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Vision to Prosperity: A New Energy Era Emerges

IPTC-19596: Compositional Tracking: Predicting Wellstream Compositions in Tight Unconventionals

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whitson

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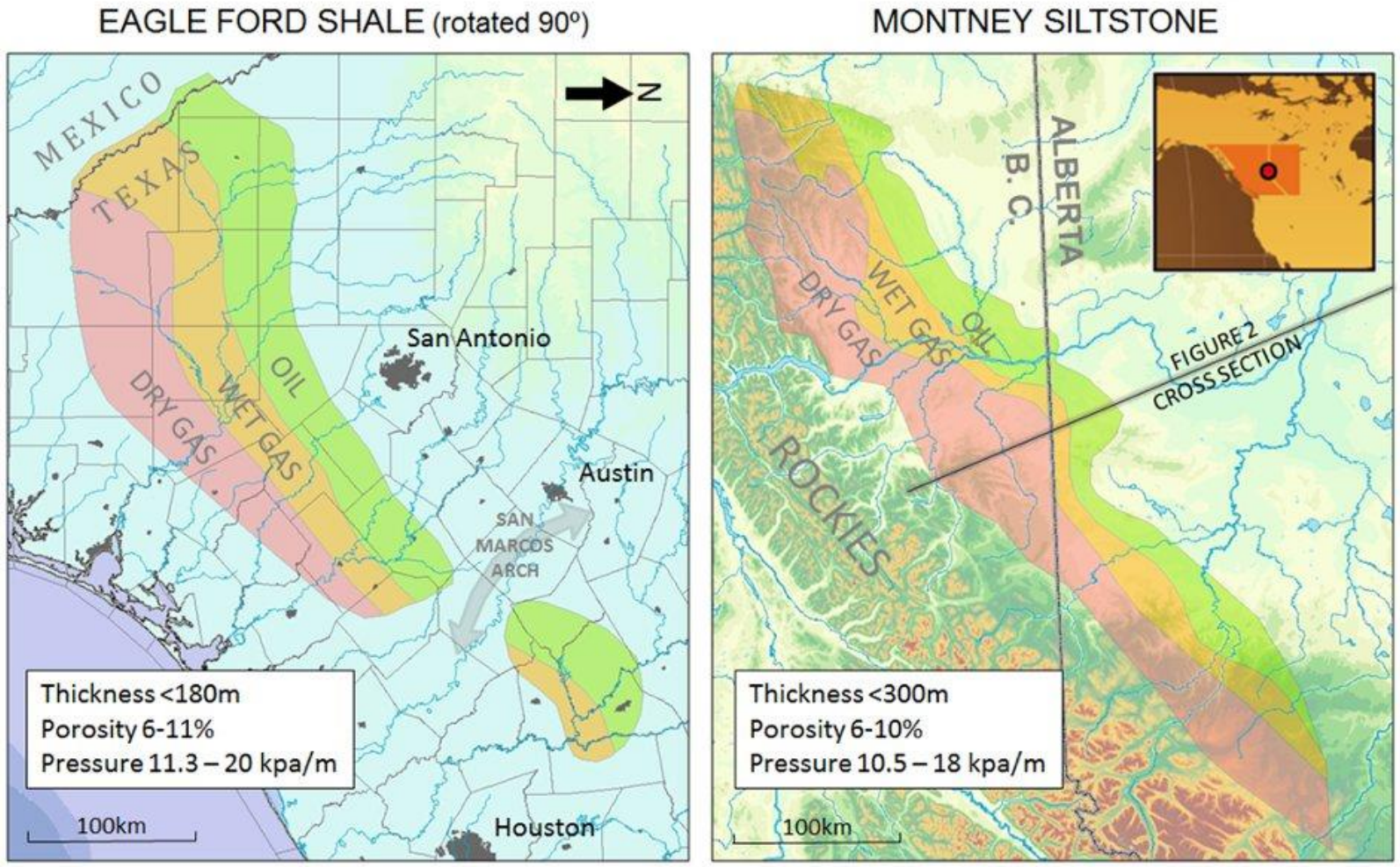
Agenda

- Tight Unconventionals
- Compositional Tracking “Crash Course”
- Examples
- Closing remarks …

1.Tight Unconventionals

“Shale” Basins Span a Wide Range of Fluids



“Unconventional” Well Performance

- Producing GOR strong function of
  - Flowing bottomhole pressure – GOR(p_{wf})
  - Degree of undersaturation
- “Conventional” reservoirs – GOR(p_{avg})

Sources: Whitson and Sunjerga 2012; Jones 2017

“Unconventional” Wells is Characterized by

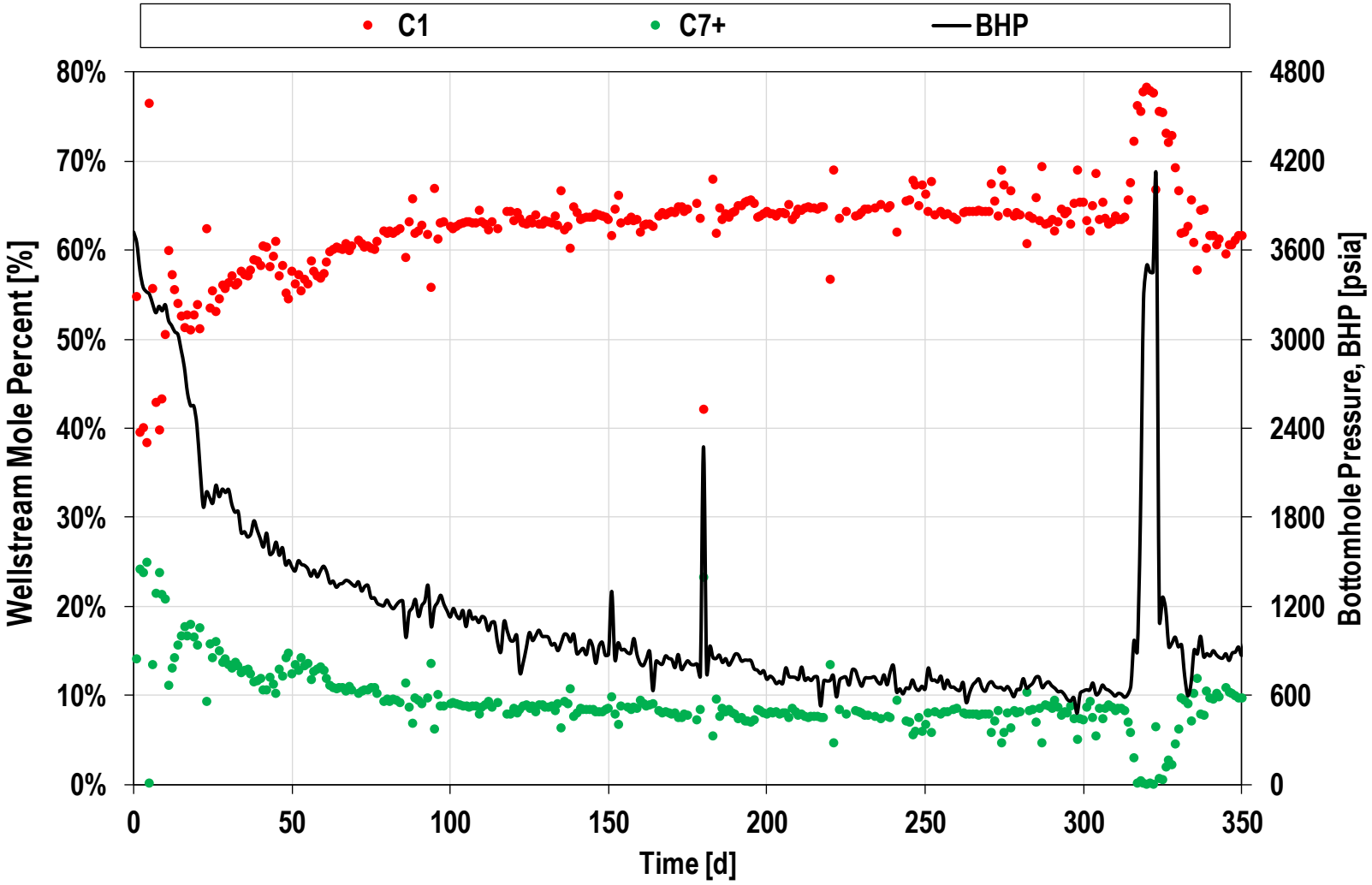
- Rapid decline in bottomhole pressure (p_{wf})
- Slightly undersaturated / saturated

→ rapid change in “produced fluid properties”

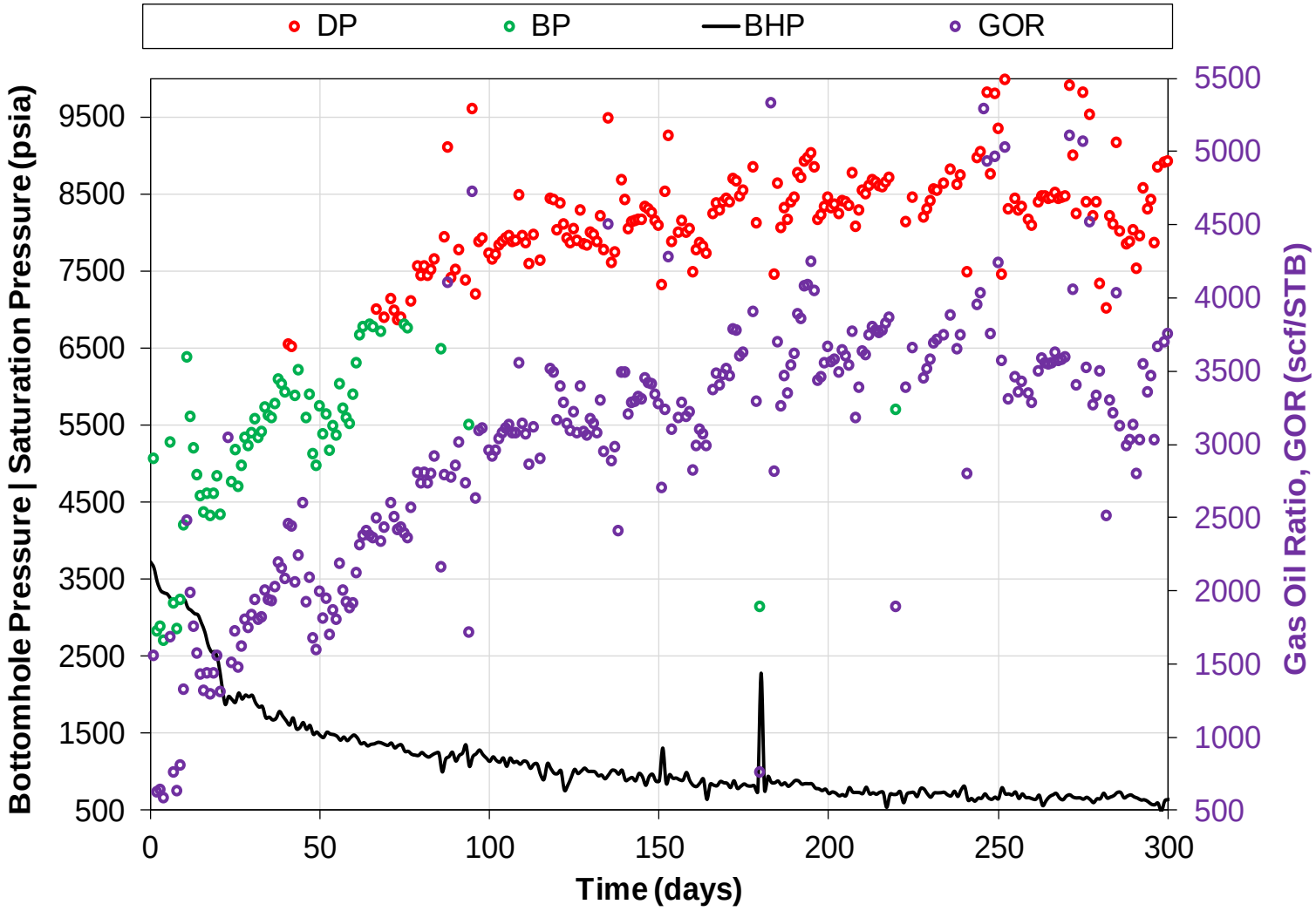
i.e. GOR | STO API

Source: Fluid Sampling in Tight Unconventionals (Carlsen et al. 2019)

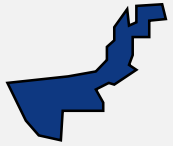
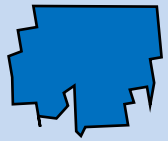
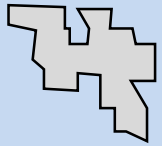
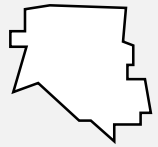
Rapid Decline in Flowing Bottomhole Pressure



Rapid Decline in Flowing Bottomhole Pressure



“Shale” Basins have areas saturated/

Basin	
	Eagle Ford
	Bakken
	Montney
	SCOOP/STACK
	Permian

Producing GOR and API change – what does it mean?

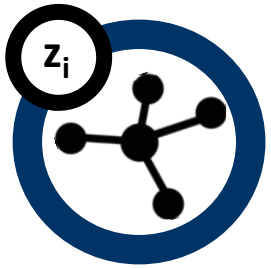
Produced compositions are changing!

Video?

2.Compositional Tracking – “Crash Course”

What is a Composition?

"The amount of different components"

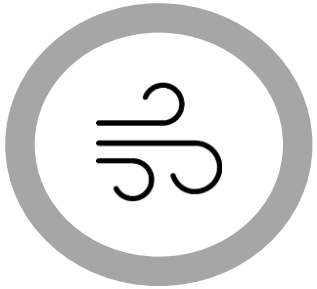
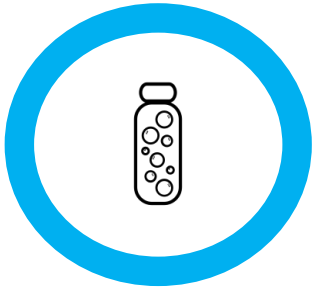


usually expressed in mol%

$$z_i = n_i \,/ \sum_j n_j \;|\; y_i = n_{Vi} \,/ \sum_j n_{vj} \;|\; x_i = n_{Li} \,/ \sum_j n_{Lj}$$

Total *Vapor* *Liquid*

What is a Composition?

Air	Sparkling Water	Petroleum Fluids
		
z_i	z_i	z_i
N_2 = 78%	H_2O = 99%	C_1
O_2 = 21%	CO_2 = 1%	C_2
...	...	...
		C_{7+}
Total = 100%	**Total = 100%**	**Total = 100%**

What is a Wellstream Composition?

Wellstream:
composition a well produces
at one point in time

Wellstream compositions ≠
in-situ representative fluid compositions

“Representative” Compositions

“In-situ Representative” Composition

- A sample representative of original fluid(s) in place

“Reservoir Representative” Composition

- Any uncontaminated composition produced from a reservoir

What is “Compositional Tracking”?

=How produced wellstream compositions change with time

- Non-hydrocarbons (H_2S, CO_2, N_2)
- Known hydrocarbons (C_1, C_2, …, C_6)
- Single carbon number components (C_{7+})

Compositional Tracking – Why?

- Indicate …
  - $p_{wf} < p_{sat}$
  - Production from layers w/ different z_i?
  - Gas coning (conventional reservoirs)
- Assist in history matching

Compositional Tracking – Why?

- Consistent well-to-well comparison
- Gas | oil allocation to individual wells
- Condensate tracking
  - Relative contributions from gas cap
- Assist in Fluid Initialization (R_{si} | r_{si})

Compositional Tracking – Why?

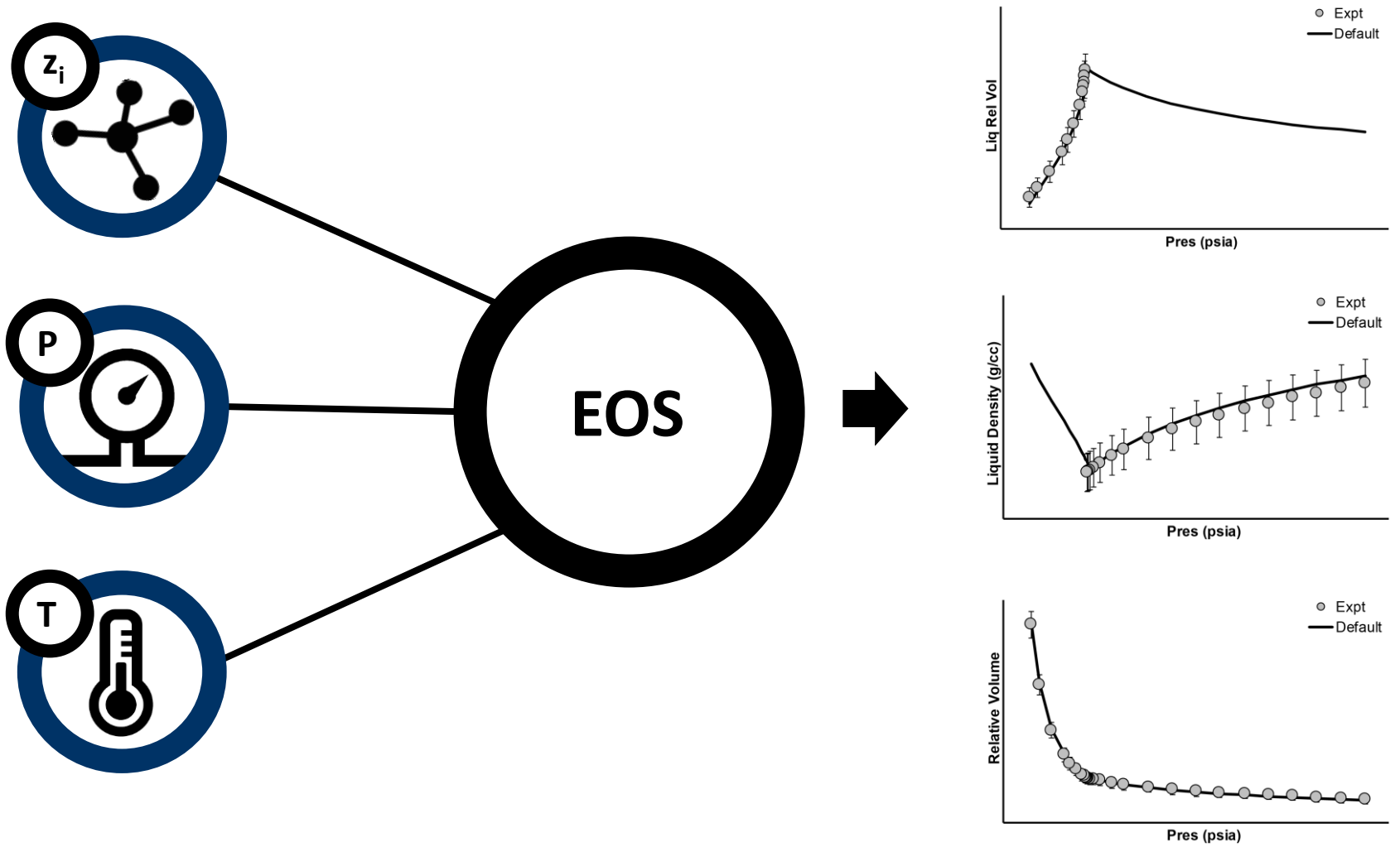
- Understand compositionally sensitive processes
  - e.g. gas EOR, condensate blockage
- Separator optimization
- +++

Compositional Tracking – Three Methods …

Difference in what data you have available

Method	1. Production Data Only	2. Limited Welltest Data	3. Extensive Welltest Data
Data Available	Separator GOR Separator Pressure Separator Temperature	Separator Gas Compositions Stock-Tank Liquid API Separator GOR Separator Pressure Separator Temperature	Separator Gas Compositions Separator Oil Compositions Separator GOR Separator Pressure Separator Temperature
Cost	-	~ 200-800 USD	~1000-3000 USD

What is an EOS Model?



1. Production Data Only (Hoda & Whitson, 2013)

Requirements:

- A properly tuned EOS Model
- "Seed feed" – estimate of z_i
- Separator rates (GOR_{sep})
- Separator conditions (p_{sep}, T_{sep})

1. Production Data Only (Hoda & Whitson, 2013)

Method:

- Flash "seed feed" to p_{sep} | T_{sep} → y_i, x_i
- Recombine y_i | x_i at GOR_{sep} → z_i

$$n_i = x_i\left(\frac{q_{om}}{v_o}\right) + y_i\left(\frac{q_{gm}}{v_g}\right)$$

v: molar volume – M/ρ (calculated from EOS model)

2. Limited Welltest Data (Whitson & Sunjerga, 2012)

Requirements:

- A properly tuned EOS Model
- Separator gas composition – y_i
- Stock-tank liquid API - γ_{API}
- Separator rates (GOR_{sep})
- Separator conditions (p_{sep}, T_{sep})

2. Limited Welltest Data (Whitson & Sunjerga, 2012)

Method:

Regress until z_i + EOS matches

- Sep. gas. (yi) ≈ N_2, CO_2, C_1, …,C_6
- Sep. GOR ≈ C_{7+} amounts
- Liquid API ≈ C_{7+} component distribution

2. Limited Welltest Data (Whitson & Sunjerga, 2012)

Method:

N+2 knowns: y_i | GOR_{sep} | γ_{API}

N+2 unknowns: z_i | F_g | MW_{C7+}

C_{7+} characterization:

Field-wide gamma model (α=fixed, η=fixed)

MW_{C7+} regression variable

3. Extensive Welltest Data

Requirements:

- A properly tuned EOS Model
- Separator gas composition – y_i (up to C_{7+})
- Separator oil composition – x_i (up to C_{7+})
- Separator rates (GOR_{sep})
- Separator conditions (p_{sep}, T_{sep})

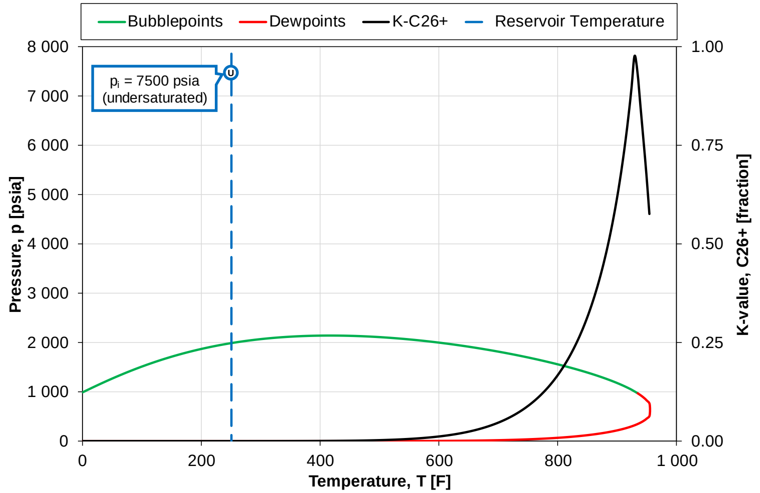
3. Extensive Welltest Data

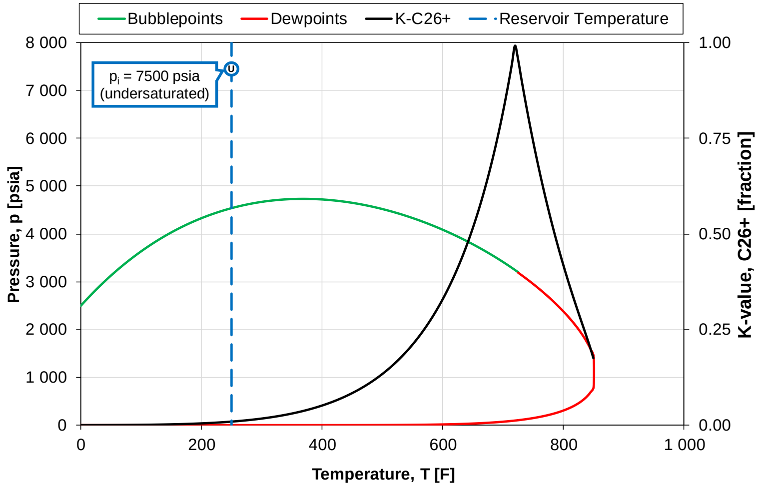
Method:

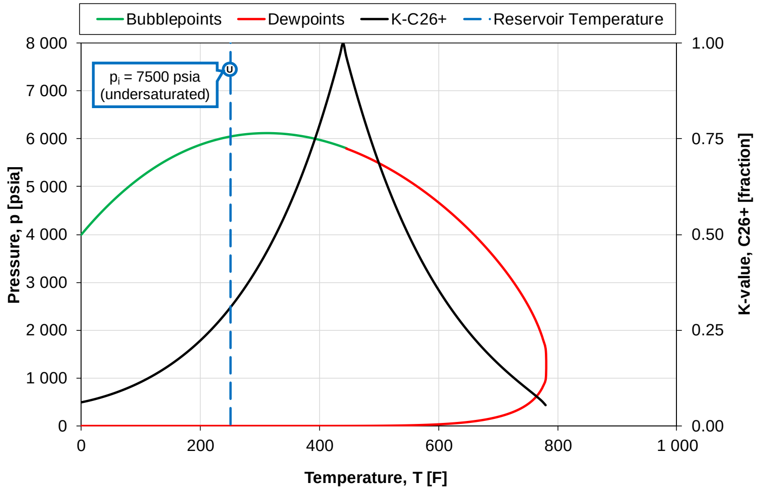
- Sep. comp in equilibrium? – Hoffman-Plot
- Split x_{7+} to x_{n+} (e.g. x_{36+}) w/ gamma model
- Split y_{7+} to y_{n+} (e.g. y_{36+}) w/ gamma model
- Recombine x_i and y_i at GOR_{sep} at p_{sep}, T_{sep}

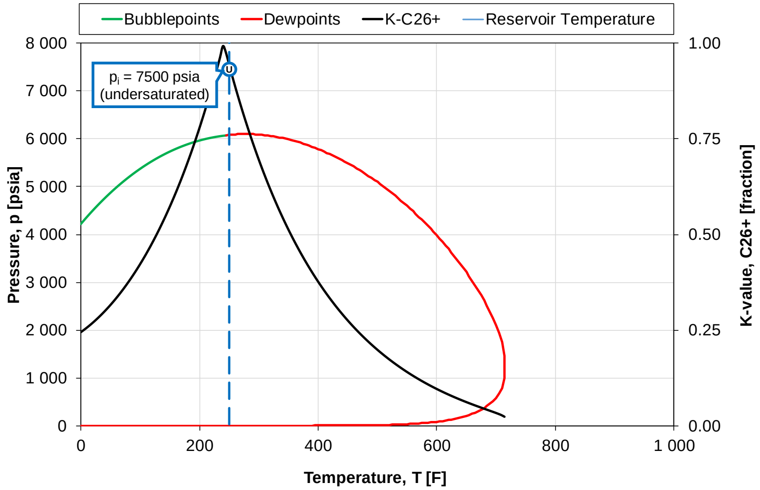
3.Examples

Example: Simulated Data









Example: Simulated Data

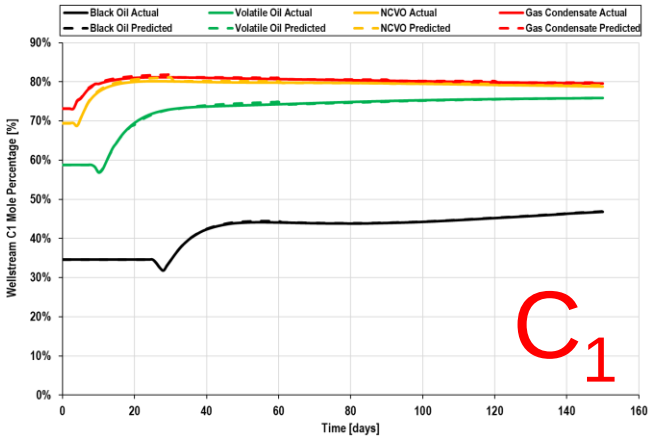
Black Oil

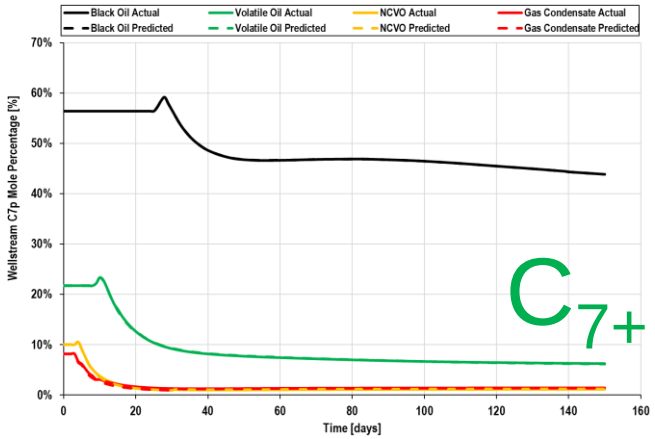
Volatile Oil

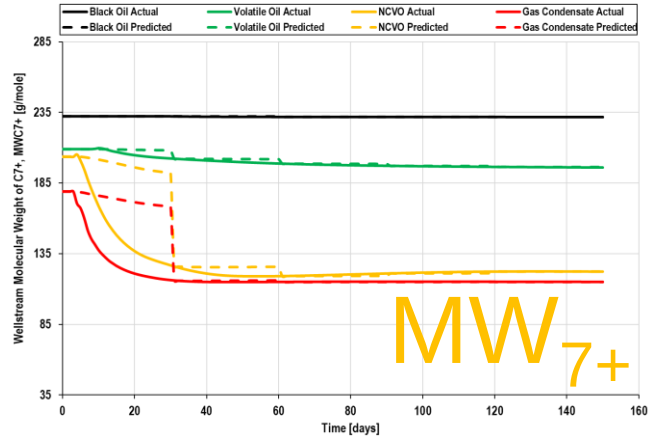
Near Critical Volatile Oil

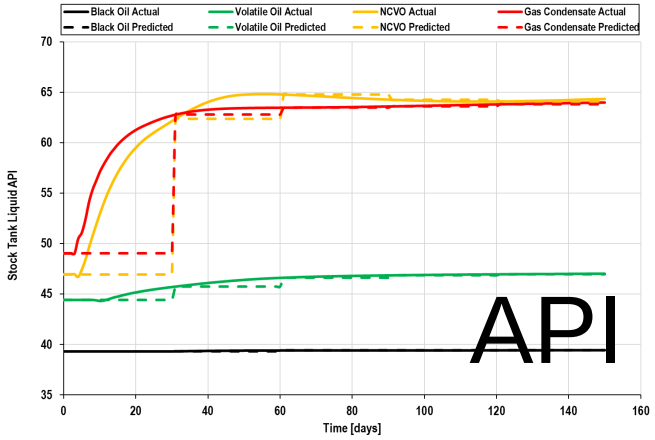
Near Critical Gas Condensate

Example: Method 1



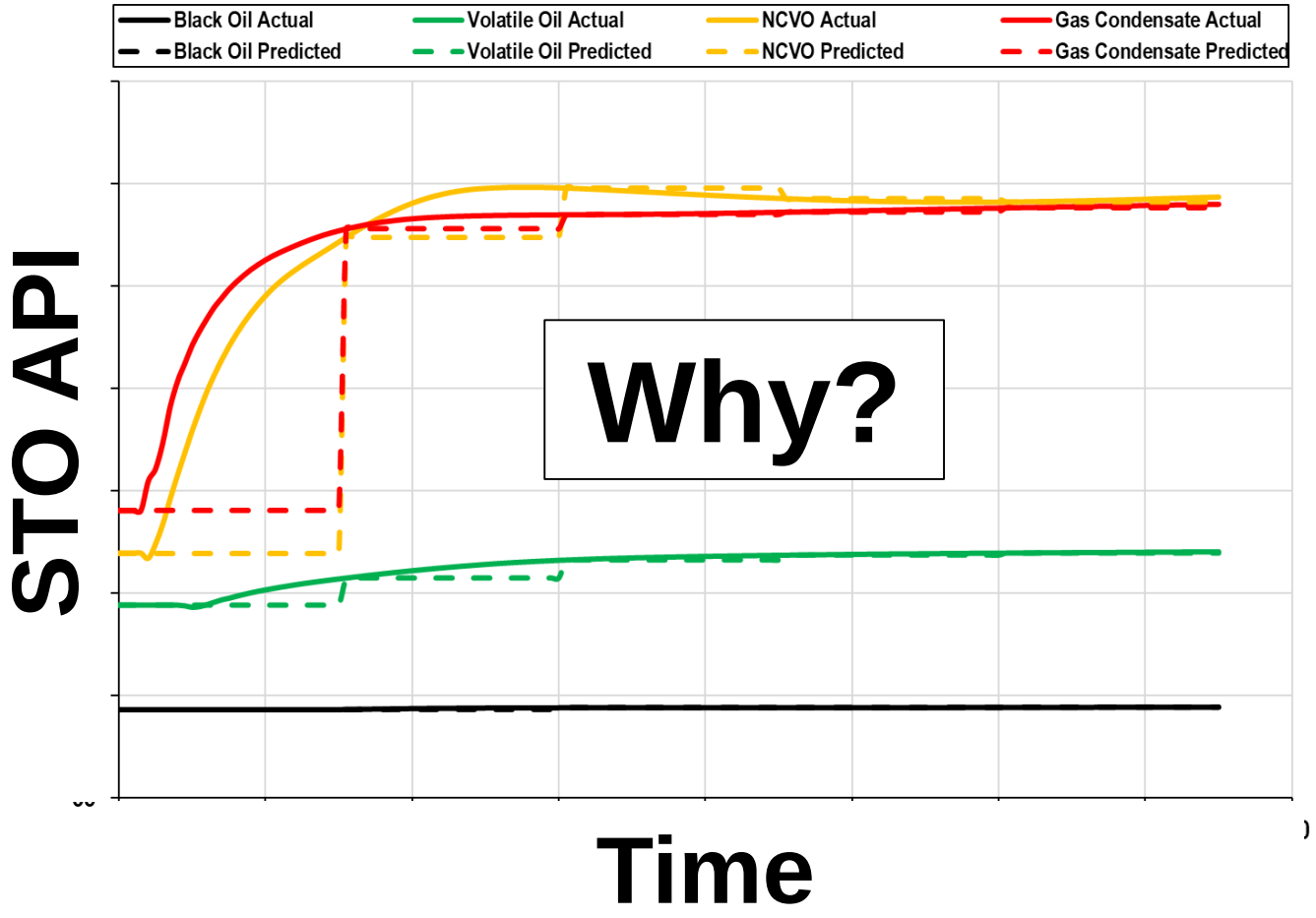






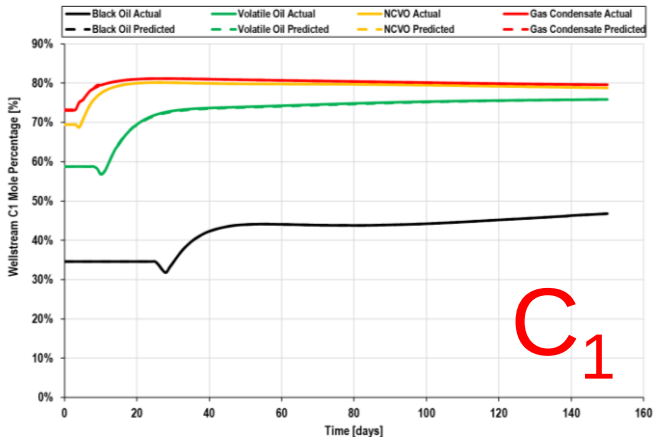
- C_1: Accurate
- C_{7+}: Accurate
- MW_{7+}: ***Not*** accurate for GC and VO
- API: ***Not*** accurate for GC and VO

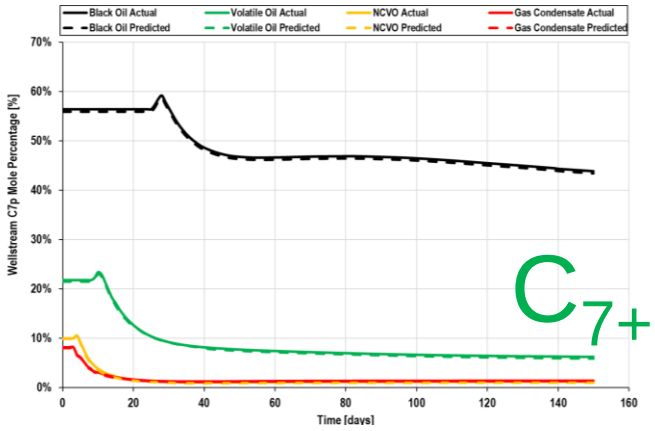
Example: Method 1

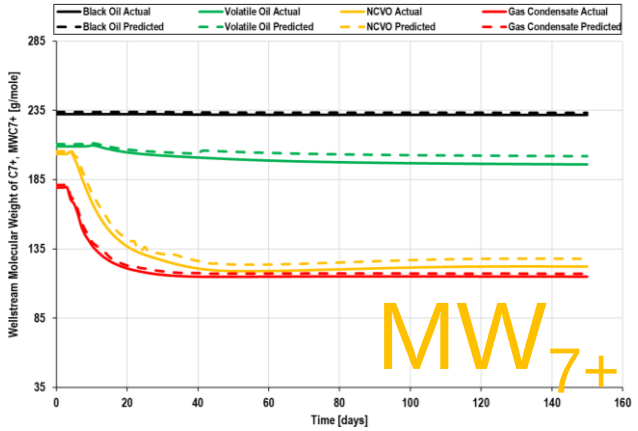


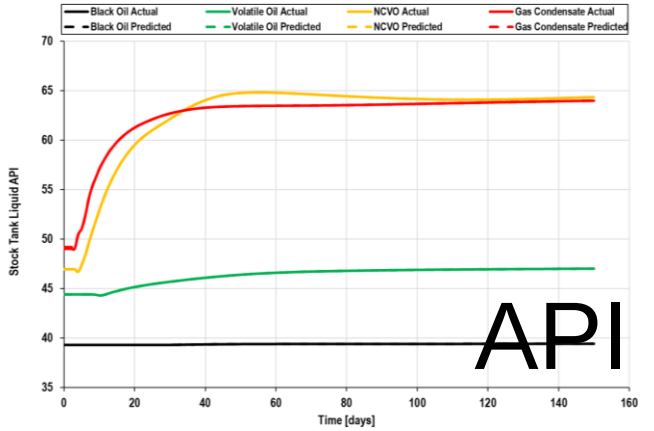
- C_1: Accurate
- C_{7+}: Accurate
- MW_{7+}: ***Not*** accurate for GC and VO
- API: ***Not*** accurate for GC and VO

Example: Method 2



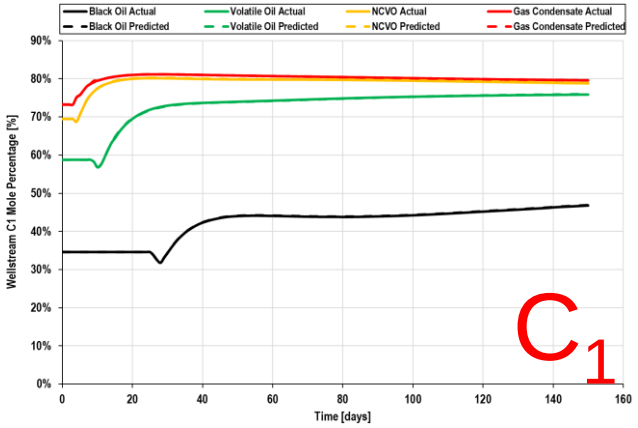


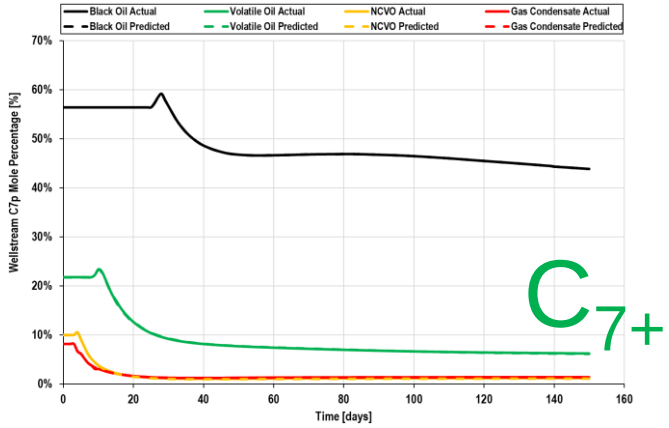


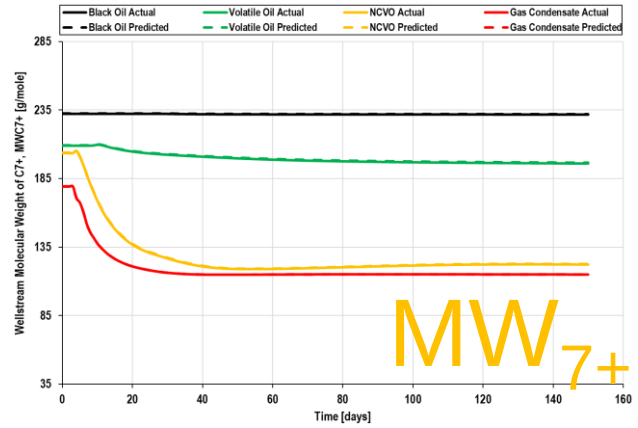


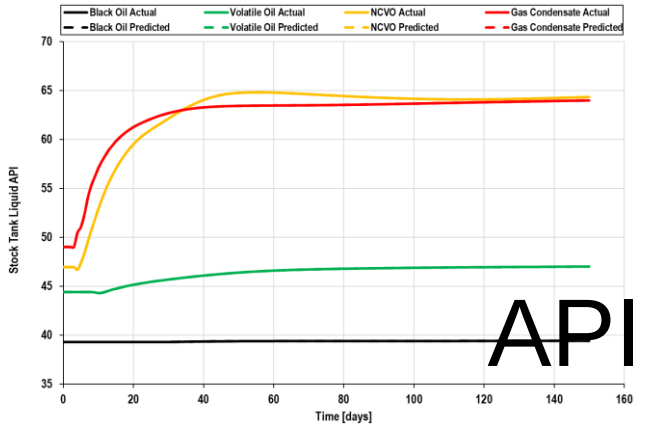
- C_1: Spot on
- C_{7+}: Accurate
- MW_{7+}: Accurate
- API: Spot on

Example: Method 3



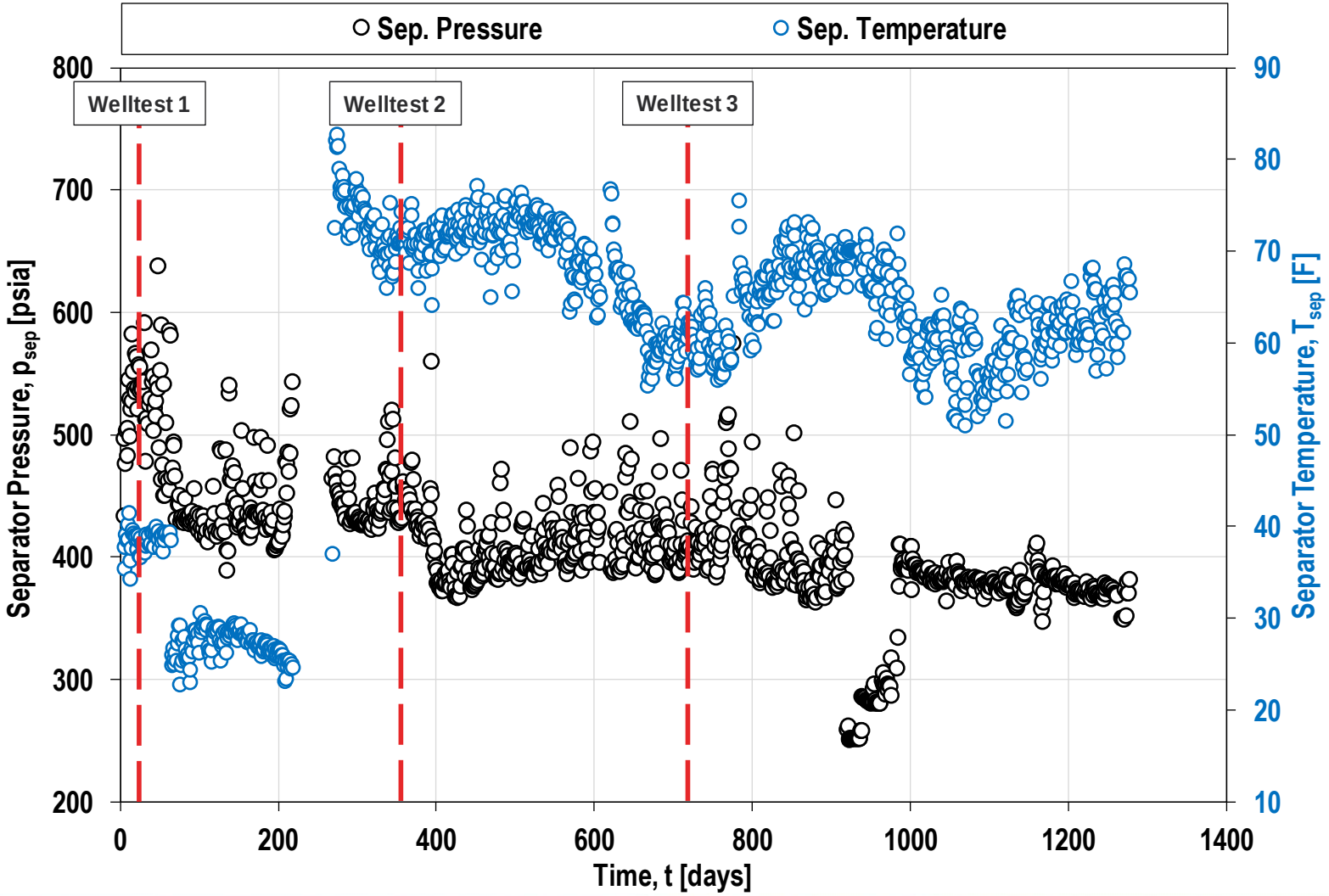






- C_1: Spot on
- C_{7+}: Spot on
- MW_{7+}: Spot on
- API: Spot on

Example: Field Example



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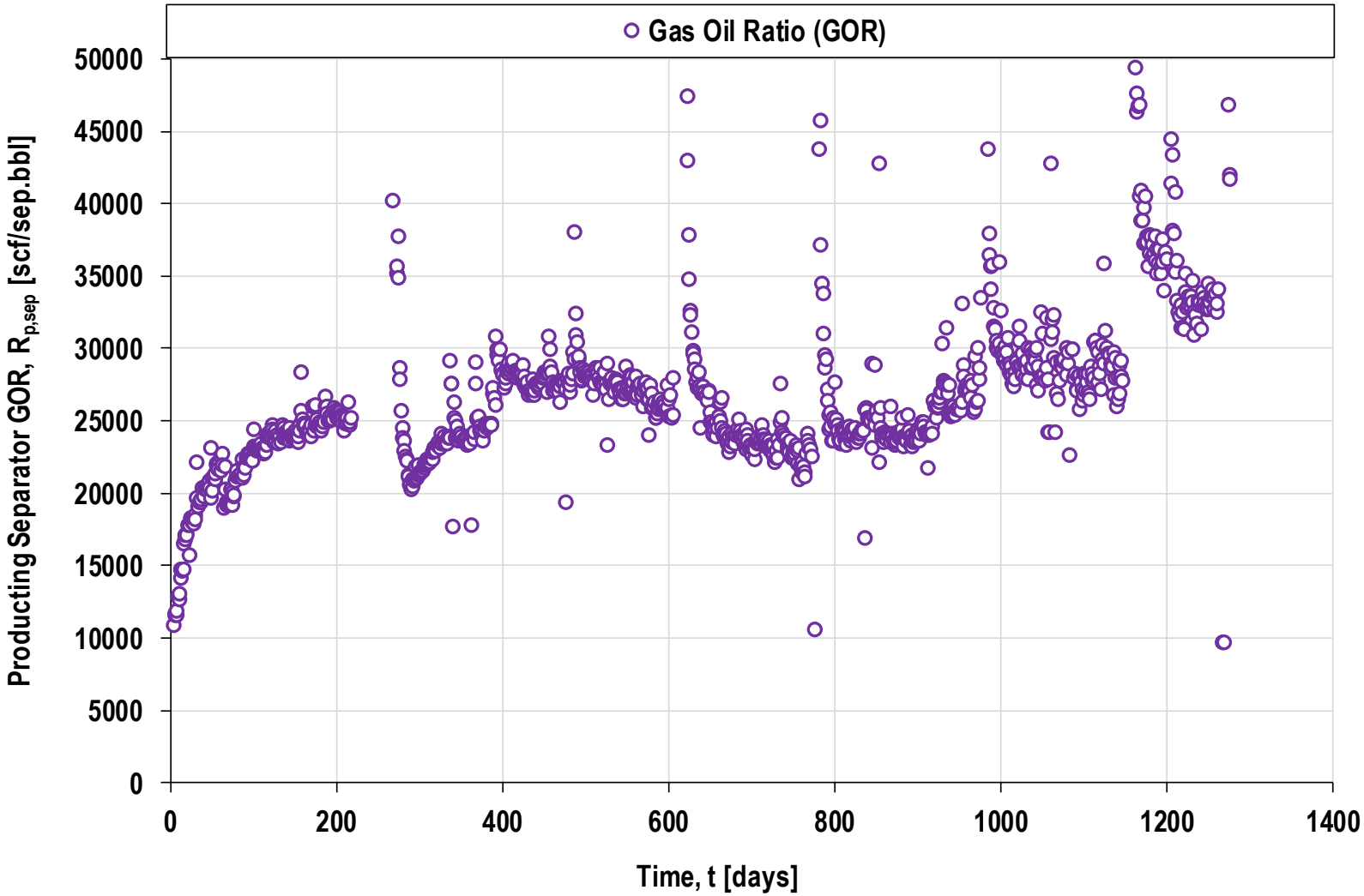

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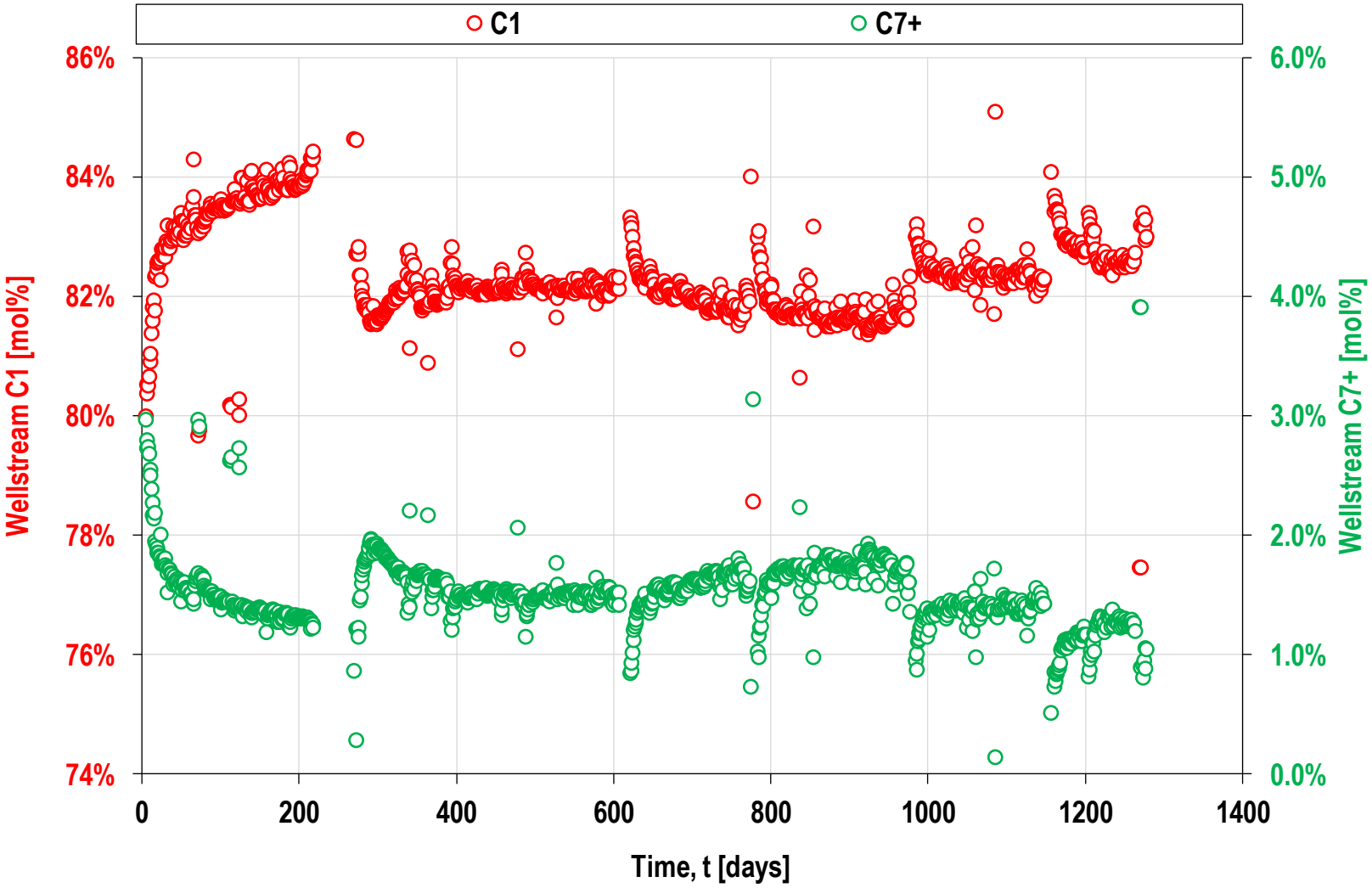

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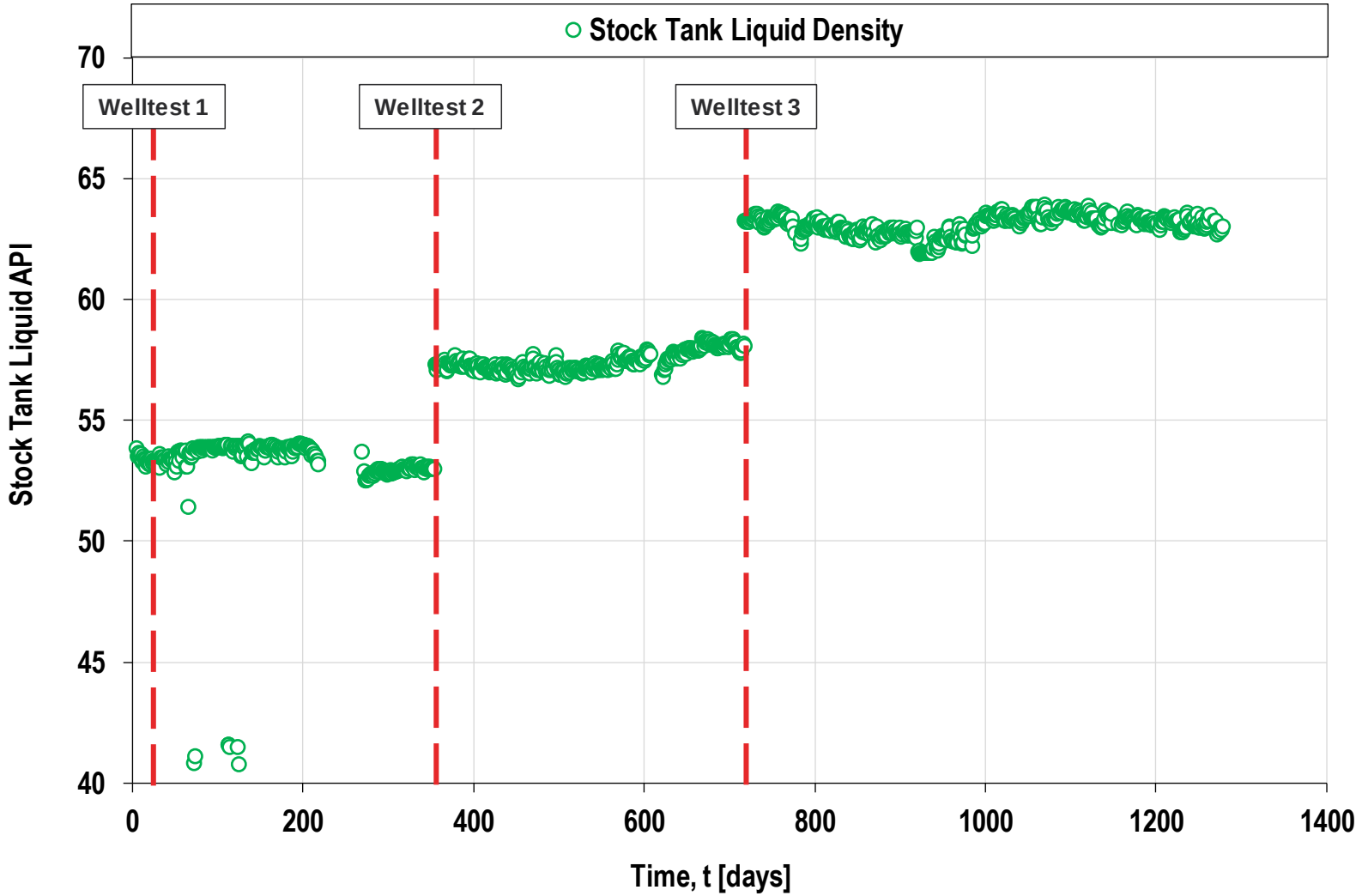

4. Closing Remarks

Closing Remarks …

- Methodologies: Accurate, reliable and cost-efficient daily wellstream compositions
- Accuracy – function(data, quality, EOS)
- Different methods for different available data
- Rapid change in producing GOR = update “seed feed” by collecting more data

Thank You

Innovation Norway

Norwegian Research Council

Colleagues at **whitson**