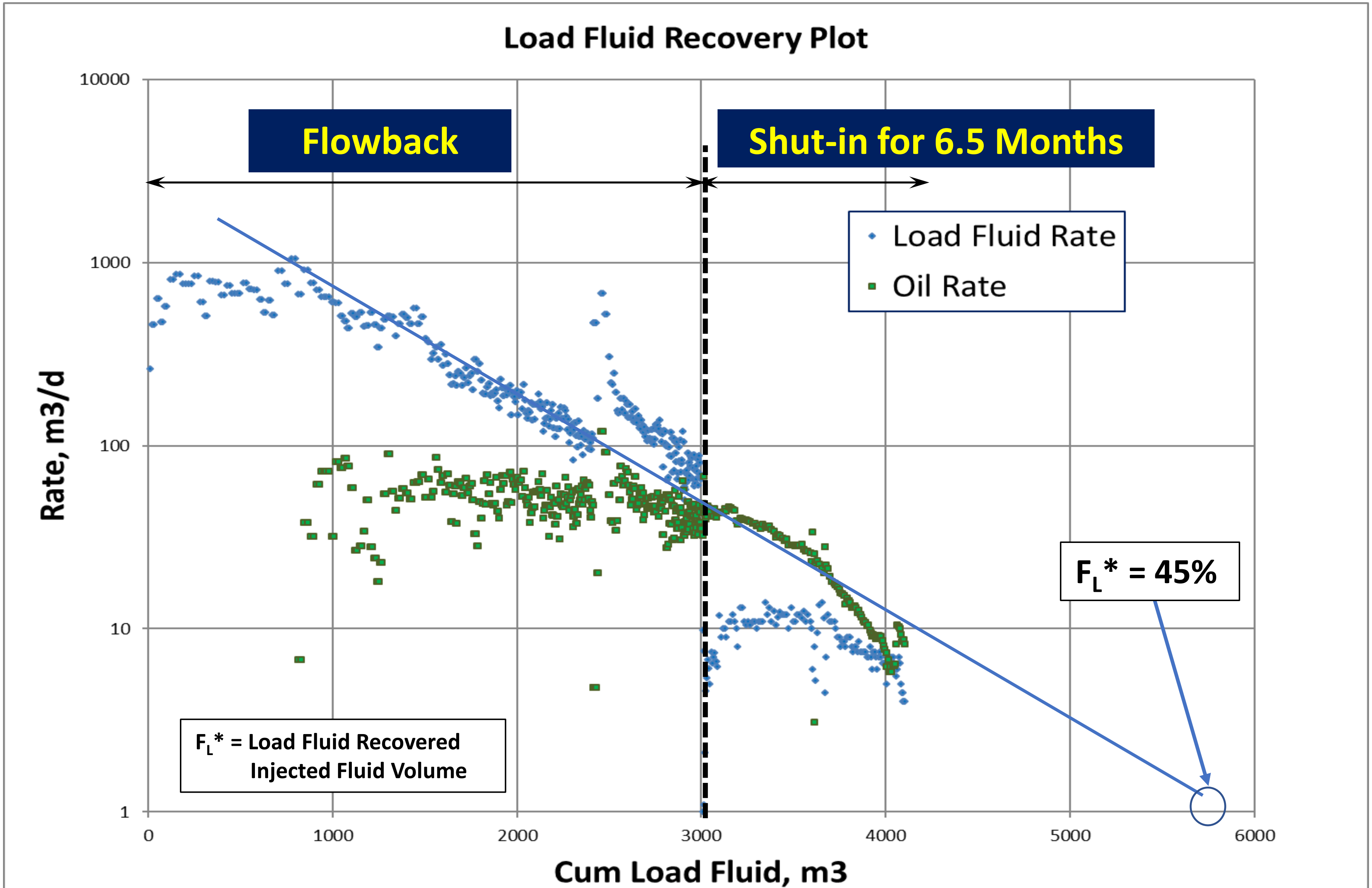
Field Observation

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

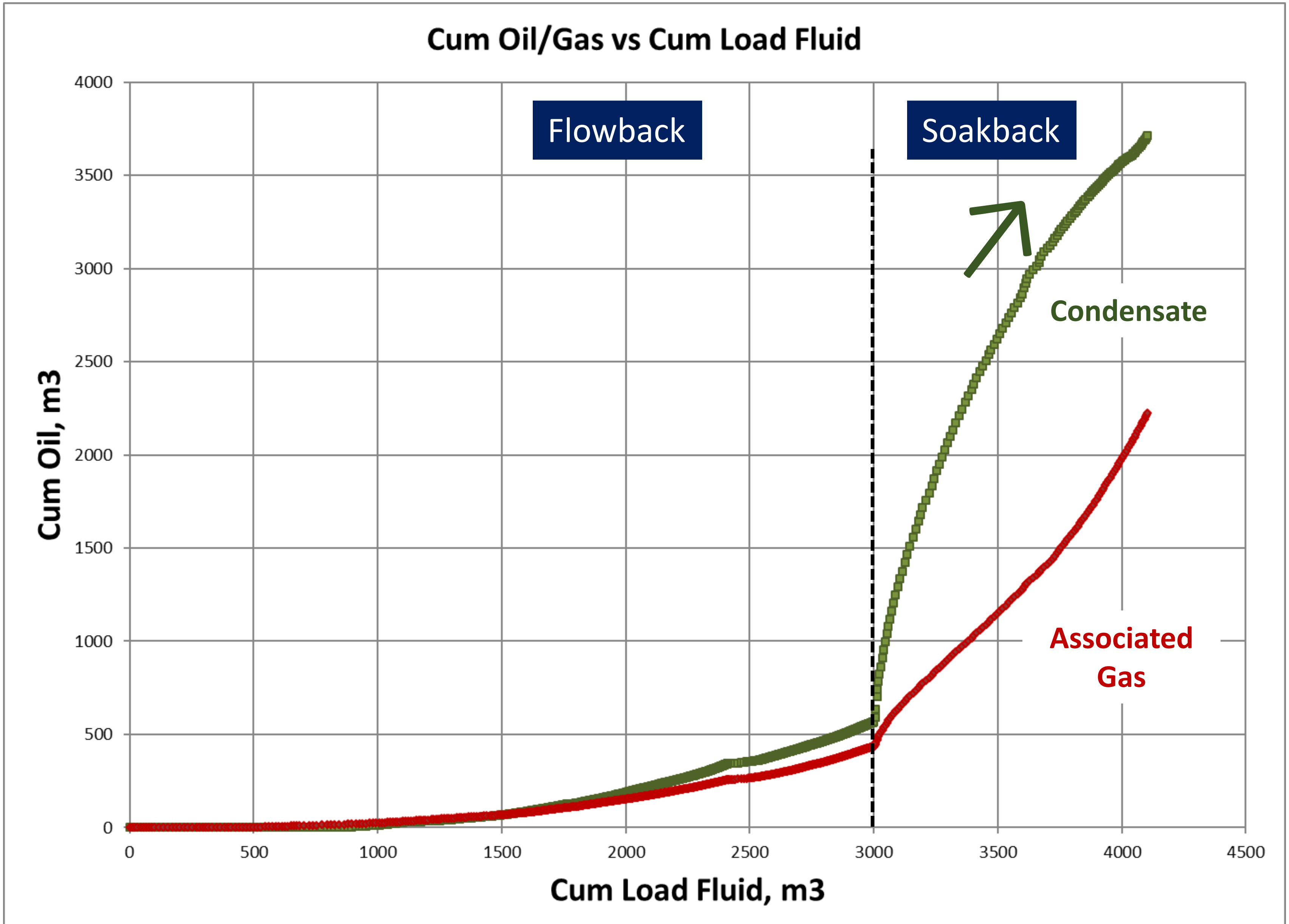
West DUVERNAY EXAMPLE

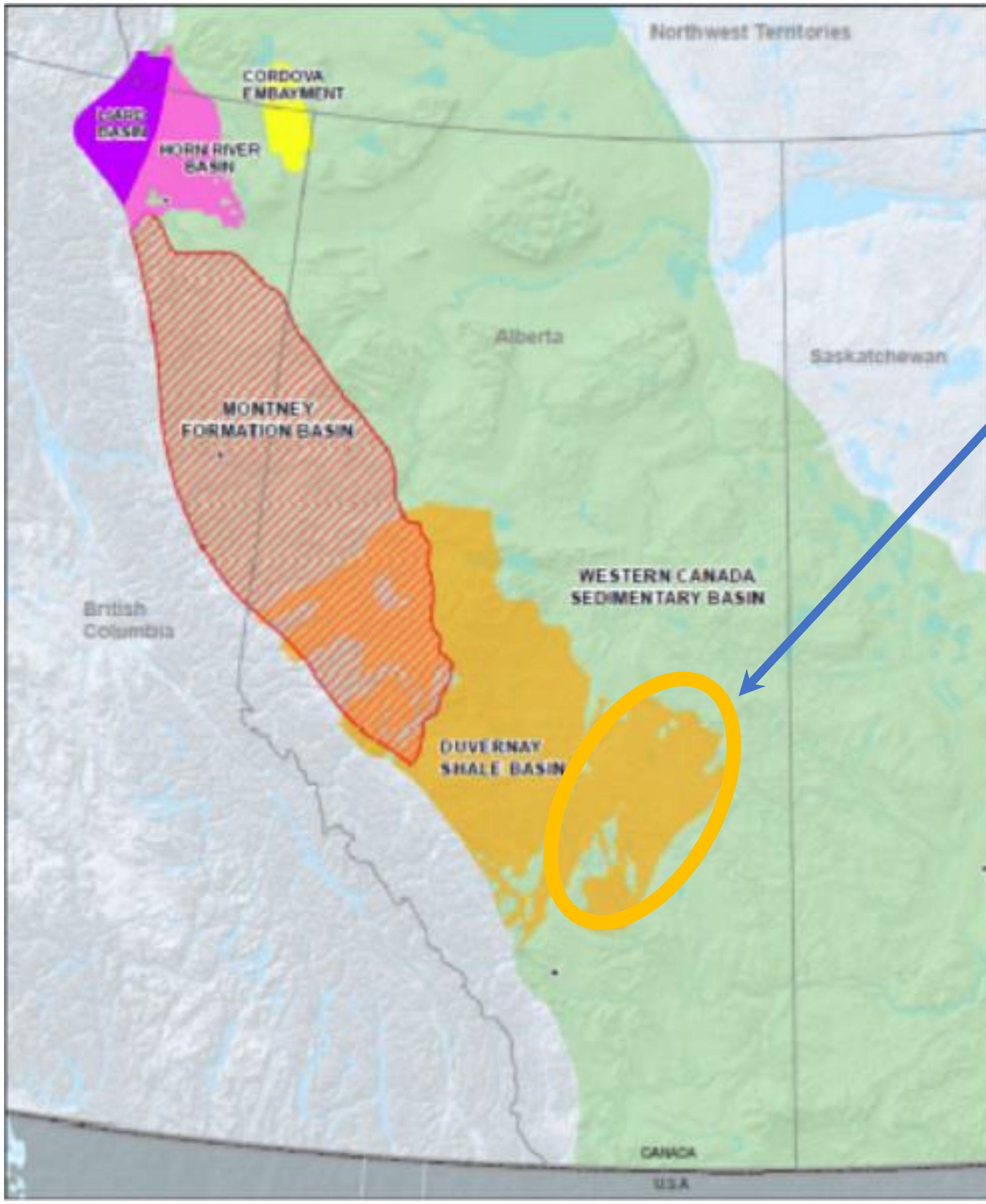


West DUVERNAY EXAMPLE



West DUVERNAY EXAMPLE





Source: National Energy Board

East Duvernay Oil Shale

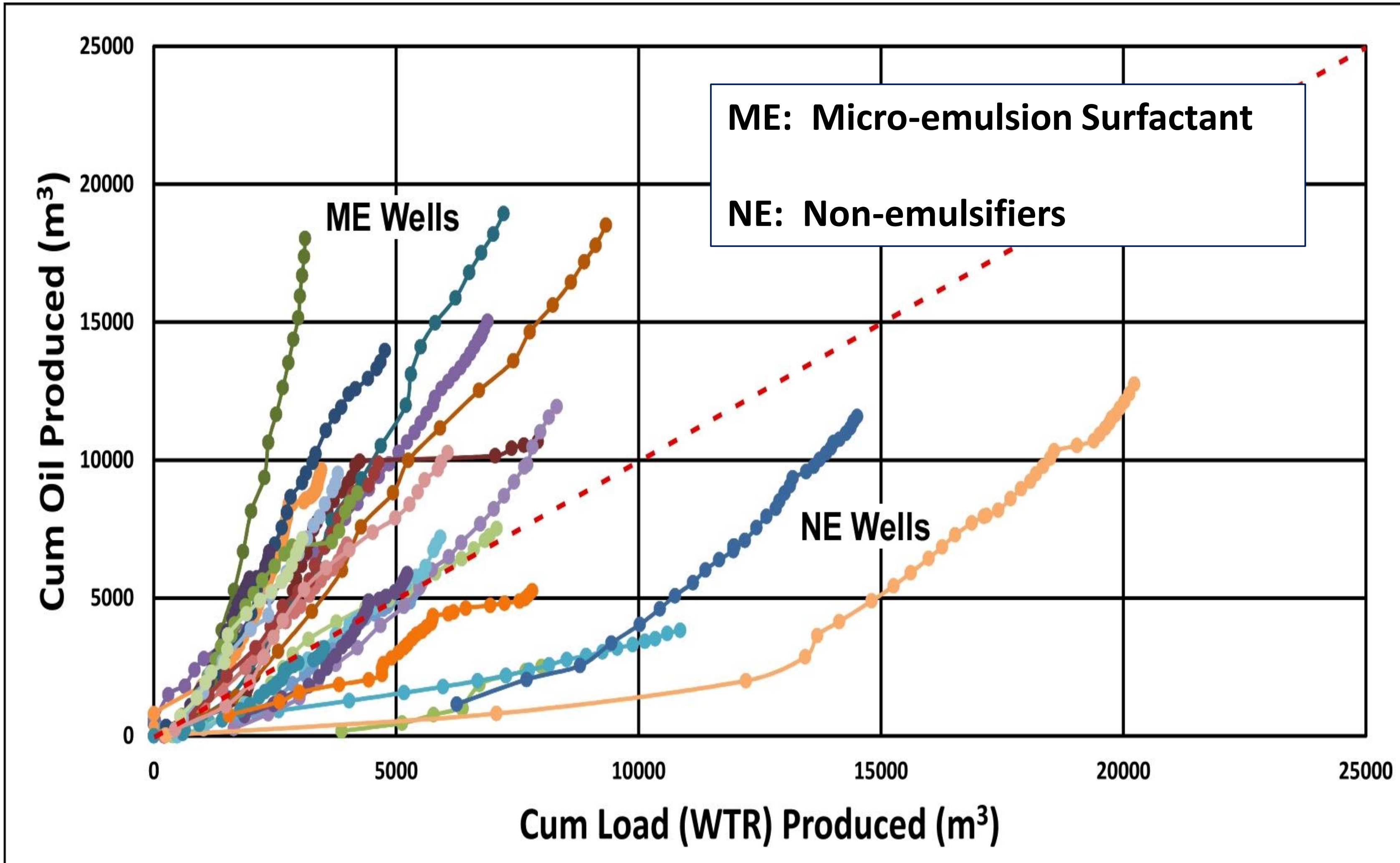
Analogous to Eagleford

Field Observation

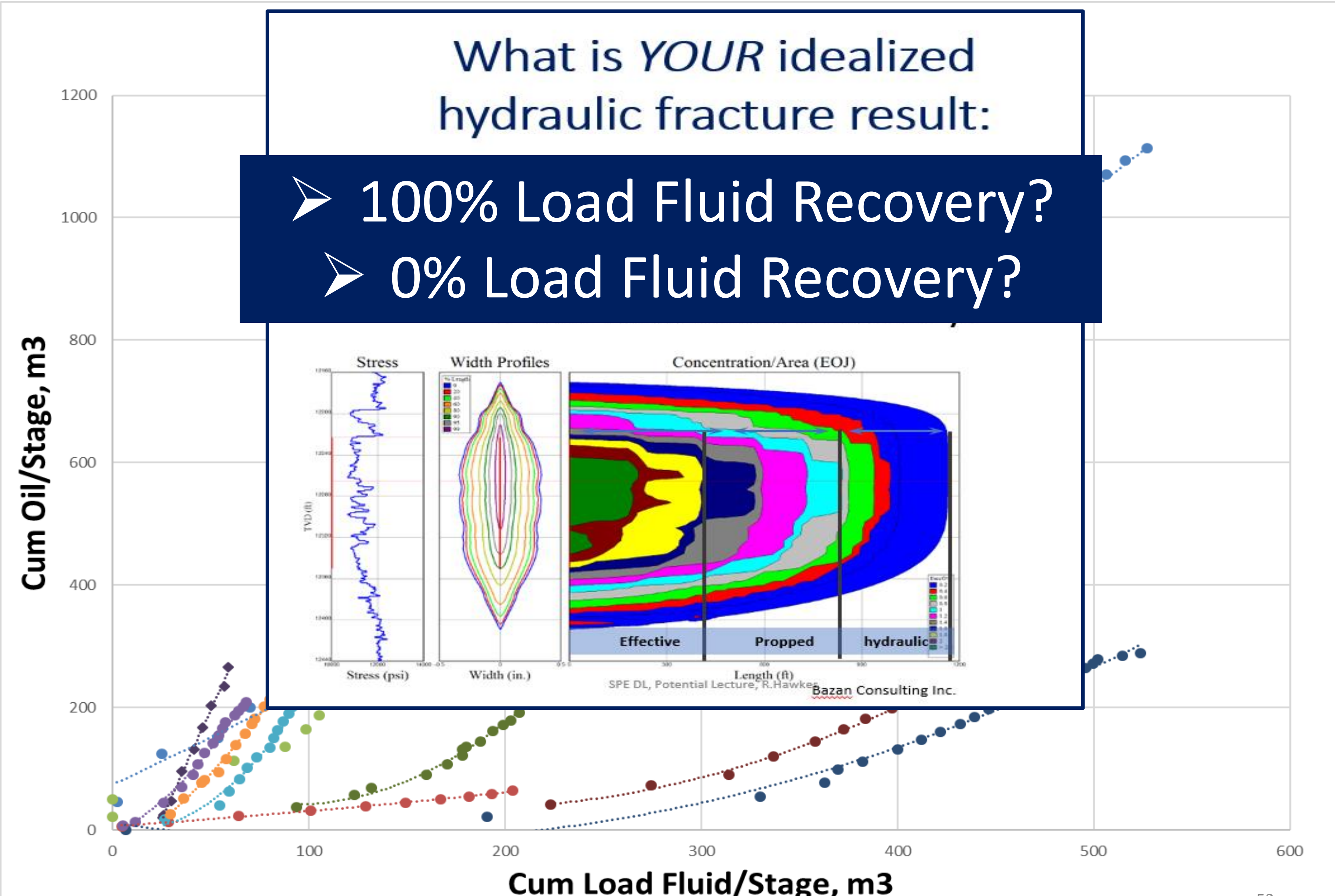
East Duvernay Oil Shale Completion

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?

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 un-propped 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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