PERA

A-to-Z

of

Preparing Oil & Gas PVT Data

for

Reservoir Simulation

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NTNU / PERA

PERA

Tasks

- Collecting samples.
- Which PVT lab tests to use.
- Designing special PVT studies.
- Quality controlling PVT data.
- Heptanes-plus data and characterization.
- Initial EOS model.
- Tuning an EOS model.
- Viscosities.
- Fluid initialization.
- Minimizing number of EOS components.
- Black-oil PVT tables.

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Collecting Samples

Why?

1. **PVT data to develop a model.**

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Collecting Samples

Why?

1. PVT data to develop a model.

2. Compositions for fluid initialization.

Collecting Samples

Why?

1. PVT data to develop a model.
2. Compositions for fluid initialization.
3. Crude assays for process design.

Collecting Samples

How?

Oils

- Bottomhole samples.
- Surface separator samples.
- MDT / RCI

Gas Condensates

- Surface separator samples.
- MDT / RCI

Collecting Samples

How?

Oils

- Bottomhole samples.
- Surface separator samples.
- MDT / RCI

Gas Condensates

- Surface separator samples.
- MDT / RCI

Saturated Gas / Oil Systems

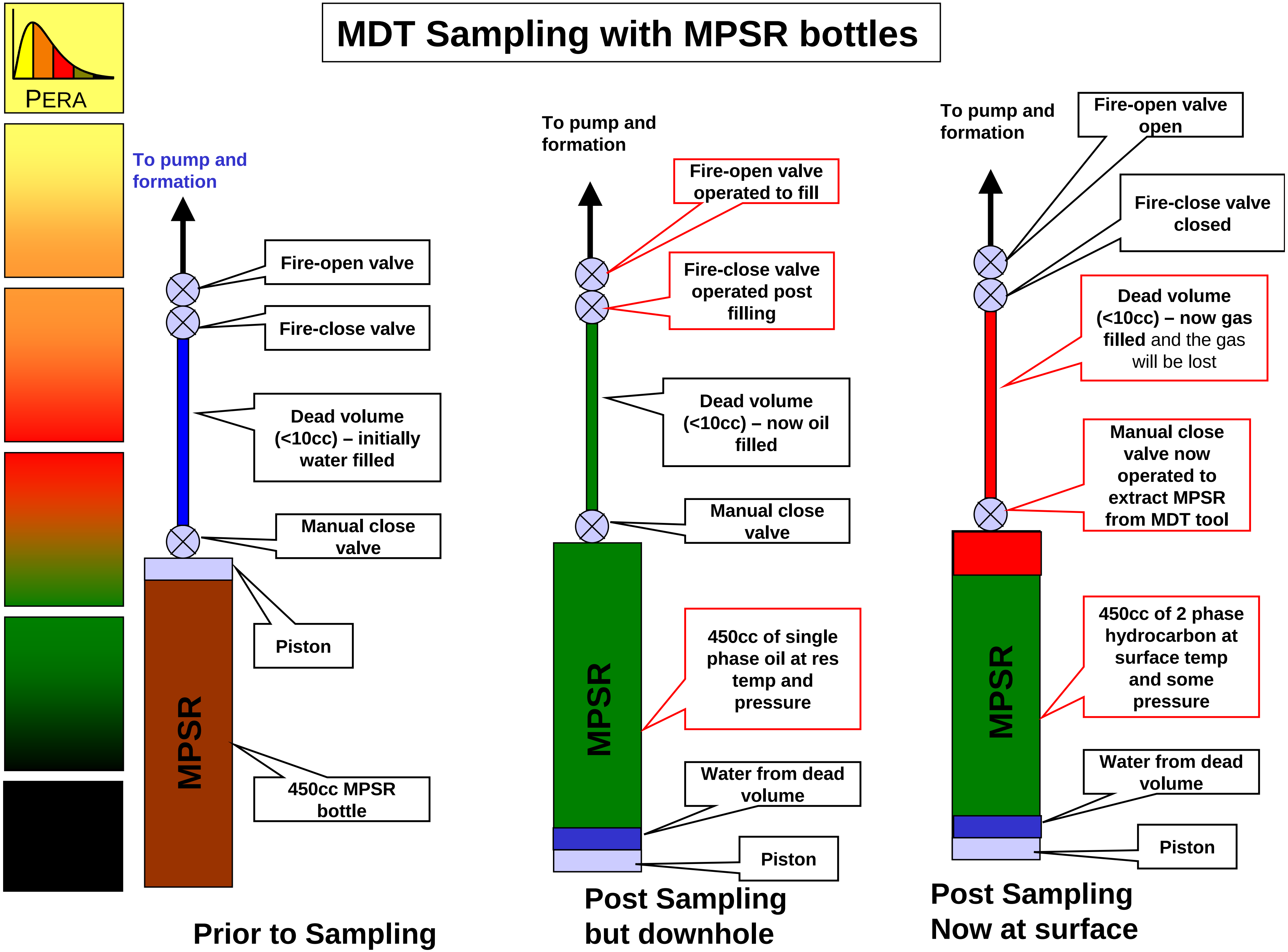
- Gas-cone an oil producer – *perfect!*.
- ECM (equilibrium contact mixing)

Open-hole Samplers

MDT / RCI

- **Potential Problems**
  - Oil-based muds.
    - *Oils -- OK for composition.*
    - *Gas condensates – OK for composition.*
  - Surface cooling before removal.
    - *Bubblepoint suppression.*

MDT Sampling with MPSR bottles



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Which PVT Lab Tests to Use

What are you simulating?

- **Depletion.**
- **Water injection.**
- **Condensate blockage.**
- **Gas injection.**
    - ***Miscible.***
    - ***Immiscible.***

Designing Special PVT Studies

- **Condensate Blockage.**
    - **Condensate viscosities.**
- **Miscible Gas Injection.**
    - **Through-critical swelling test.**
        - ***V_{ro}, compositions and K-values!***
- **Immiscible Gas Injection.**
    - **Vaporization tests.**

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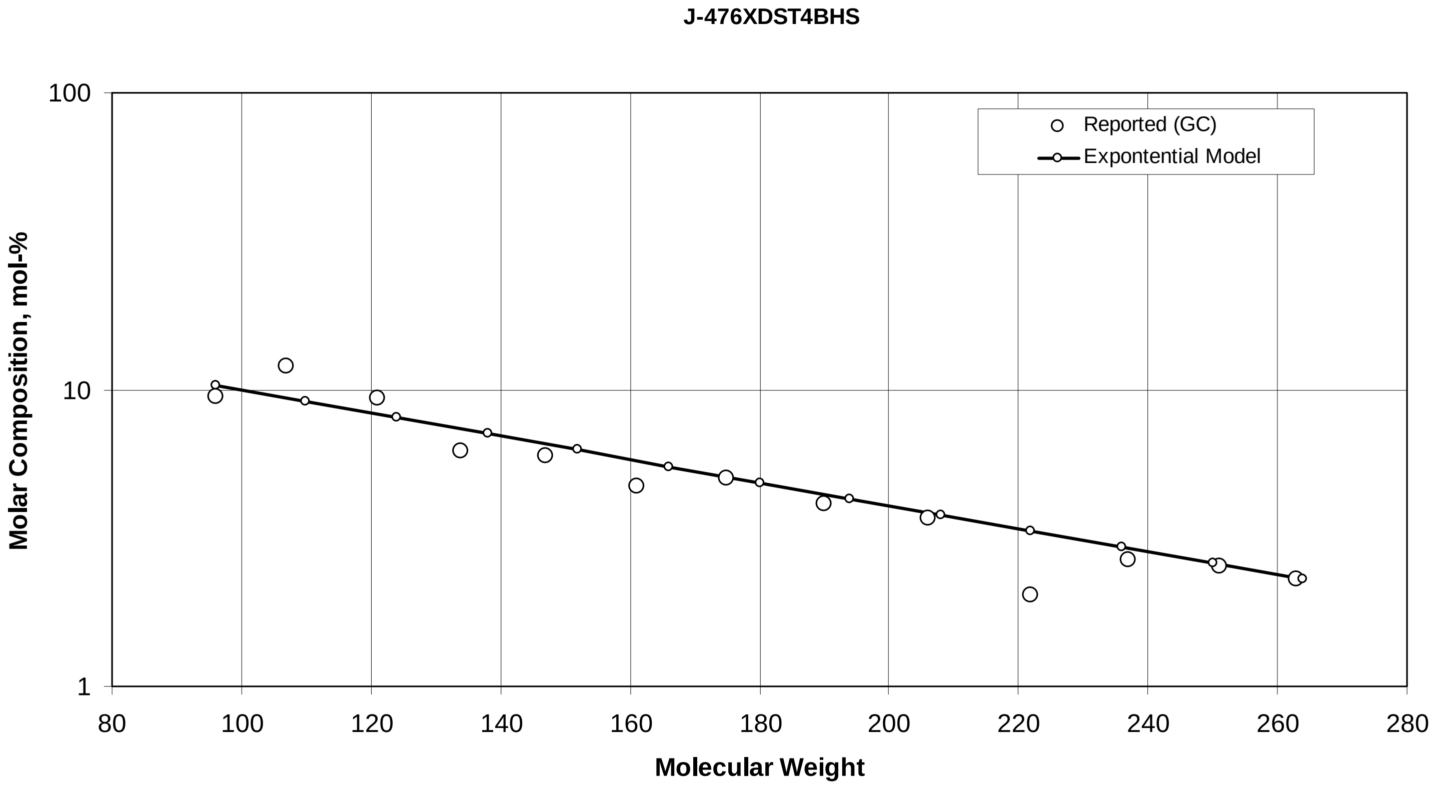
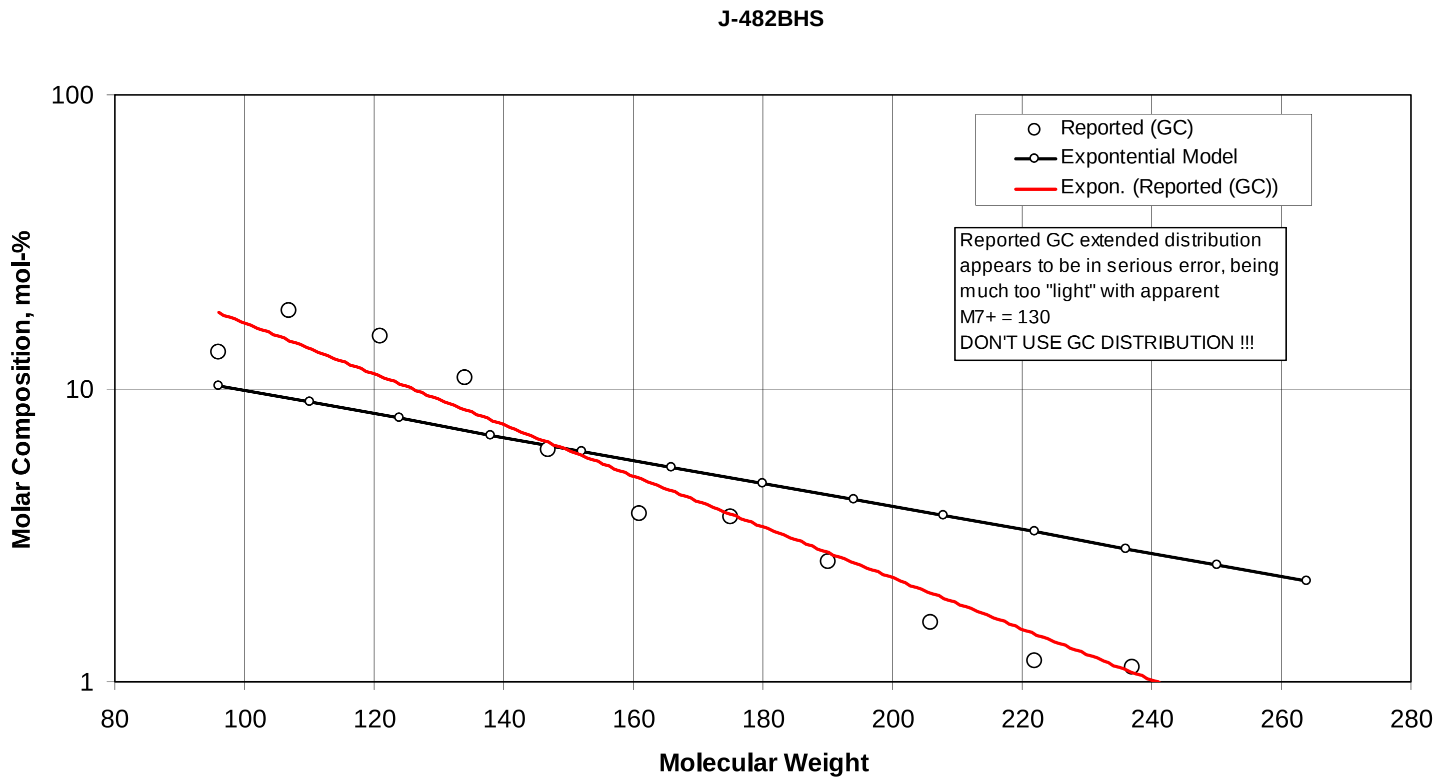
Quality Controlling PVT Data

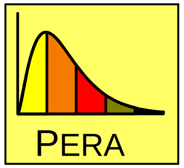
- **Compositions !!!**
  - Recombination.
  - Extended GC.
  - Mass-to-mole conversion.
- **C_{7+} properties.**
  - *Molecular weight* and specific gravity.
- **Use trend plots.**
  - P_s vs wt-% methane and/or C_{7+}.

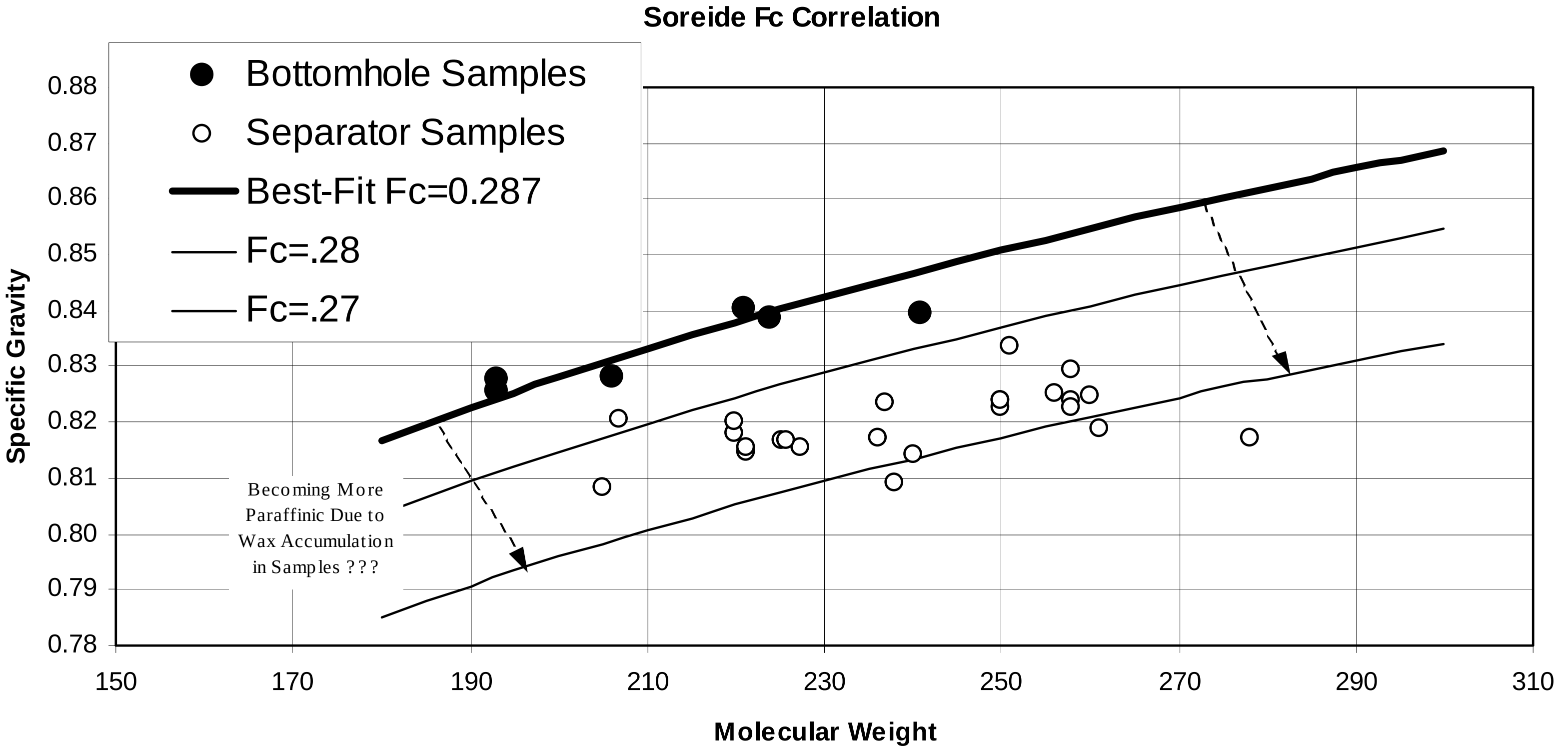

J-476XDST4BHS
Reported (GC)
Expontential Model
Molar Composition, mol-%
100
10
1
80
100
120
140
160
180
200
220
240
260
280
Molecular Weight

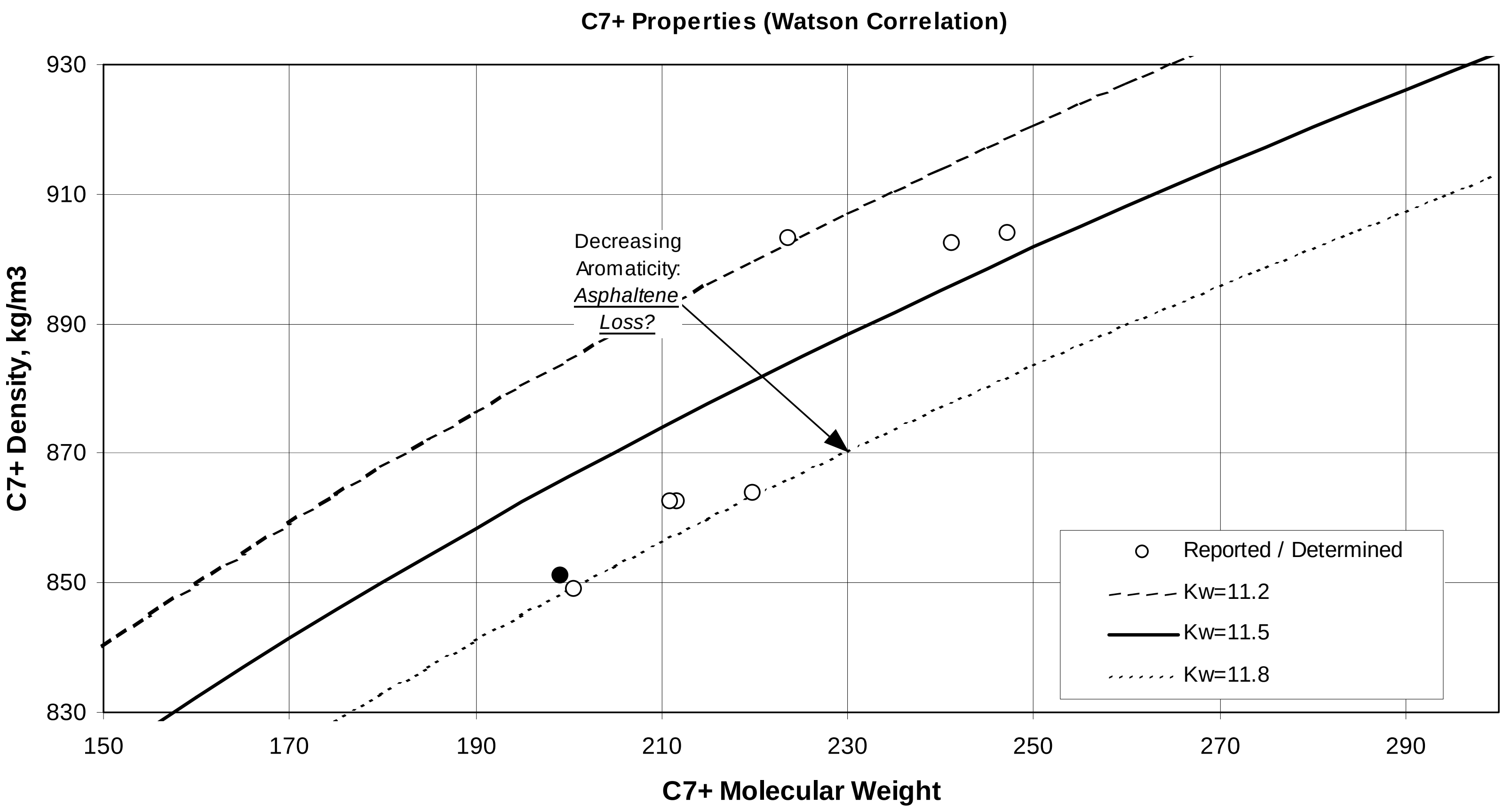

J-482BHS
100
10
1
80
100
120
140
160
180
200
220
240
260
280
Molar Composition, mol-%
Molecular Weight
Reported (GC)
Expontential Model
Expon. (Reported (GC))
Reported GC extended distribution appears to be in serious error, being much too "light" with apparent M7+ = 130
DON'T USE GC DISTRIBUTION !!!

C_{7+} Data and Characterization

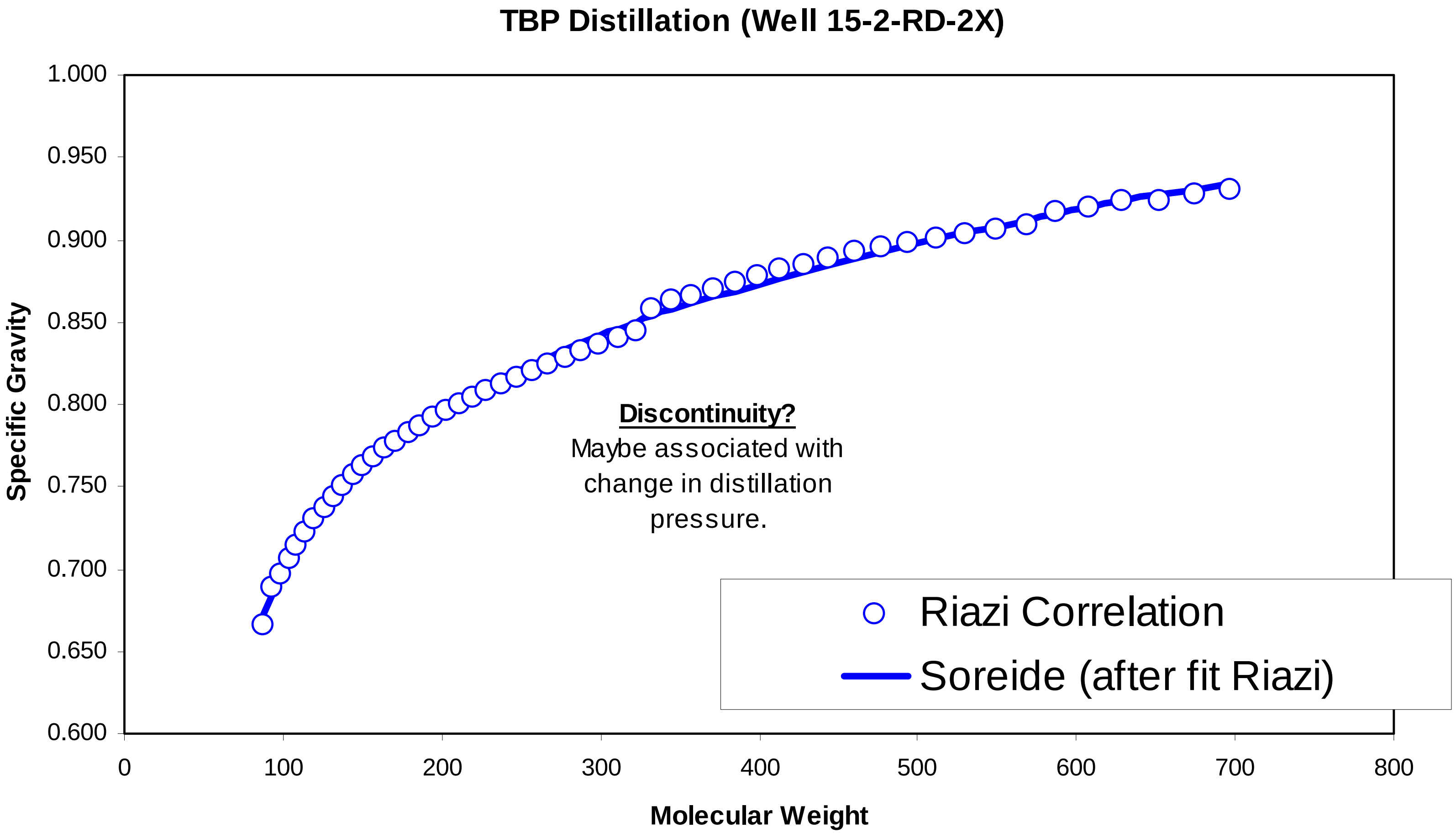
- **Correlate MW and SG of C_{7+}.**
  - Define trends & identify ”outliers”.
- **Use TBP Data.**
  - Gamma distribution model fit.
  - SCN MW-SG relationship.
  - Downstream Assay data always available.
- **Extended GC Data.**
  - Gamma distribution model fit.
    - *Ignore heaviest amount and MW.*


PERA


Soreide Fc Correlation
Bottomhole Samples
Separator Samples
Best-Fit Fc=0.287
Fc=.28
Fc=.27
Becoming More Paraffinic Due to Wax Accumulation in Samples ???
Specific Gravity
0.88
0.87
0.86
0.85
0.84
0.83
0.82
0.81
0.80
0.79
0.78
150
170
190
210
230
250
270
290
310
Molecular Weight


C7+ Properties (Watson Correlation)
C7+ Density, kg/m3
C7+ Molecular Weight
930
910
890
870
850
830
150
170
190
210
230
250
270
290
Decreasing
Aromaticity:
Asphaltene
Loss?
Reported / Determined
Kw=11.2
Kw=11.5
Kw=11.8

Assay Data



TBP Distillation (Well 15-2-RD-2X)
1.000
0.950
0.900
0.850
0.800
0.750
0.700
0.650
0.600
Specific Gravity
0
100
200
300
400
500
600
700
800
Molecular Weight
Discontinuity?
Maybe associated with change in distillation pressure.
Riazi Correlation
Soreide (after fit Riazi)

Initial EOS Model

- **Default Parameters – *don't mess with 'em*.**
  - C_{6-} properties M, T_c, p_c, ω.
  - C_{6-} properties volume shift s(=c/b).
  - Non-HC / HC BIPs k_{ij}.
- **C7+ Characterization.**
  - Minimum 3 fractions *(not C_7, C_8, C_{9+} !).*
  - Methane-C_{7+} BIPs.
  - SG-TB-MW relationship; T_c, p_c, $\omega(T_b)$.
  - Volume shift treatment $s(\gamma)$.
    - *Always keep fraction SGs "fit" by EOS.*

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Tuning an EOS Model

- **Densities Don't Need Regressing!**
- **What's Left to Fit?**
  - Nothing but *K-values* ... *but how ???*
- **Check Consistency!**
  - Monotonic K-values of hydrocarbons.
  - Three-phase existence (from EOS model).
    - *Serious problem for EOS models!*

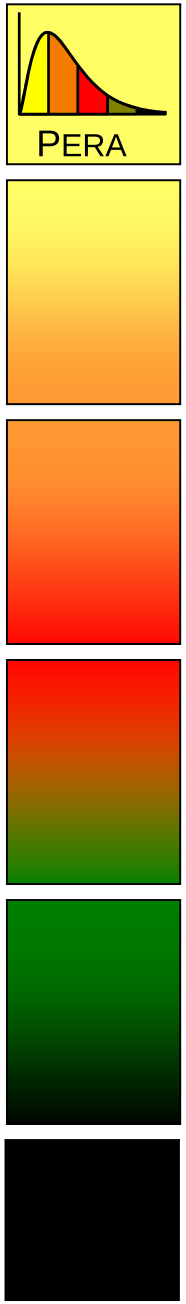
Viscosities

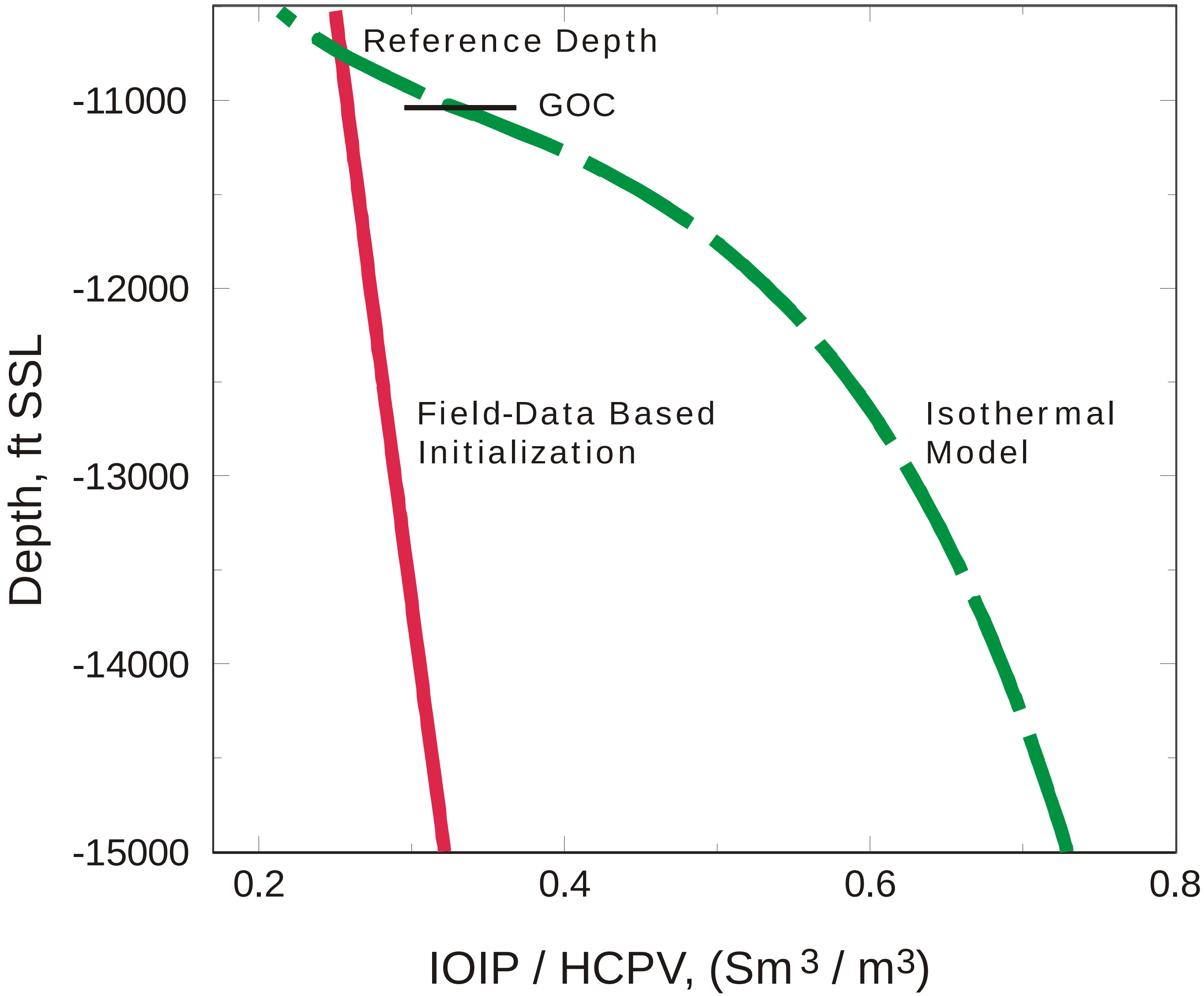
- **LBC** (Lorenz-Bray-Clark / Jossi-Thodos)
  - Need accurate densities.
  - Modify C_{7+} V_c values.
  - Make sure fraction viscosities are monotonic.
  - LBC polynomial coefficients.
    - *BE CAREFUL!*
- **Pedersen.**
  - Better predictions than LBC.
  - Regression - ?

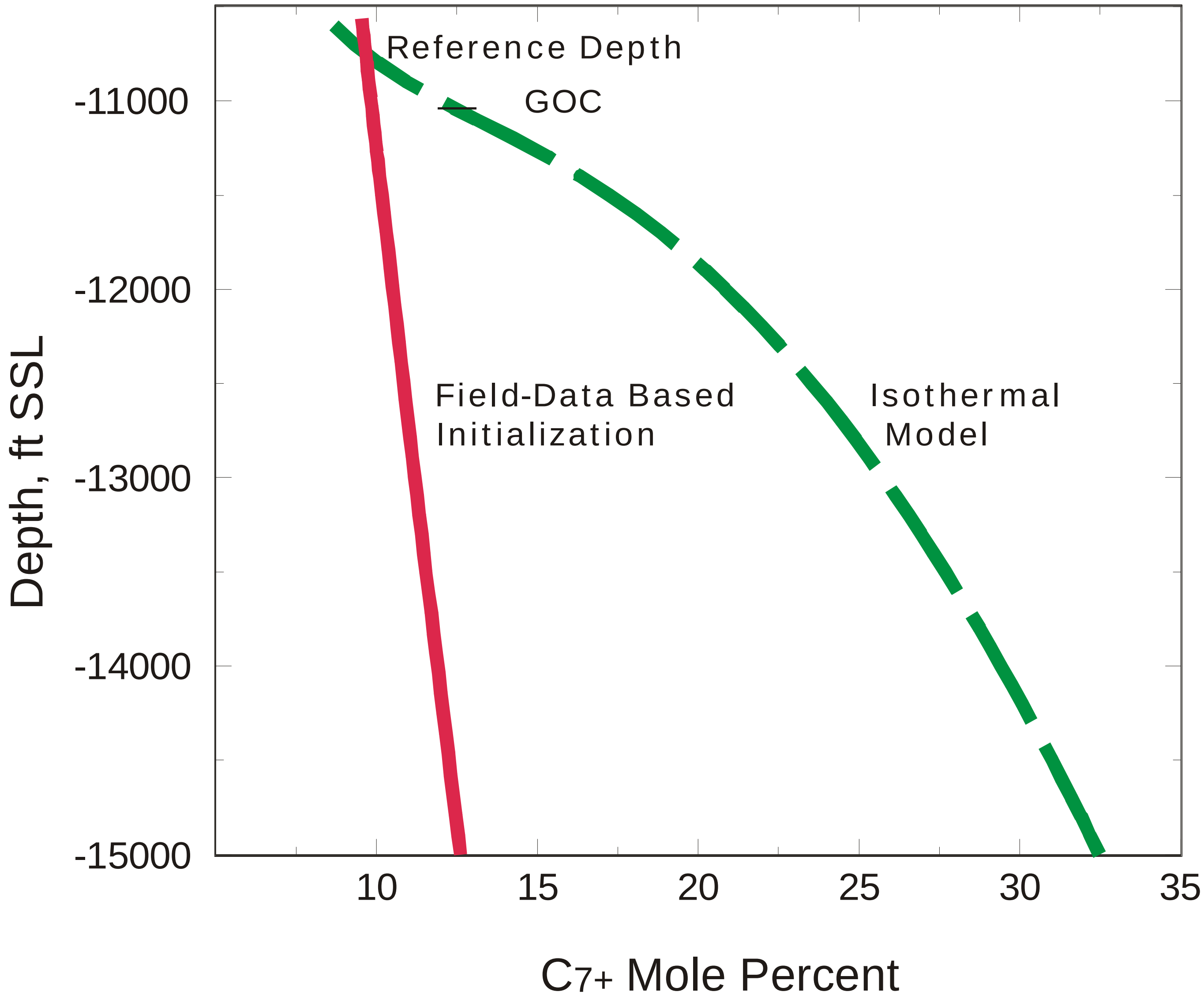
Fluid Initialization

- **Plot C_{6+} versus Depth.**
  - *Initial Oil in Place plot.*
  - Use error bars.
    - *Depth and composition.*

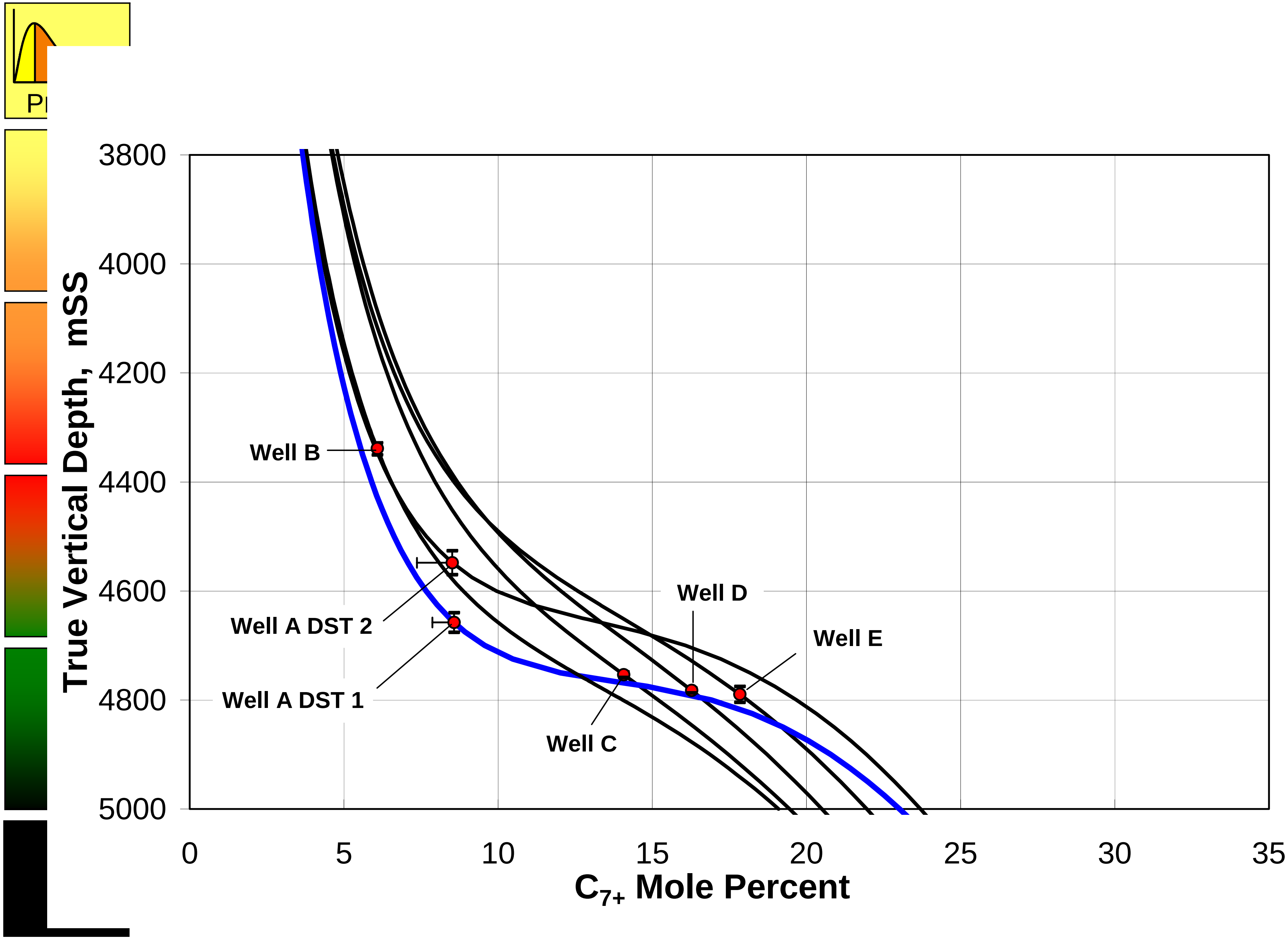
- **Uncertainty Analysis.**
  - Use isothermal gradient model.
    - *Defines maximum compositional variation.*
  - Use constant composition.
    - *Defines minimum compositional variation.*



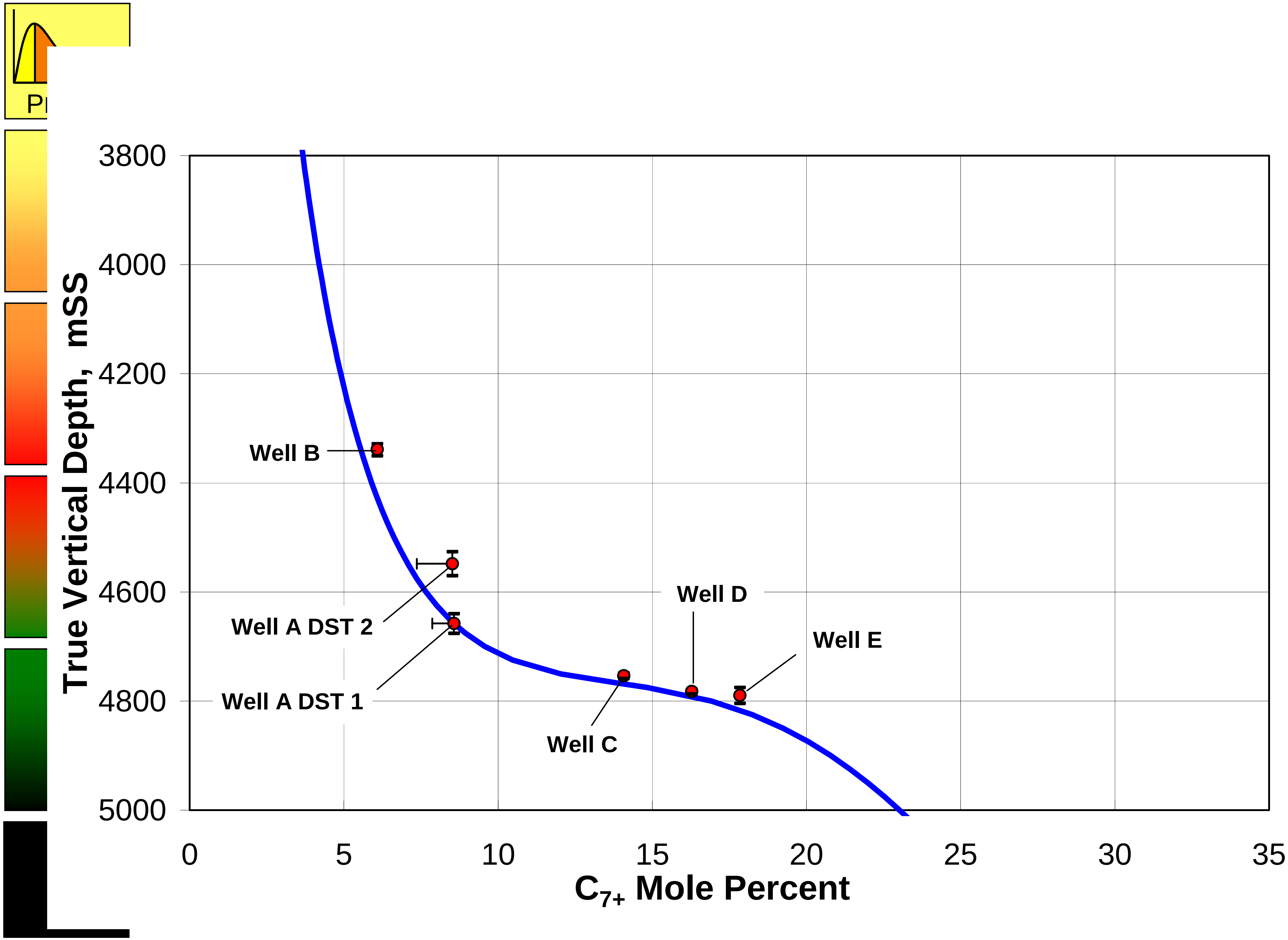

Reference Depth
GOC
Field-Data Based
Initialization
Isothermal
Model
-11000
-12000
-13000
-14000
-15000
Depth, ft SSL
0.2
0.4
0.6
0.8
IOIP / HCPV, (Sm3 / m3)



Reference Depth
GOC
Field-Data Based
Initialization
Isothermal
Model
-11000
-12000
-13000
-14000
-15000
Depth, ft SSL
10
15
20
25
30
35
C7+ Mole Percent



Pr
3800
4000
4200
4400
4600
4800
5000
True Vertical Depth, mSS
Well B
Well A DST 2
Well A DST 1
Well C
Well D
Well E
0
5
10
15
20
25
30
35
C_{7+} Mole Percent



Pr
True Vertical Depth, mSS
3800
4000
4200
4400
4600
4800
5000
Well B
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Well C
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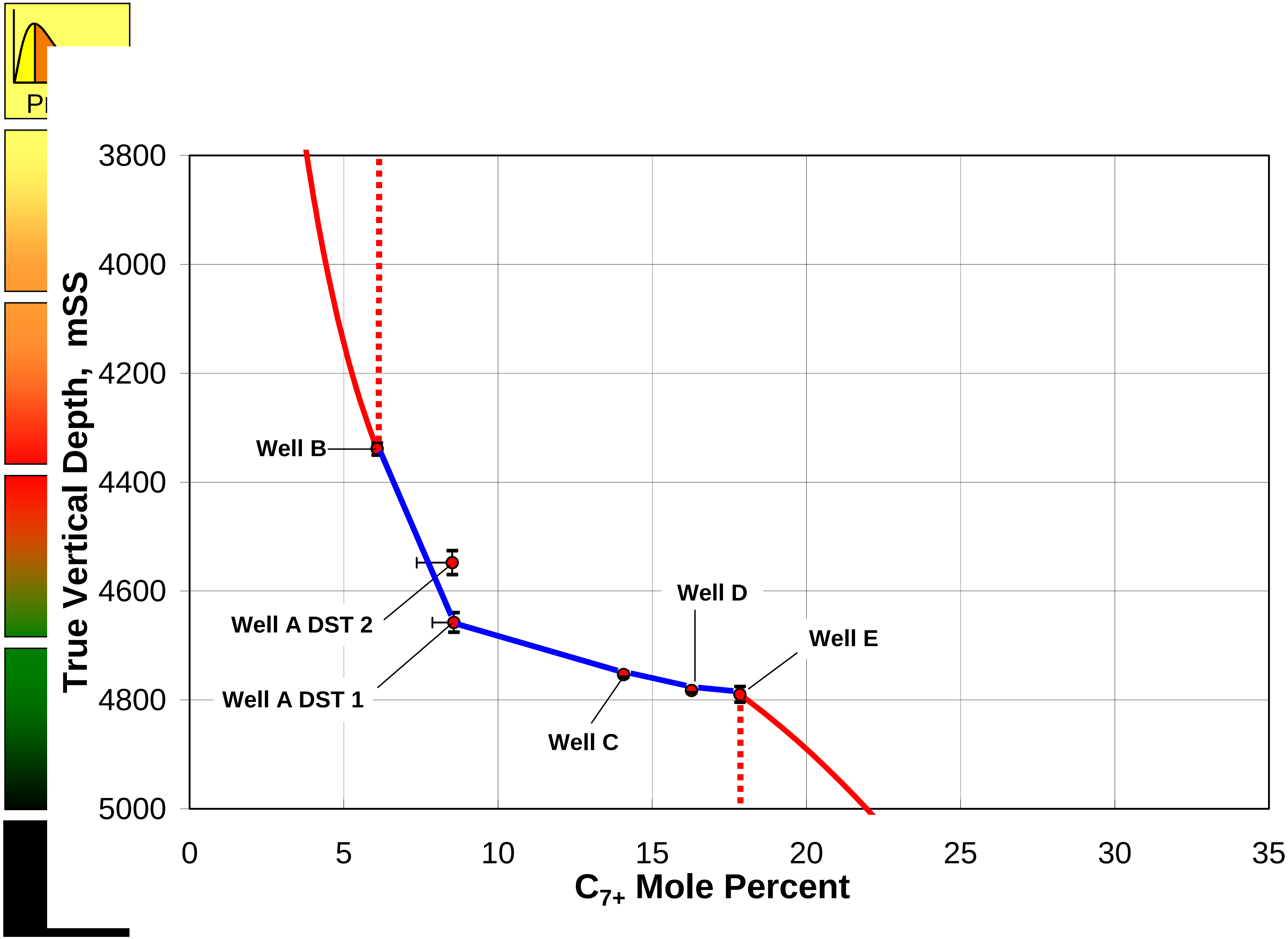
Well E
0
5
10
15
20
25
30
35
C7+ Mole Percent



Pr
3800
4000
4200
4400
4600
4800
5000
True Vertical Depth, mSS
0
5
10
15
20
25
30
35
C7+ Mole Percent
Well B
Well A DST 2
Well A DST 1
Well C
Well D
Well E

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Fluid Initialization

- **Black-Oil vs Compositional.**
    - Use consistent EOS model.
    - Use consistent surface process.
    - Use solution GOR (R_s and R_v) for black-oil model.
        - *Based on EOS model initialization.*

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Minimizing Number of EOS Components

- **Basis of Comparison.**
  - Detailed & Tuned EOS model.
  - Stepwise lumping procedure.
  - Check entire relevant p-compositioni space.
    - *Depletion data.*
    - *Gas injection data.*
    - *Miscibility data.*

- **Delumping ?**
  - Detailed & Tuned EOS model.

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Black-Oil PVT Tables

- **Select Depletion Test.**
- **Define Surface Separation.**
- **Consistency.**
  - Negative compressibilities.
  - Saturated gas / oil systems.
  - Compositional grading.
- **Extrapolation.**
  - Undersaturated GOC *(ECL100)*.
  - Gas injection.

Black-Oil PVT Tables

- **Delumping to Compositional Streams ?**

Split Factor

BOz Conversion

q_g, q_o → S_{ij} → z_1, z_2, ..., z_n

$$z_i = \sum_{j=1}^{2} S_{ij} \cdot q_j$$

$q_1 = q_g$
$q_2 = q_o$

$$S_{i1} = \frac{(1 + r_s C_{og})}{k(1 - r_s R_s)} y_i - \frac{r_s (C_{oo} + R_s)}{k(1 - r_s R_s)} x_i$$

$$S_{i2} = \frac{(C_{oo} + R_s)}{k(1 - r_s R_s)} x_i - \frac{R_s (1 + r_s C_{og})}{k(1 - r_s R_s)} y_i$$

North Sea Full-Field

Black-oil to Compositional conversion

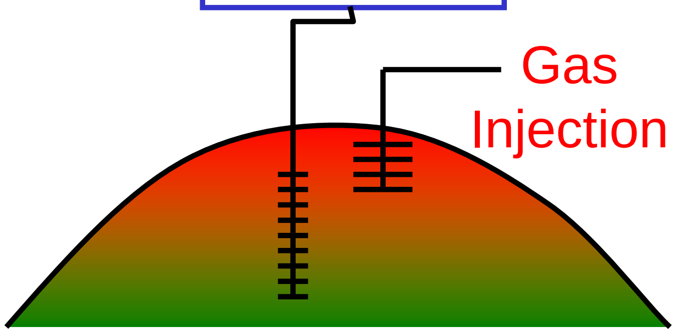
- **2 Platforms / 2 Processes.**
- **~ 50 wells.**
- **~ 1000 well-grid connections.**
- **Gas injection.**
- **2 Black-oil PVT regions.**
- **Huge (GB) summary files.**
- **> 100,000 stream conversions.**

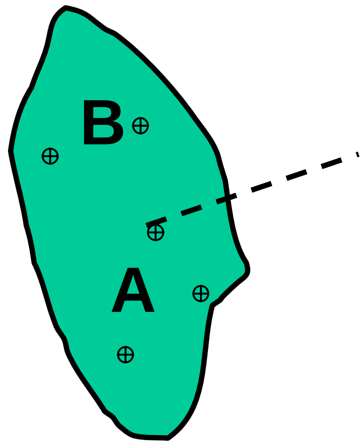
North Sea Full-Field Model

E100-BO
E300-EOS
FFM

Platform A
Process A
~ 30 Wells

Platform B
Process B
~ 15 Wells





Different Surface Processes (BO PVT) in Regions A & B

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Objective

- **Run black-oil full-field reservoir model.**
- **Convert surface rates to compositional streams.**
  - Connection level conversions.
- **Summarize results.**
  - By well, platform, field.
  - Annually, quarterly, cummulatives etc.

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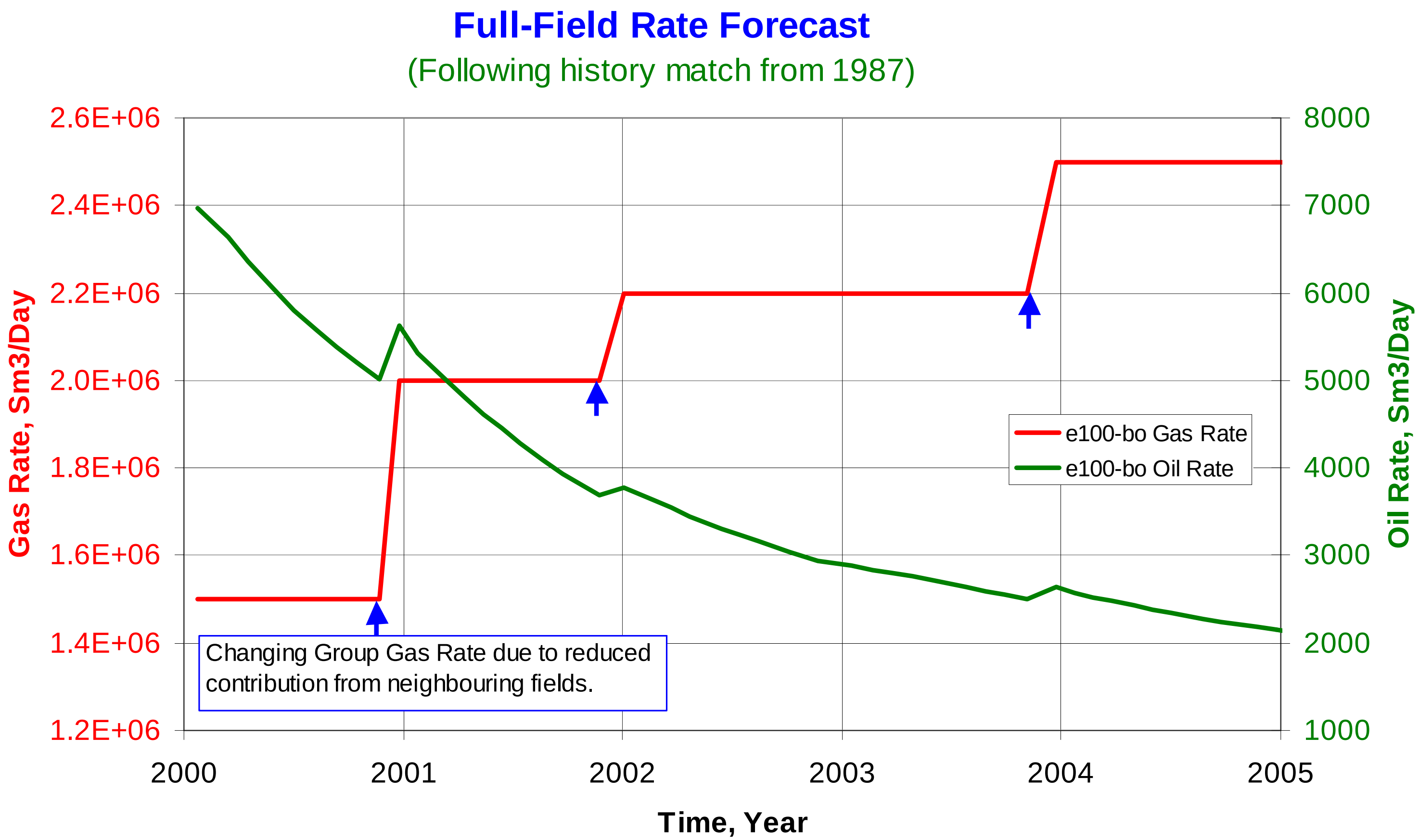
Full-Field Rate Forecast
(Following history match from 1987)
2.6E+06
2.4E+06
2.2E+06
2.0E+06
1.8E+06
1.6E+06
1.4E+06
1.2E+06
Gas Rate, Sm3/Day
8000
7000
6000
5000
4000
3000
2000
1000
Oil Rate, Sm3/Day
2000
2001
2002
2003
2004
2005
Time, Year
e100-bo Gas Rate
e100-bo Oil Rate
Changing Group Gas Rate due to reduced contribution from neighbouring fields.

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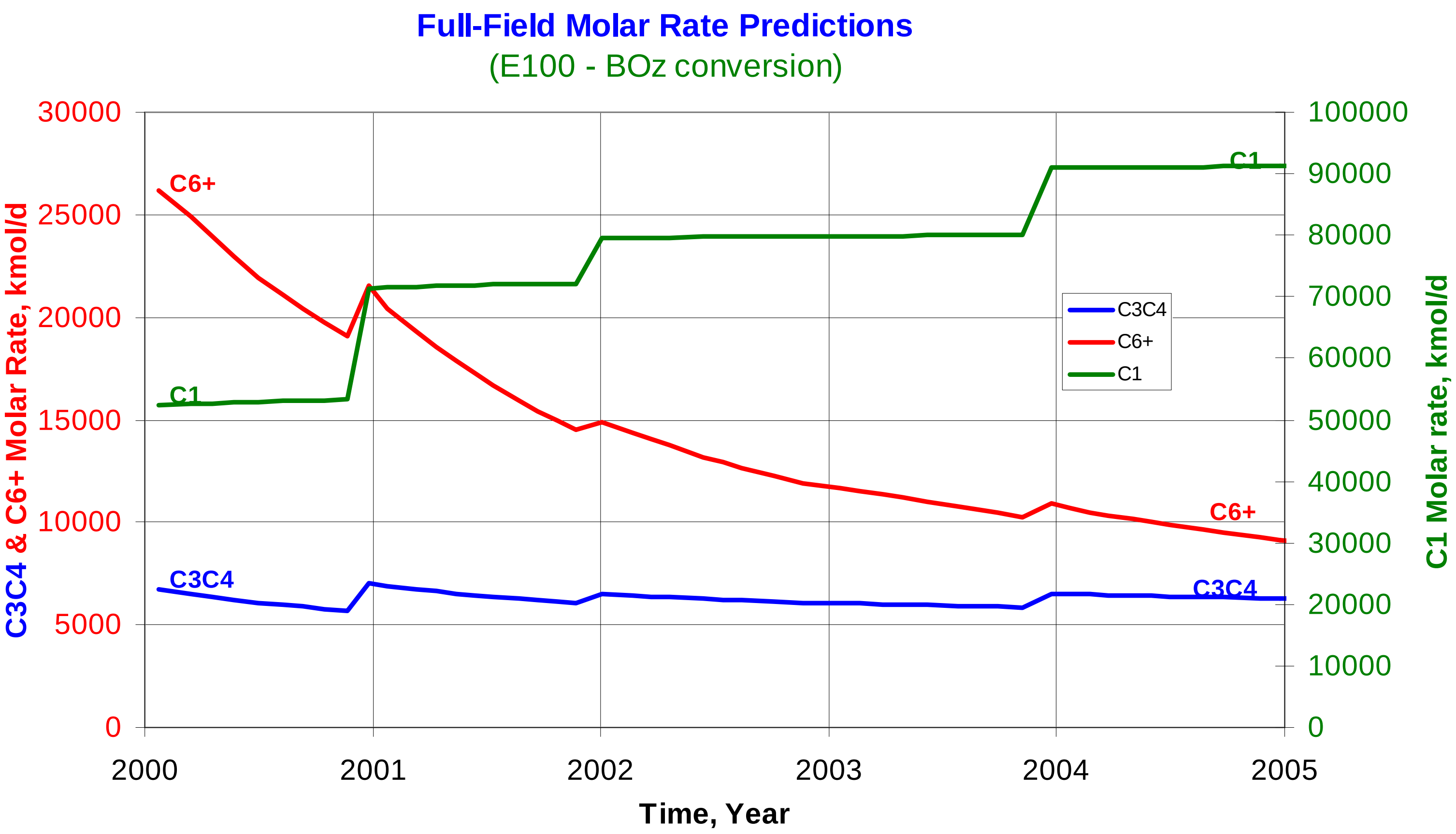
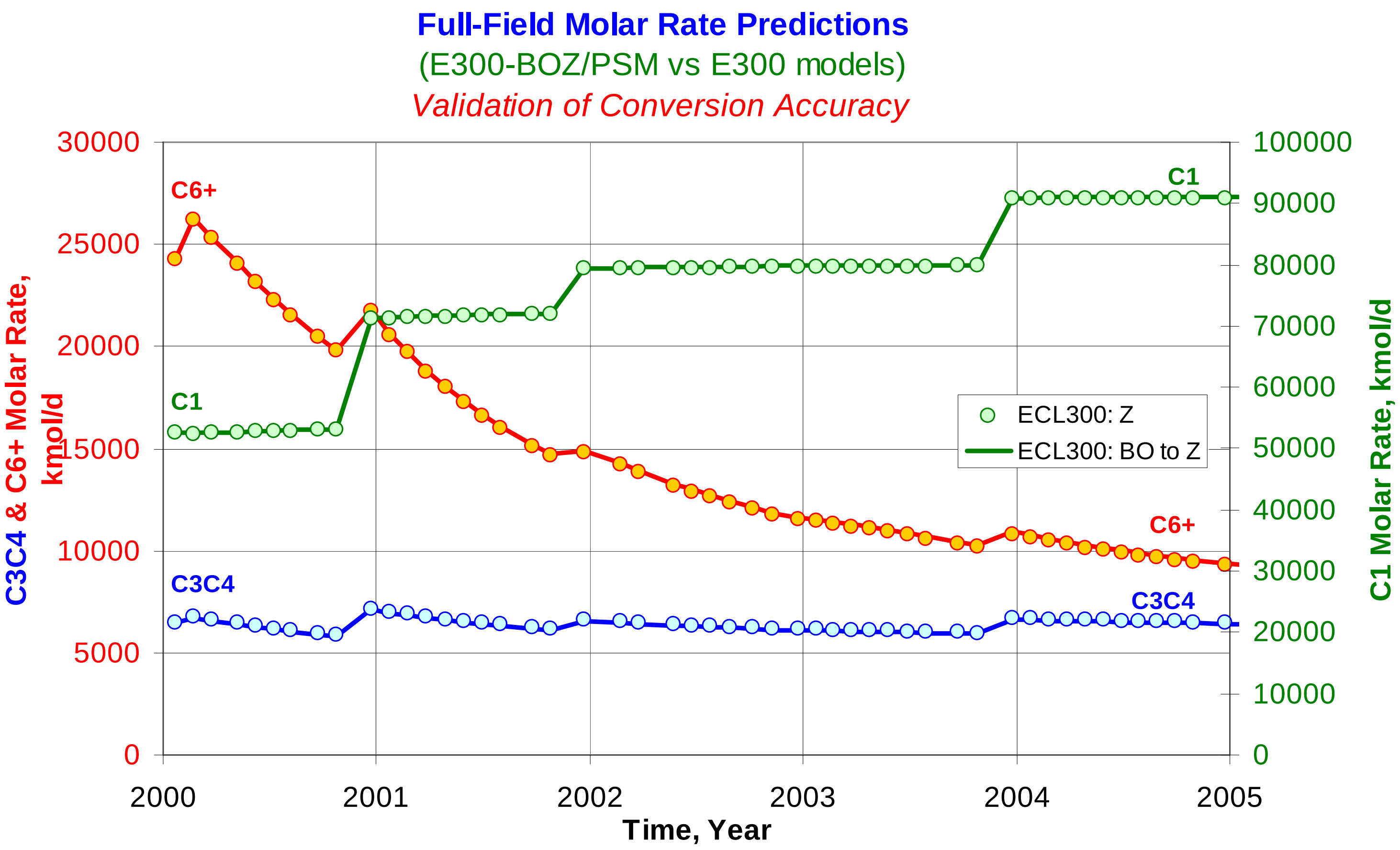

Full-Field Molar Rate Predictions
(E100 - BOz conversion)
C3C4 & C6+ Molar Rate, kmol/d
30000
25000
20000
15000
10000
5000
0
C1 Molar rate, kmol/d
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
2000
2001
2002
2003
2004
2005
Time, Year
C6+
C1
C3C4
C1
C6+
C3C4
C3C4
C6+
C1


Full-Field Molar Rate Predictions
(E300-BOZ/PSM vs E300 models)
Validation of Conversion Accuracy
C3C4 & C6+ Molar Rate, kmol/d
C1 Molar Rate, kmol/d
Time, Year
C6+
C1
C3C4
ECL300: Z
ECL300: BO to Z
0
5000
10000
15000
20000
25000
30000
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
2000
2001
2002
2003
2004
2005