RPS Energy

Developing EOR Screening Methodologies

The Maestro Methodology

- Provides an efficient framework for the selection and ranking of candidate fields for a range of enhanced oil recovery processes.

•Analytical and Numerical Tool/s

•Systematic procedure

•EOR expertise

•Field knowledge and expertise

Maestro Development

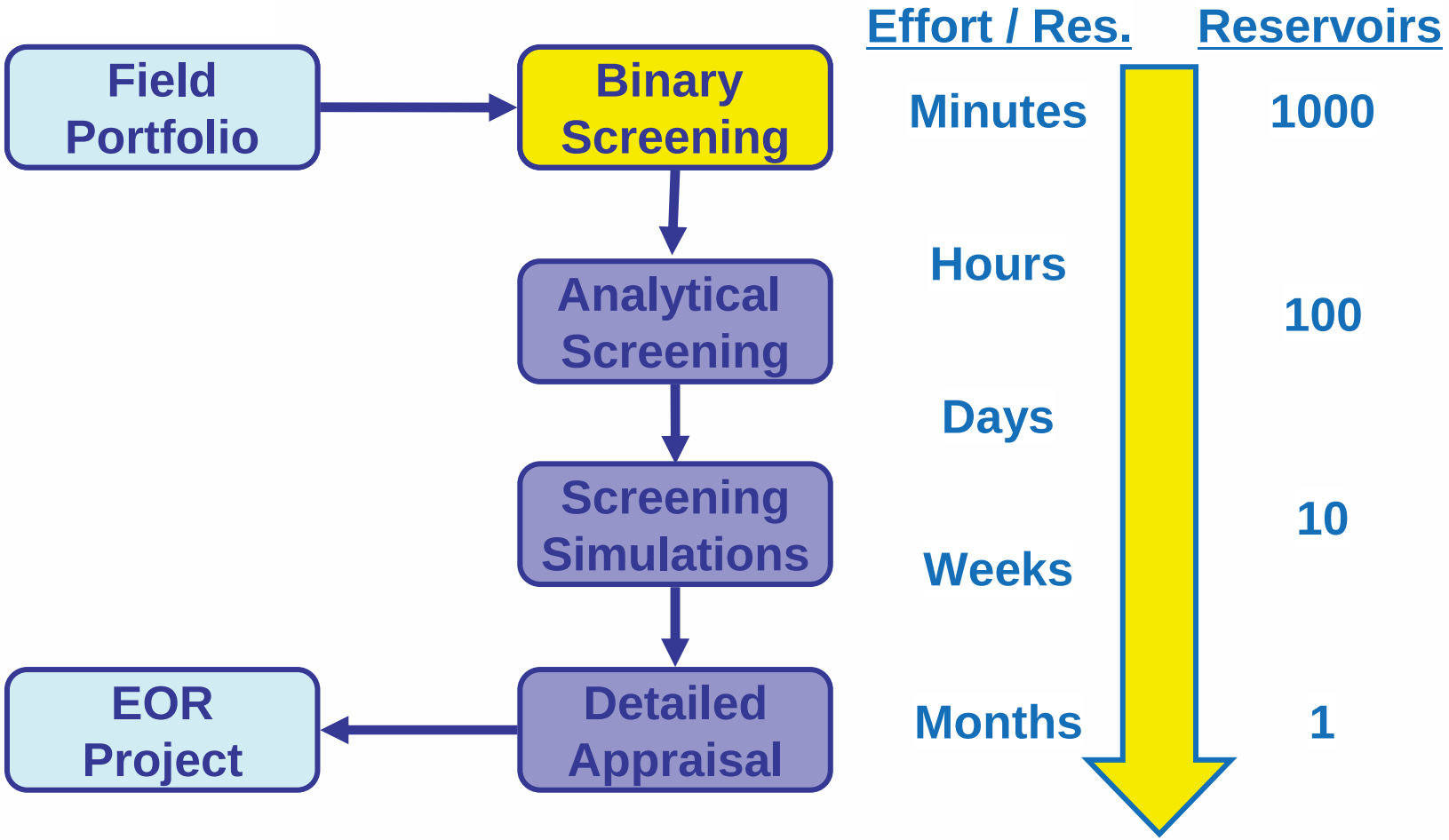
Developed by Subsurface group at Winfrith Dorset (Currently the Specialist Reservoir Engineering Group of RPS)

- 1970s – 1990s – Extensive research into EOR projects, theoretical and experimental
- 1989 – Development of METEOR I – DTI/NPD
- 1989 – 1992 EOR Screening of all UKCS oil fields – 100% success rate in identifying successful UKCS gas injection projects
- 1996 – MAESTRO™ developed to enable commercial projects to be undertaken
- 2000 – 2002 – MAESTRO™ re-development “Performance Indicators” – “Rapid Simulation”
- 2010 – 2011 – Review of methodology in light of new EOR chemicals / processes. Collaboration with BP Institute, Cambridge.

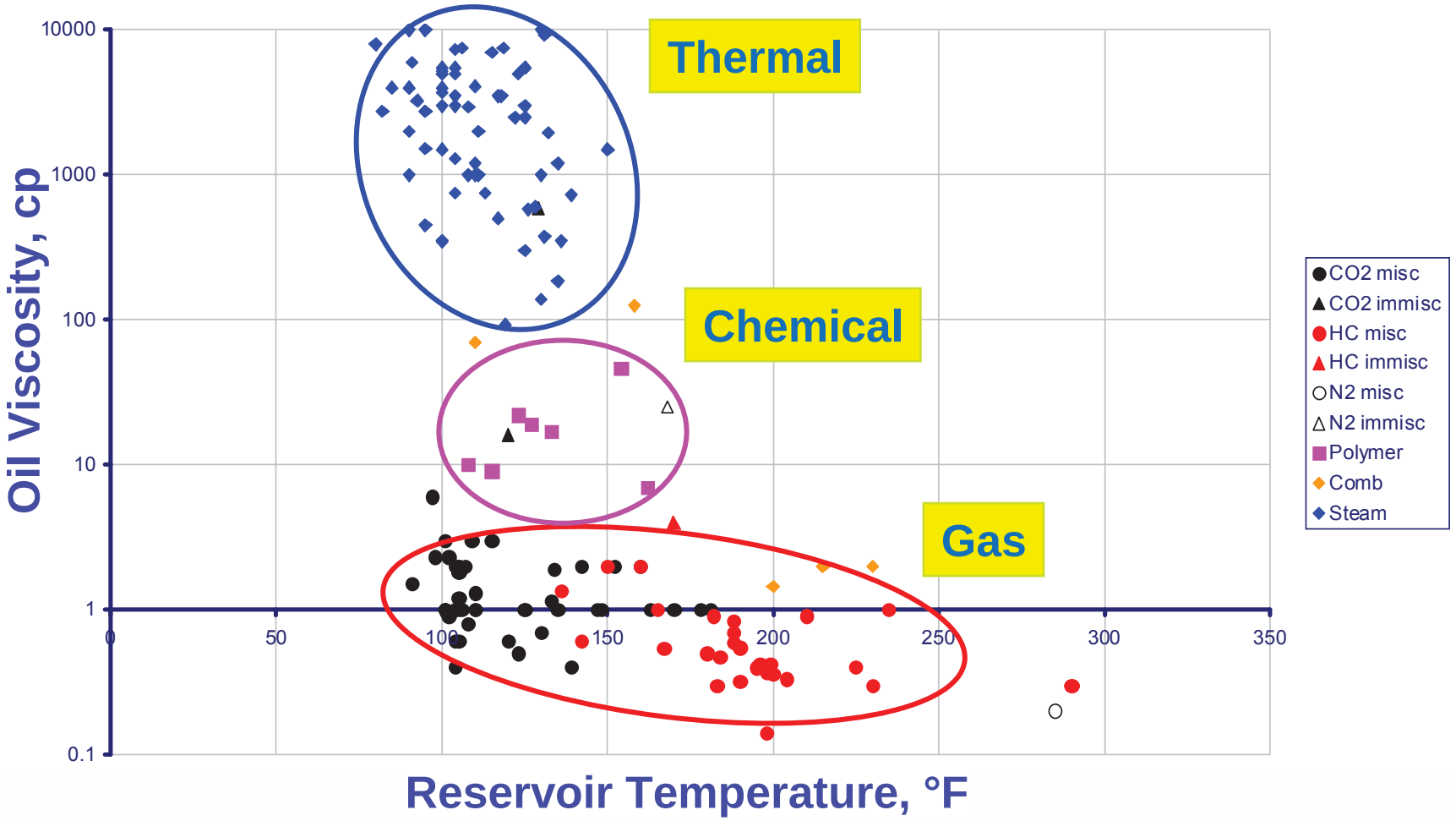
Typical Project Objectives

- Investigate potential for enhanced recovery using gas, chemical or thermal methods
- Rank performance of different displacement processes / reservoirs
- Obtain an indication of economic viability
- First pass optimisation studies of best performing processes prior to more detailed modelling

EOR Screening Methodology



EOR Projects (Oil & Gas Journal)



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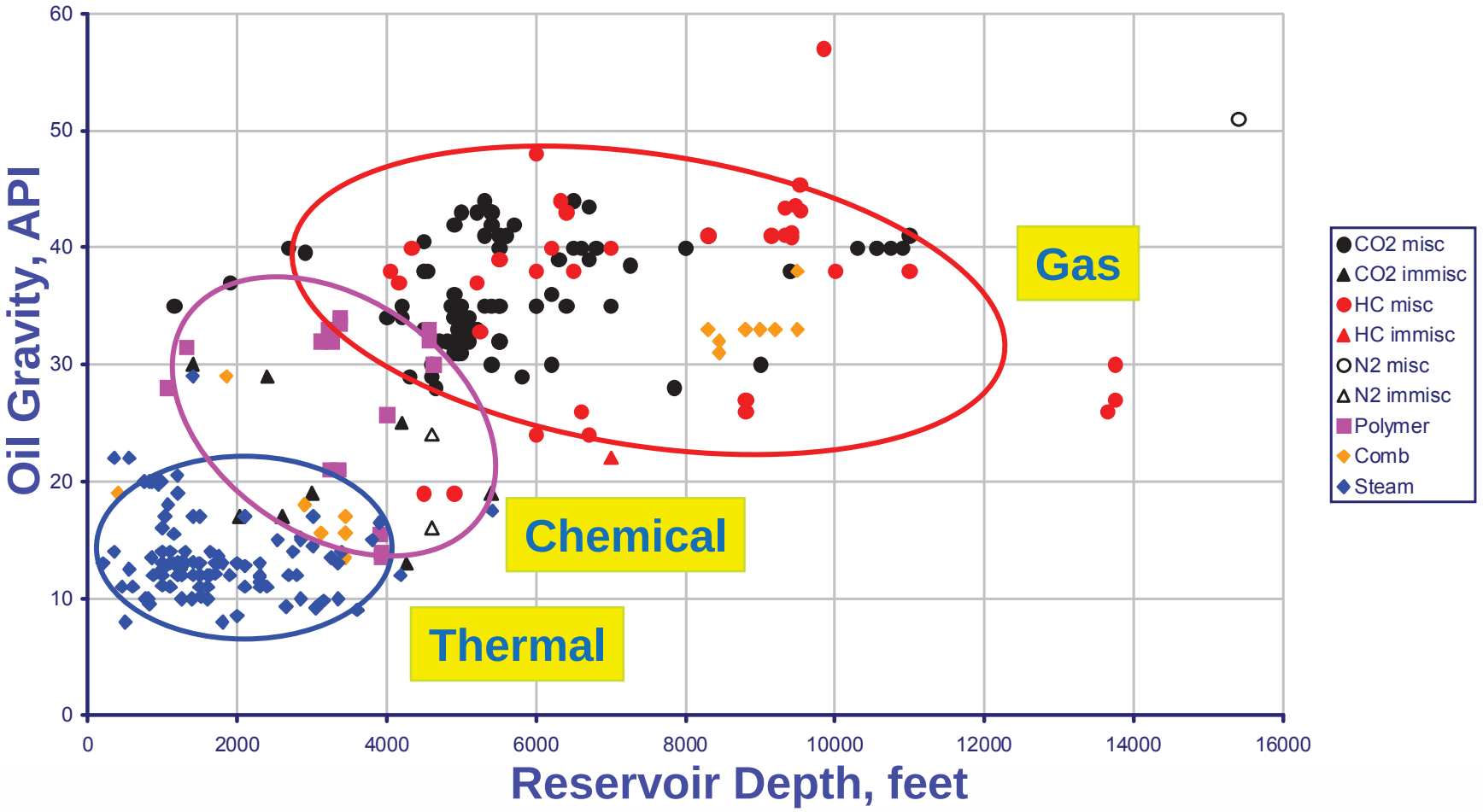

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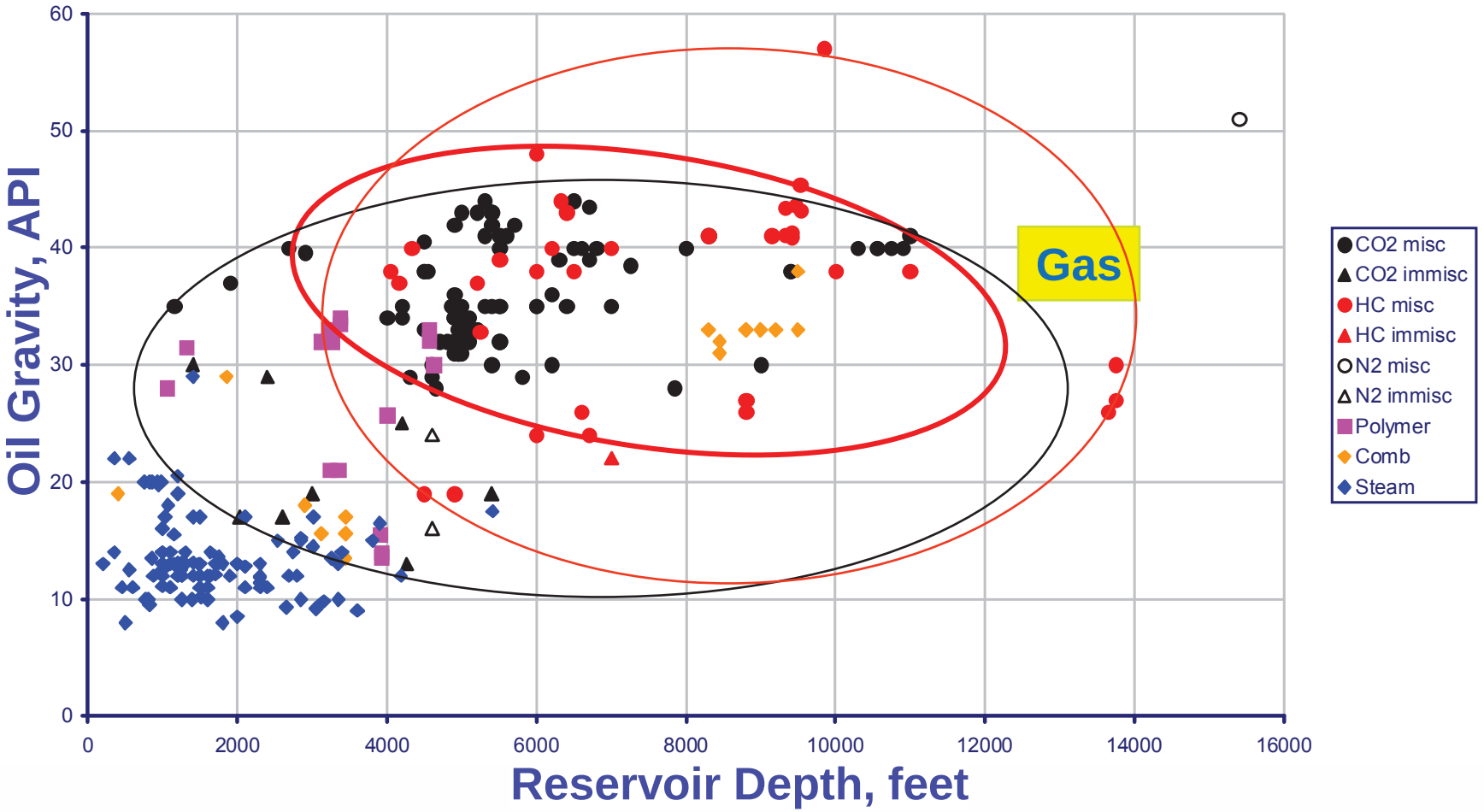
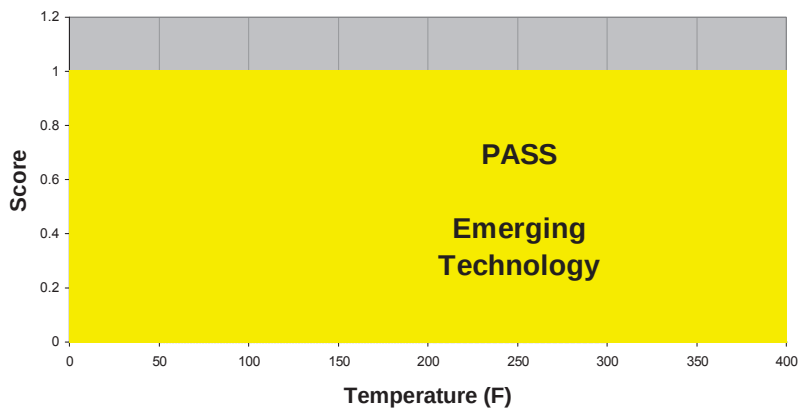
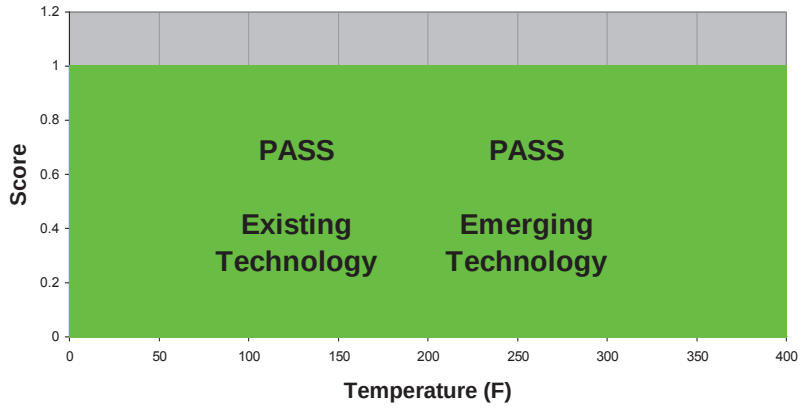


Binary Screening Criteria Developments

- Ongoing developments mean that constraints are being relaxed
  - Existing technology
  - Emerging technology
- Binary screening switches abruptly from PASS to FAIL at limits
  - Fuzzy screening criteria gives a PASS score which varies smoothly from 0 to 1





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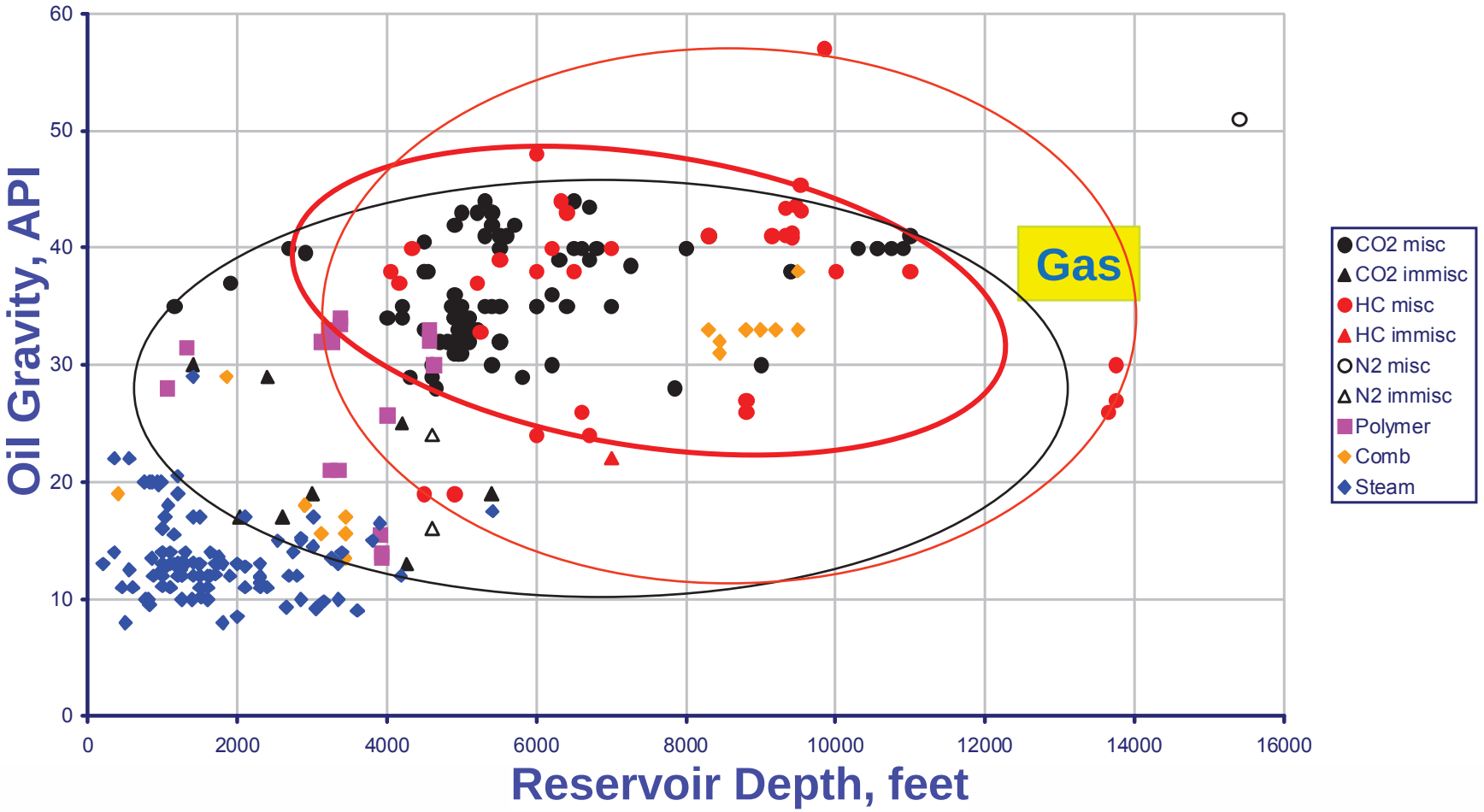

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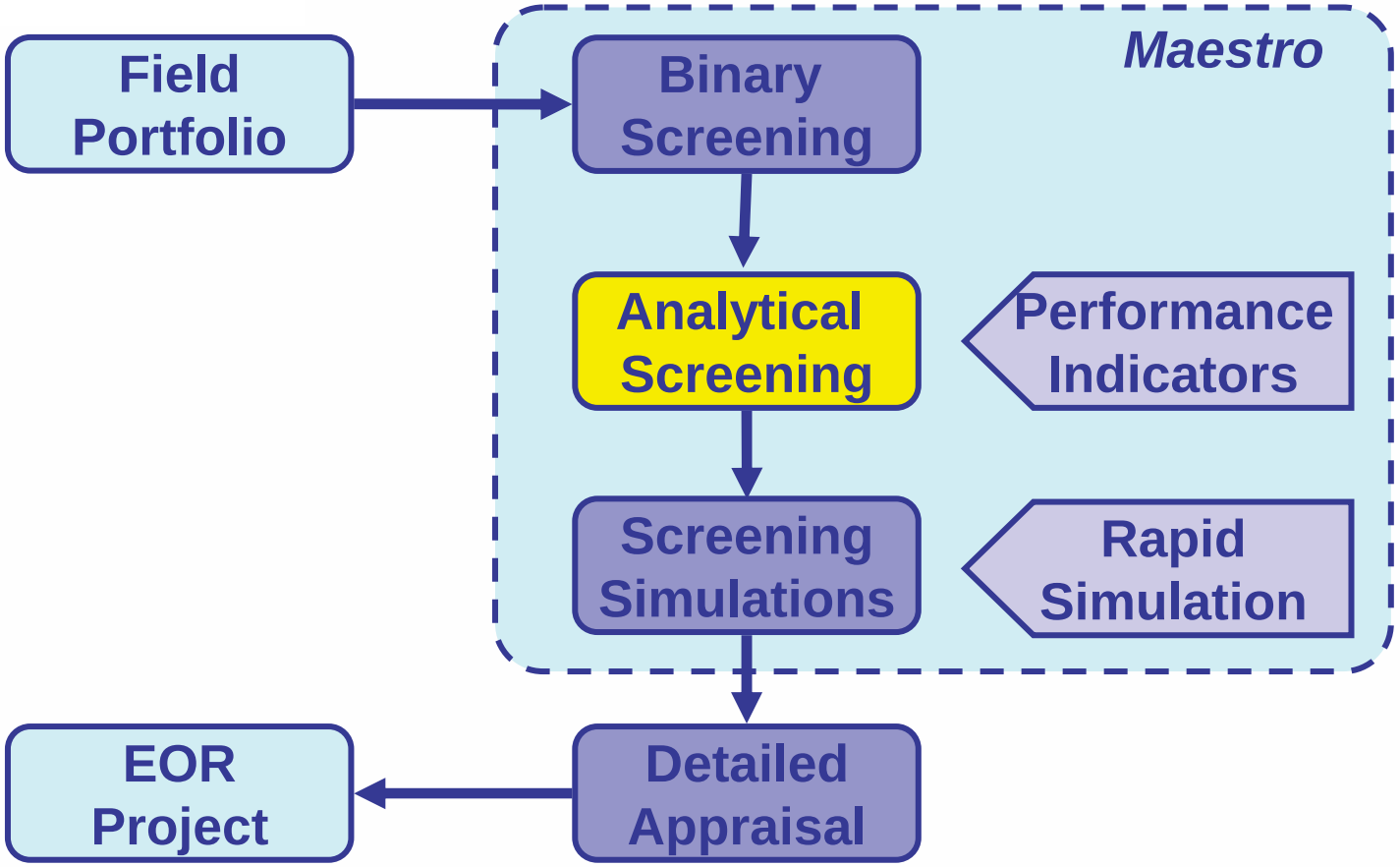
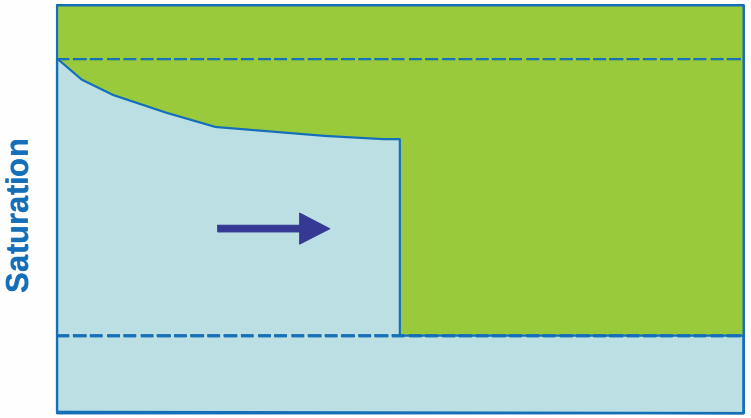


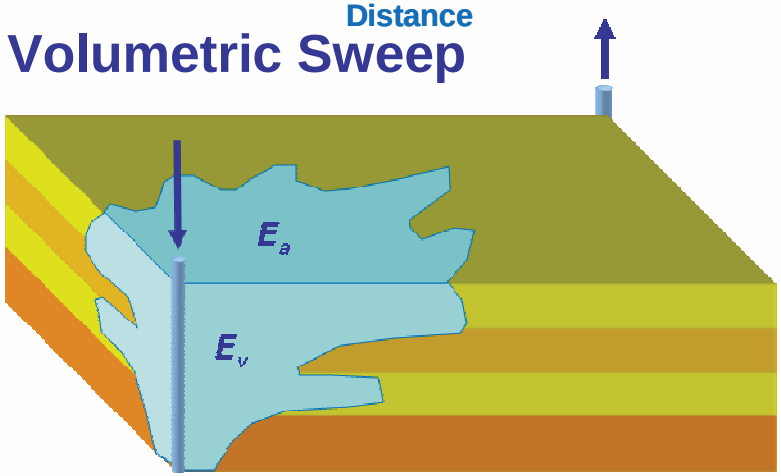
Analytical Screening

- Key performance indicators
  - Viscous/gravity ratios
    - Stone's, Crane's, Dietz etc
- Displacement Efficiency
  - Microscopic displacement
    - Buckley-Leverett theory
    - MMP correlations
  - Volumetric sweep
    - Areal sweep
    - Vertical sweep
    - Sweepable volume

Microscopic Displacement

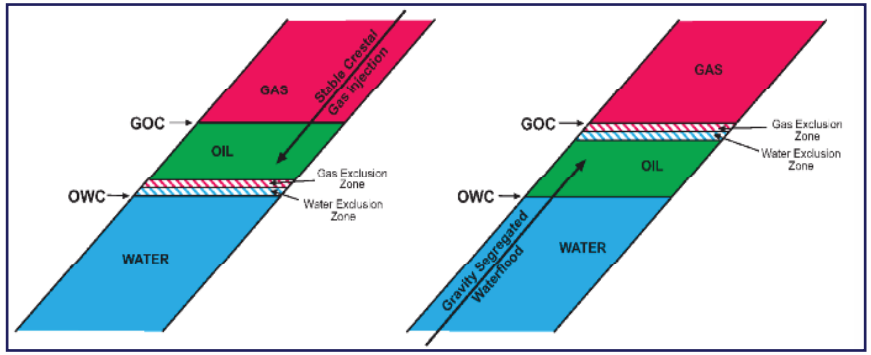


Volumetric Sweep



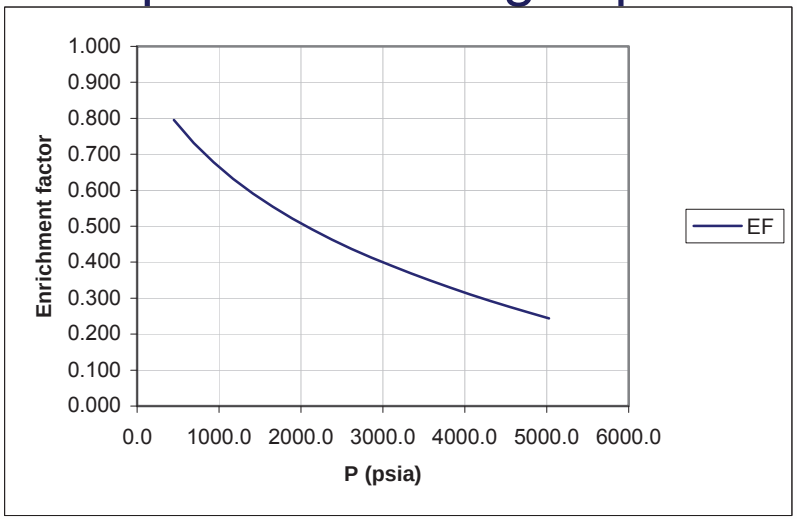
Assessing Viability

- Stability
- Estimated incremental recovery (cf waterflood)
  - Displacement Efficiencies combine to estimate Incremental Recovery
- Performance Indicators
- Economic Indicators
- Sensitivity to uncertainty

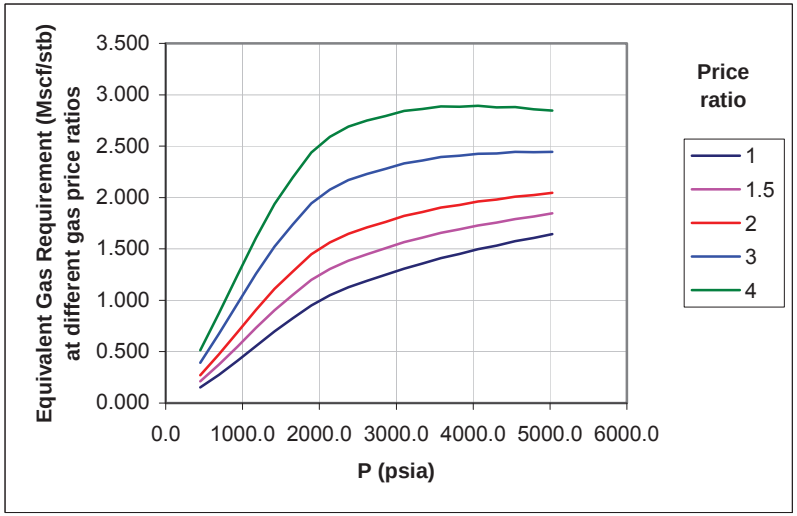


Optimisation and Economic Indicators - Miscible Gas Injection

- Economic Indicators calculated ie gas requirements per incremental barrel
- Optimisation of gas processes



Higher enrichment at lower pressures



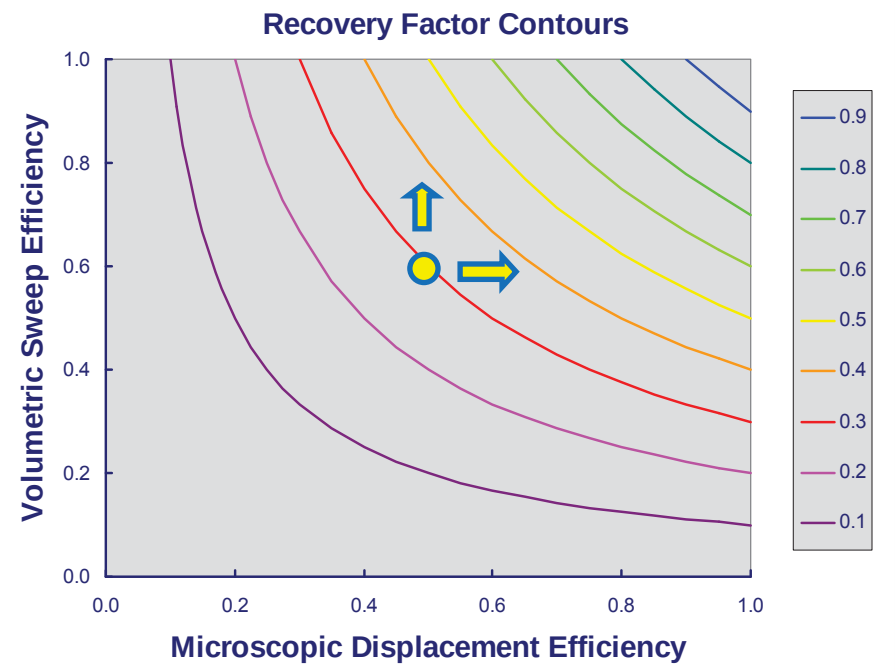
Less gas required at lower pressures

So operate at lower pressure / higher enrichment

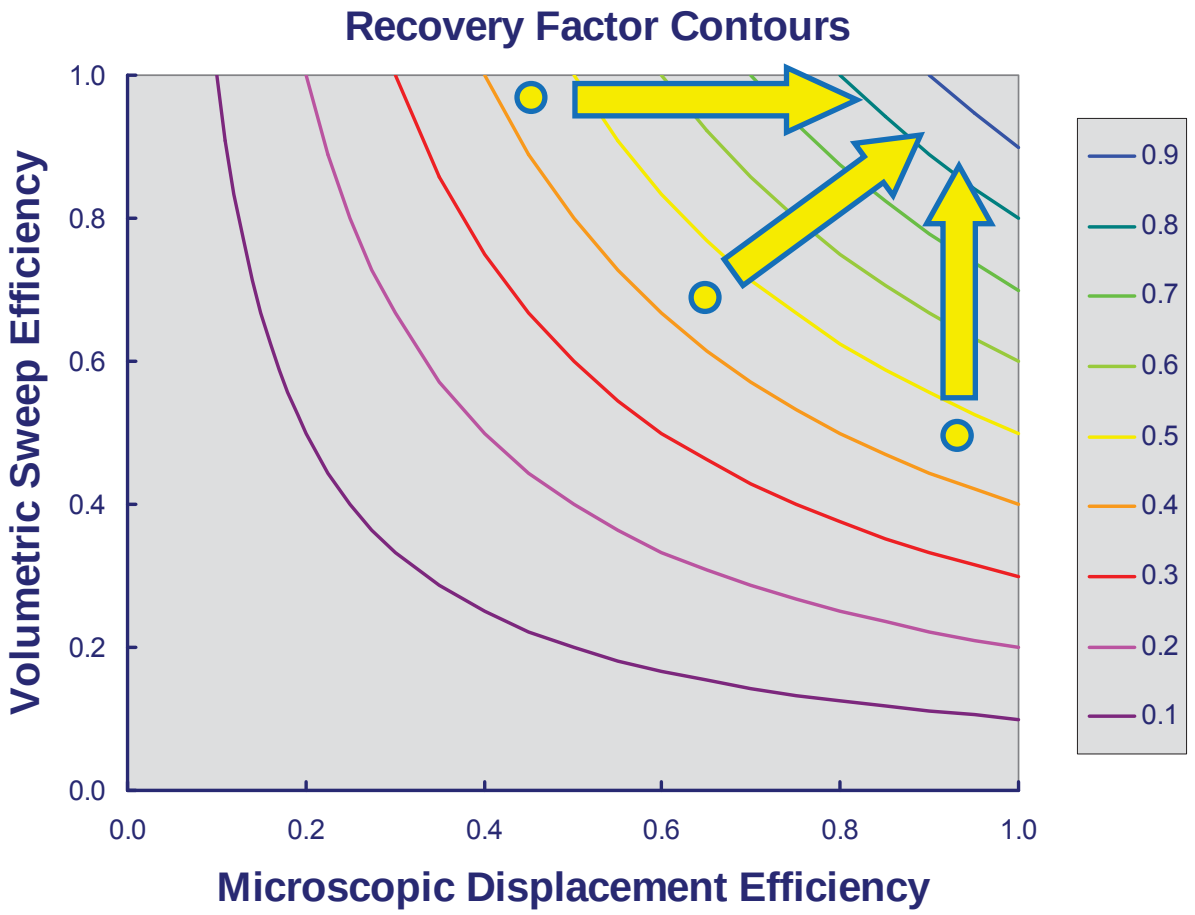
Operational policy is independent of NGL price.

Matching Model to Expected Waterflood Behaviour

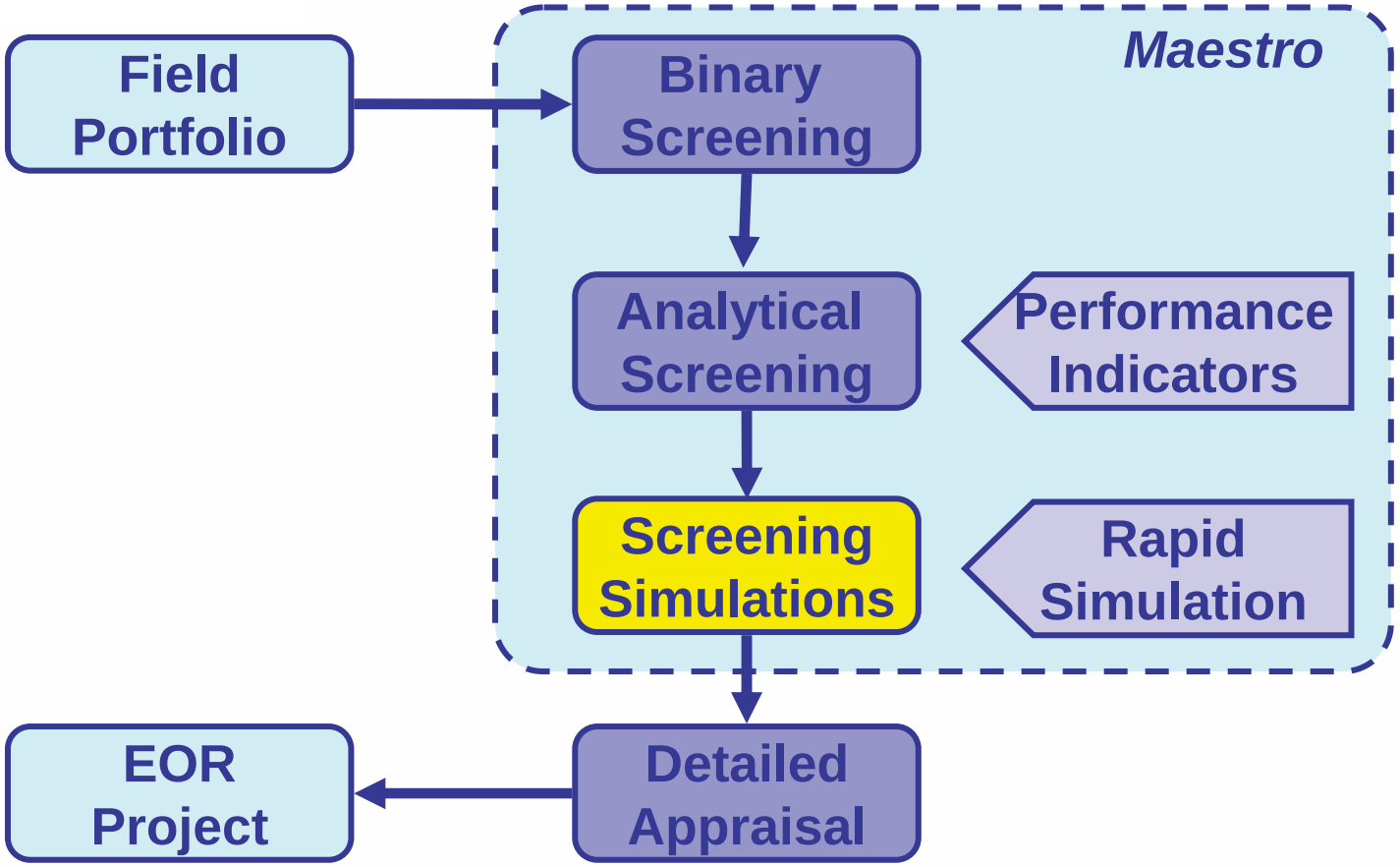
- Waterflood recovery factor estimate available from simulation model / forecasts
- Analytical model should be calibrated to waterflood estimate



Matching EOR Process to Remaining Oil



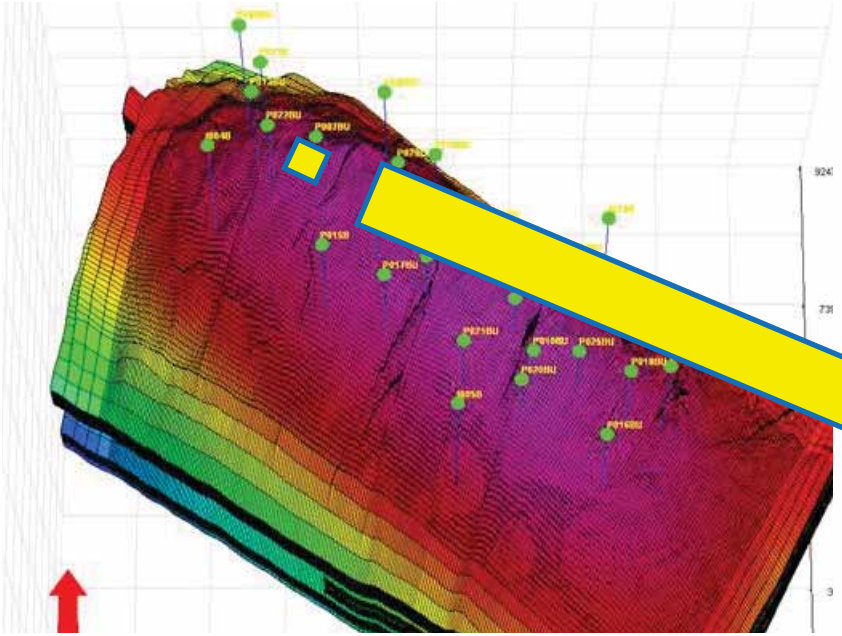
EOR Screening Methodology



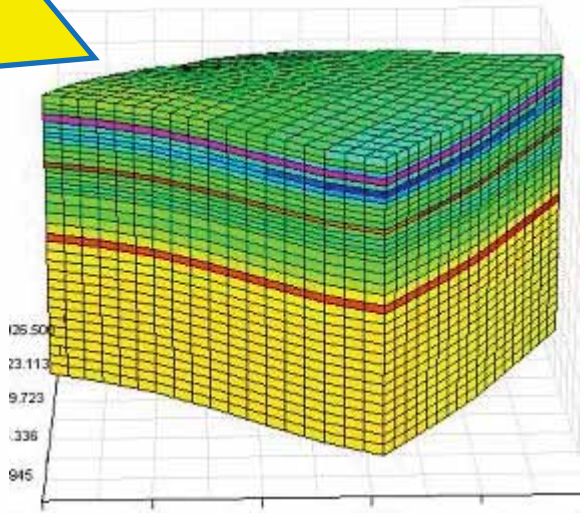
Assess and Quantify Viability

- Include lateral and vertical heterogeneity
- Include new well technologies
- Generate production and injection profiles (Input to economics)
- Sensitivities to identify/confirm critical data
- First pass optimisation

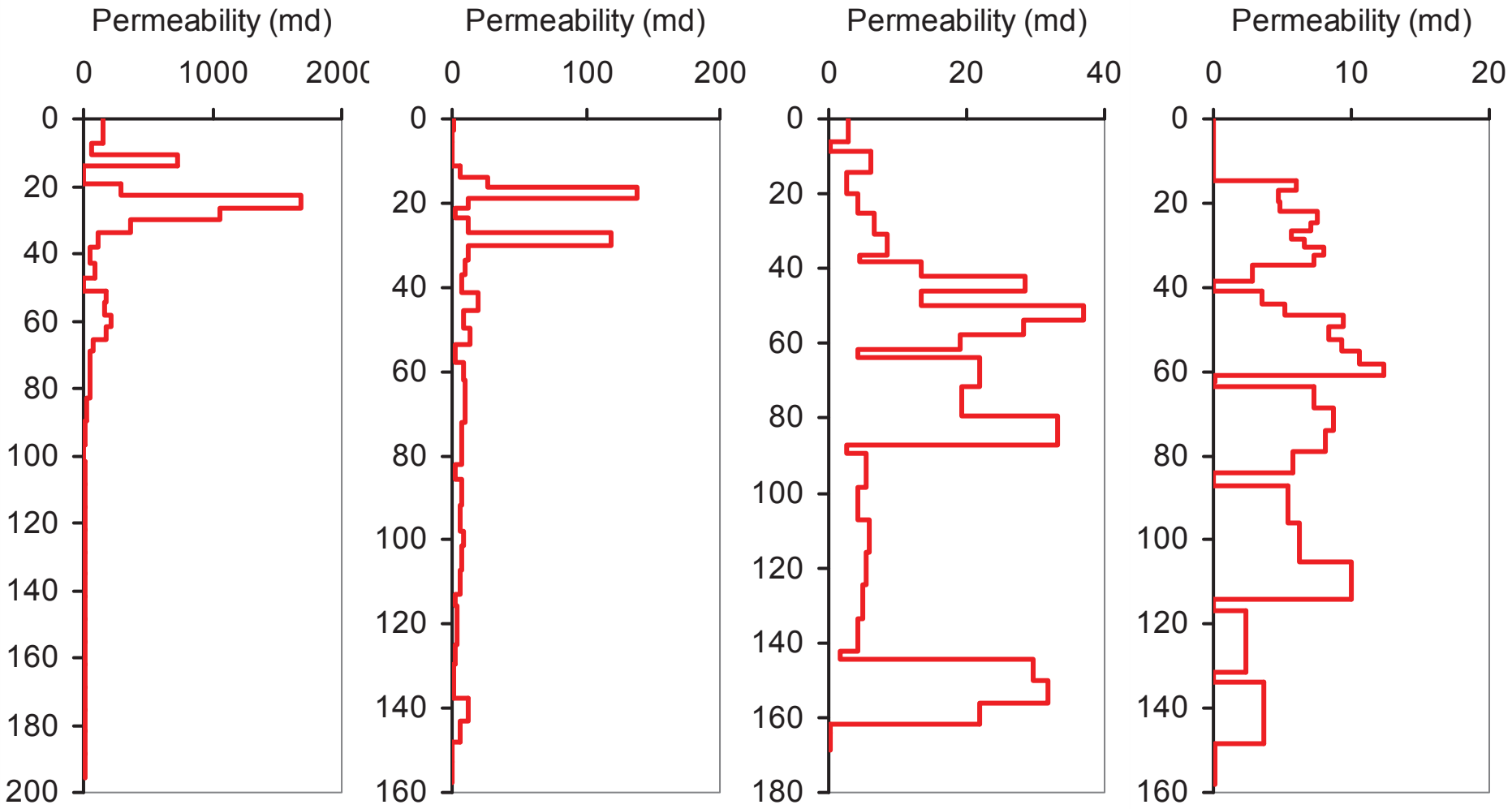
Screening Simulation Model(s)



Grid Refinement
(e.g. 3 x 3 x 1 compared with full field model)



Example Permeability Profiles

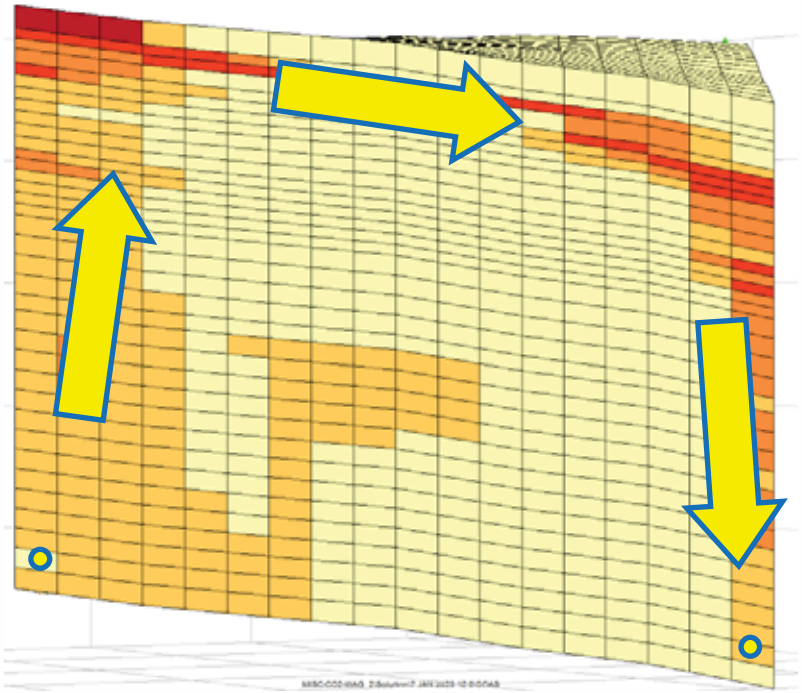


Viability of WAG Displacements

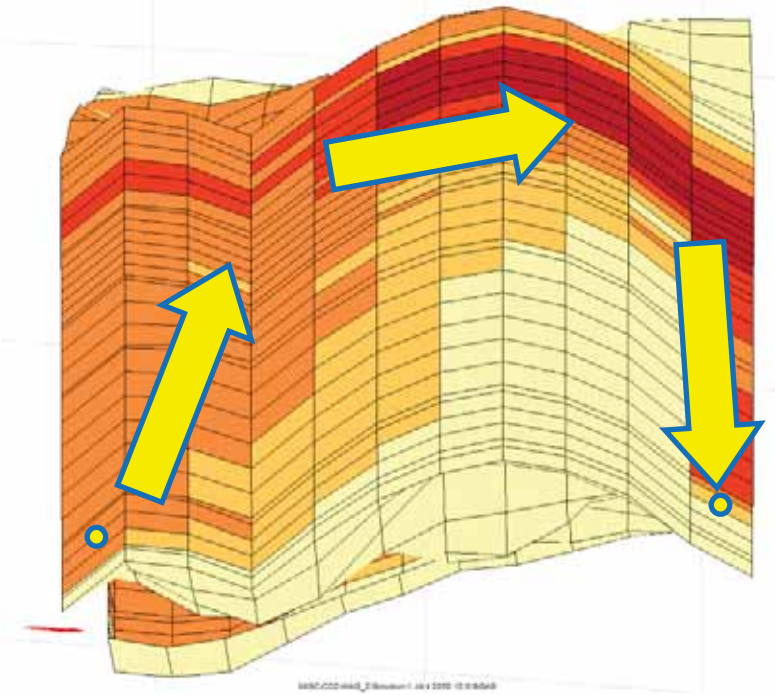
	Field 1	Field 3	Comment
Binary Screening	Score = 1	Score = 1	Does not consider vertical heterogeneity
Analytical Screening	Segregation of gas / water	Segregation of gas / water	Takes no account of the position of the high permeability layers
Simulation Screening	Total override	Partial override	Necessary

Sensitivity of Miscible CO_2 WAG to Reservoir Properties

High heterogeneity (V_{DP} ≈ 0.8) and high vertical permeability



Moderate heterogeneity (V_{DP} ≈ 0.6) and moderate vertical permeability

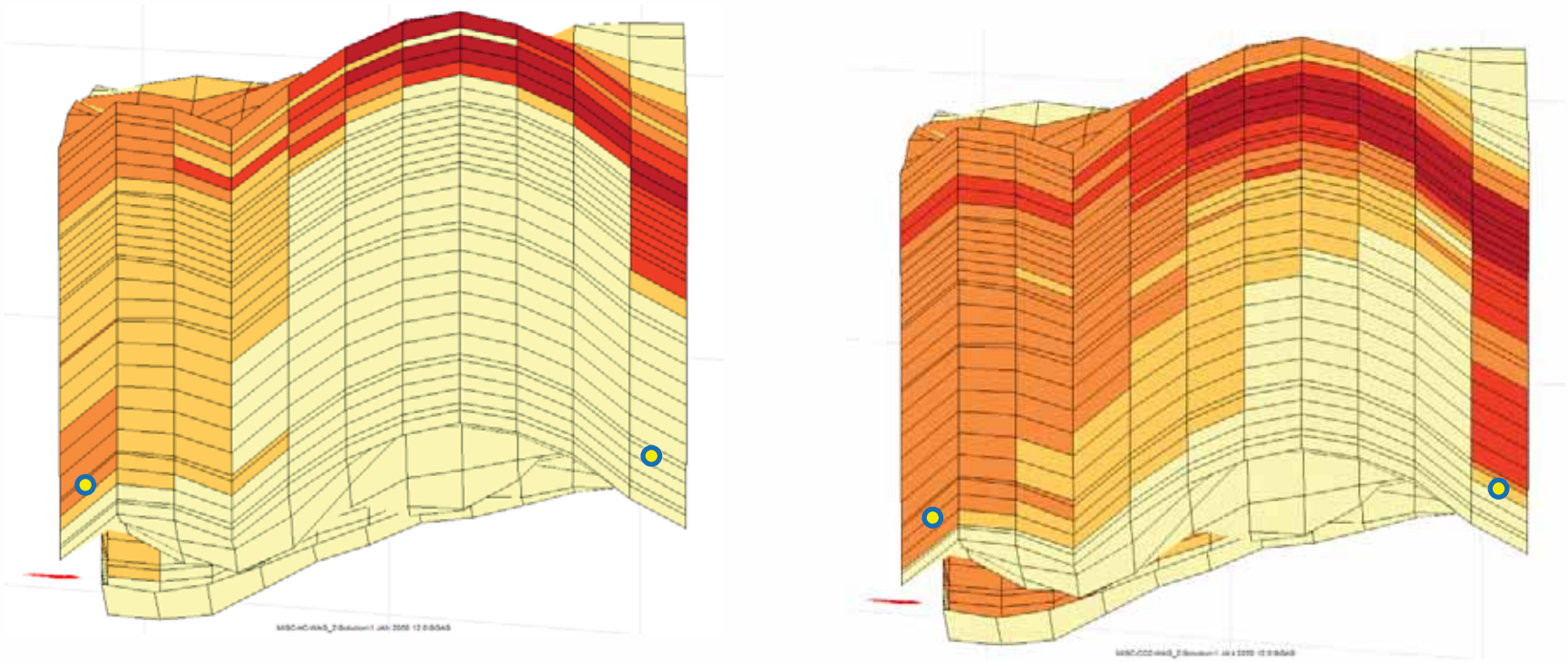


Gas Saturation

Sensitivity of WAG to Injection Gas

Hydrocarbon gas

CO_2



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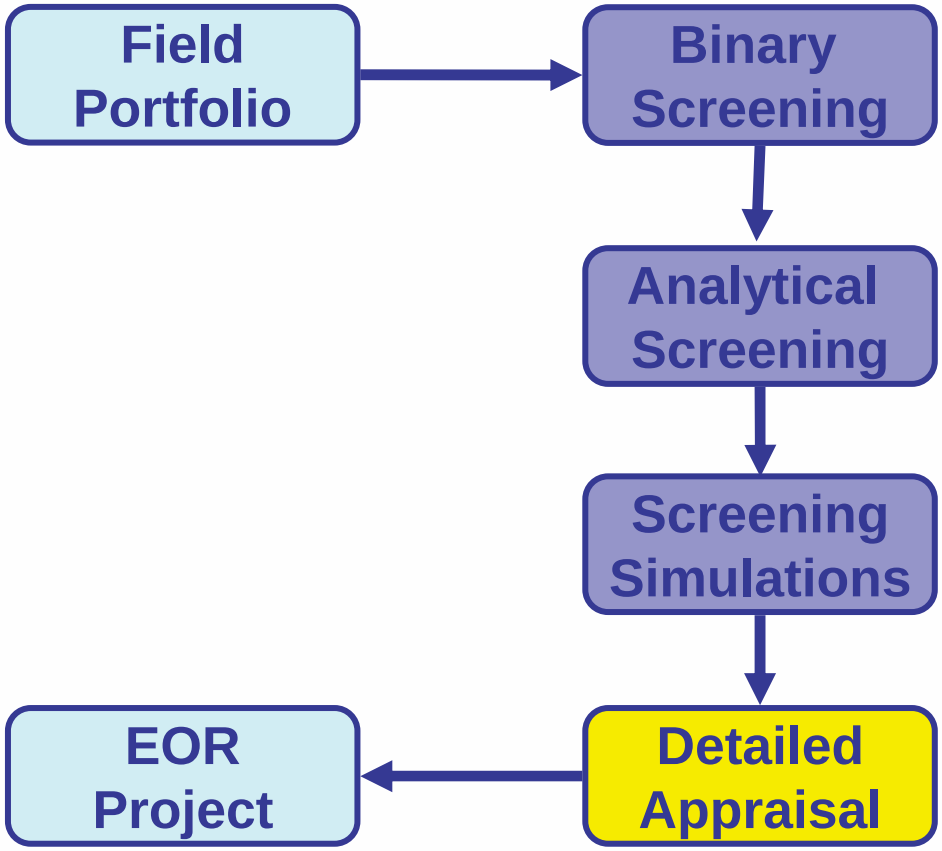

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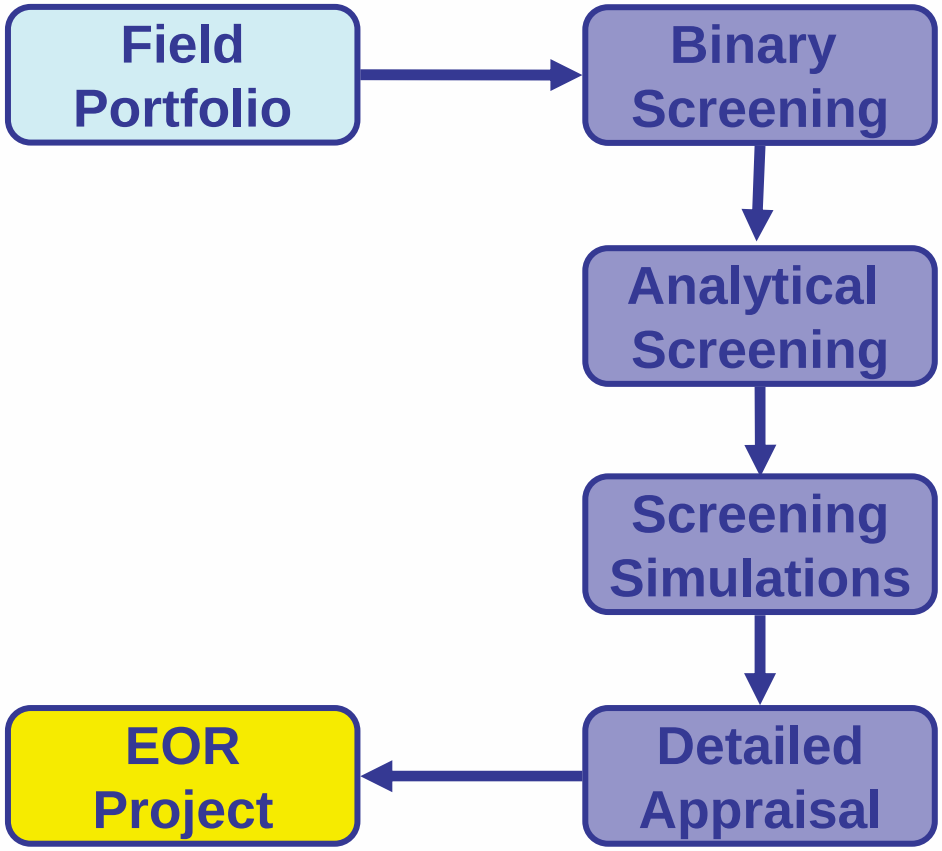
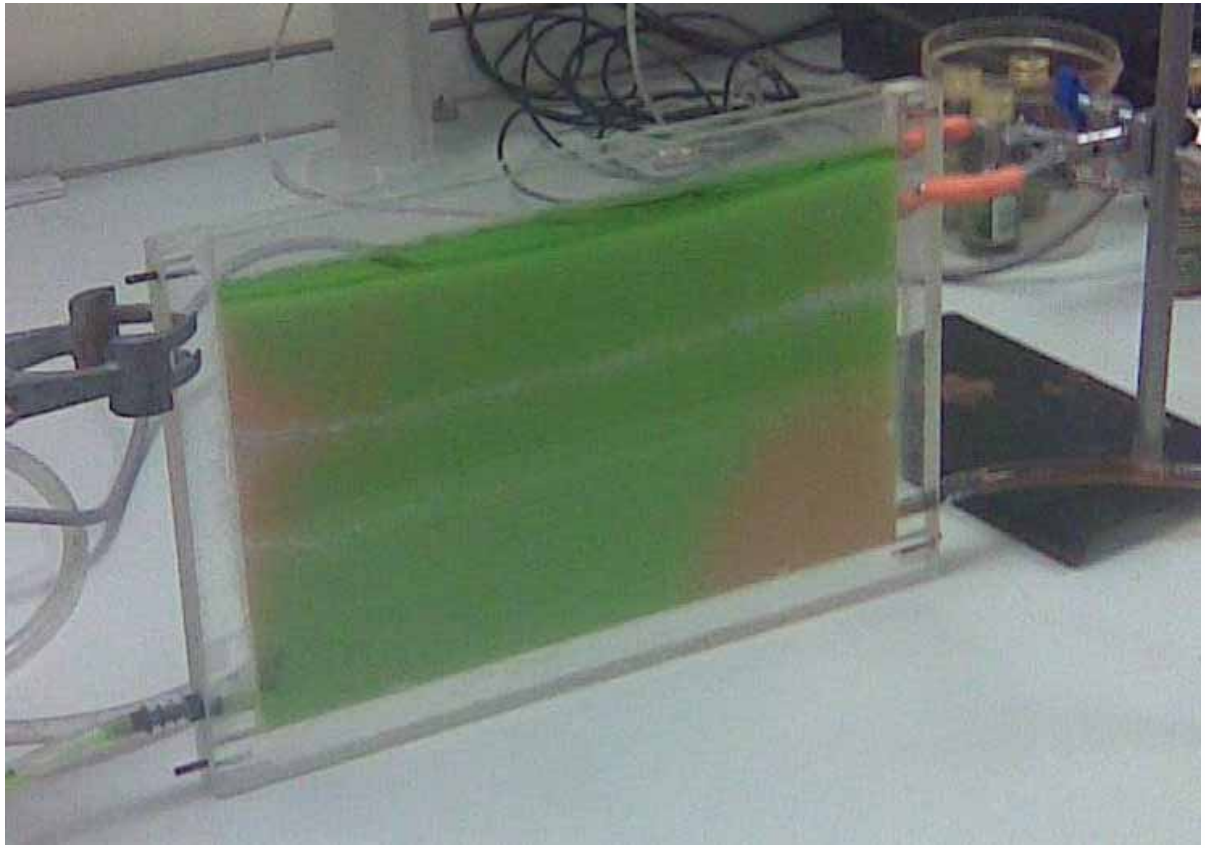


Developing Analytical/Simulation Screening

- Chemical flooding (Surfactant/Polymer)
  - Wider range of applicability (ie new chemicals stable at more extreme conditions) eg high temperatures, low permeability, high viscosity, high salinity
  - New flow mechanisms, eg Bright water, Low molecular weight polymers
- New processes (ASP, Foams, low salinity waterflood)

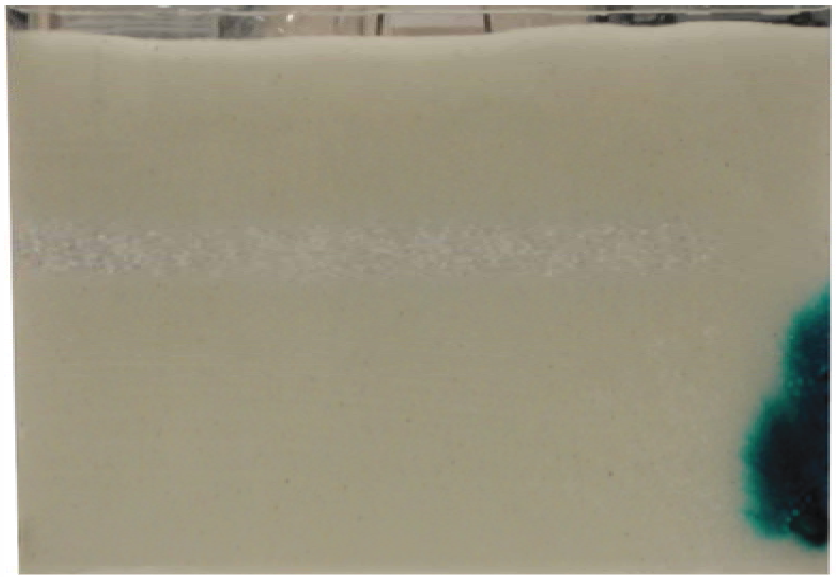
- WAG
  - Improving accuracy of analytical methods
  - Effect of heterogeneity (High/Low K layers / Baffles)

Hele-Shaw Cell Experiments – BP Institute Cambridge



Miscible Flood with High Permeability Streak – HM0014

Hele-Shaw Cell



Screening Simulation

Miscible Flood with High Permeability Streak – HM0014

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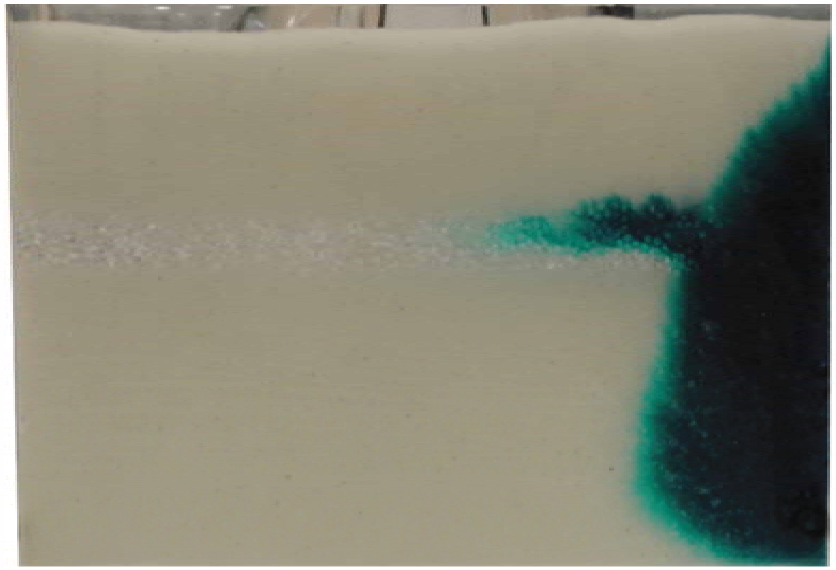

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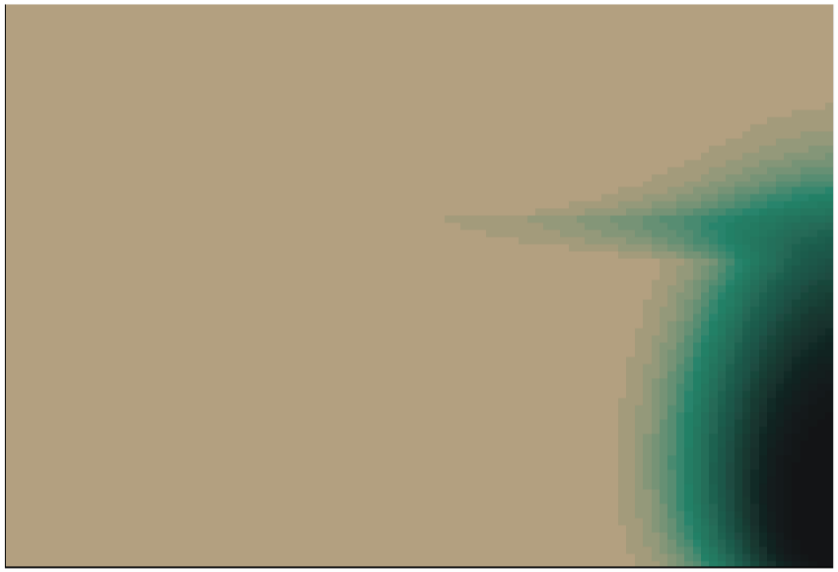

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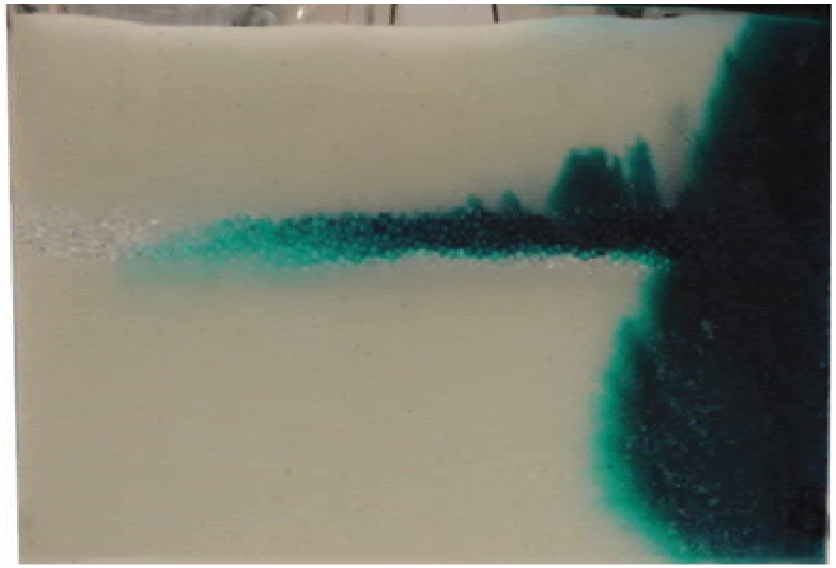

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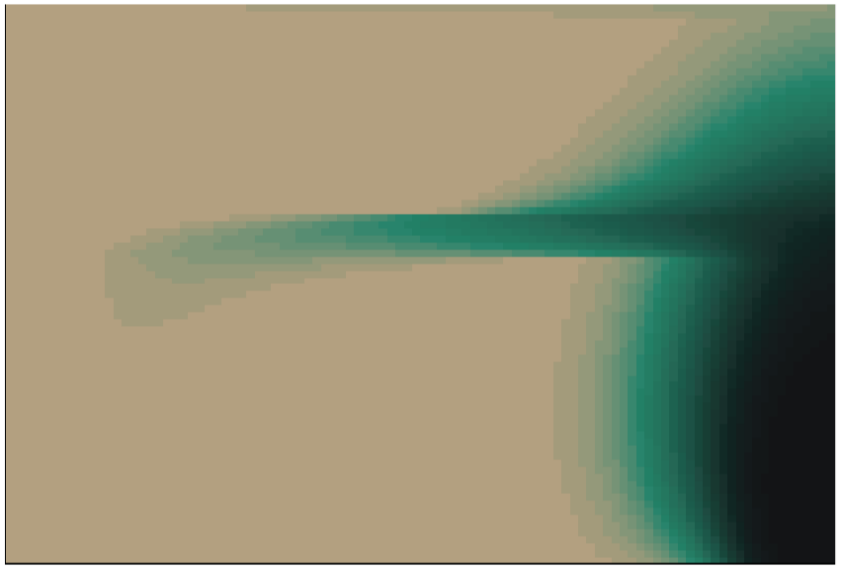

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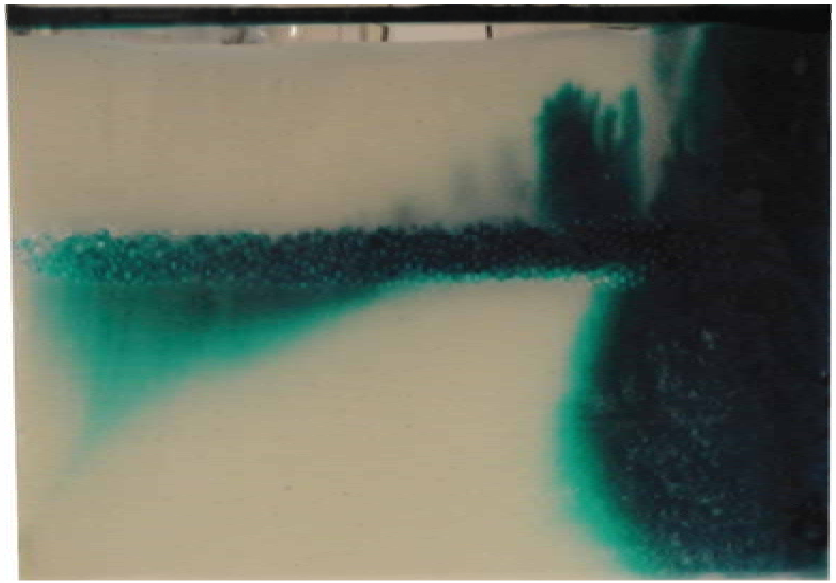

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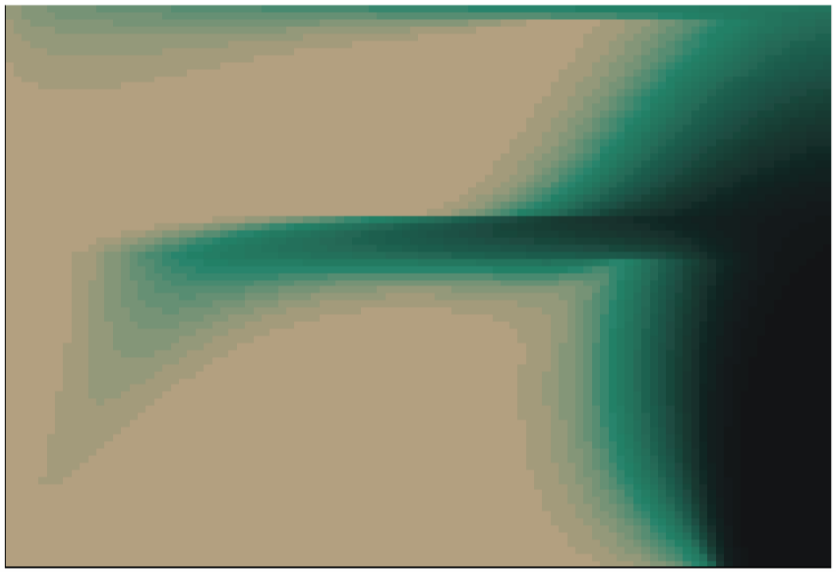

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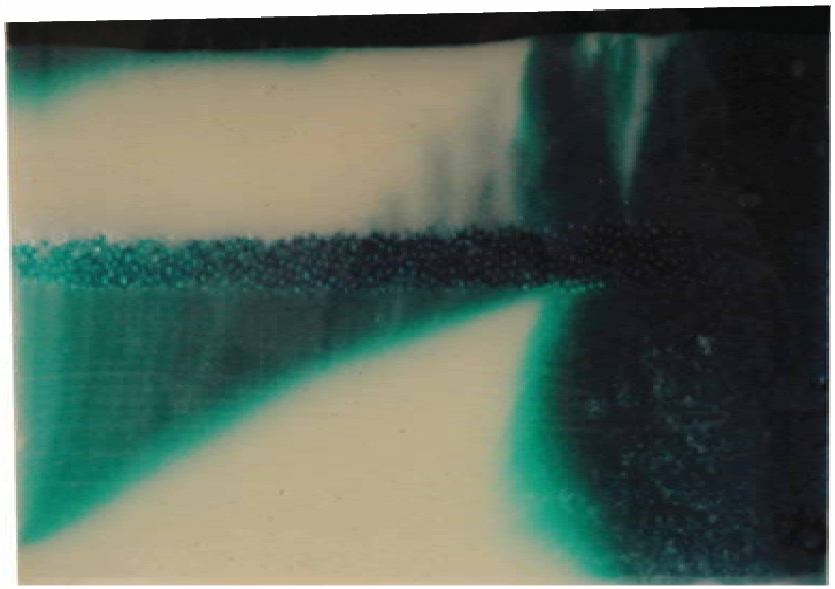

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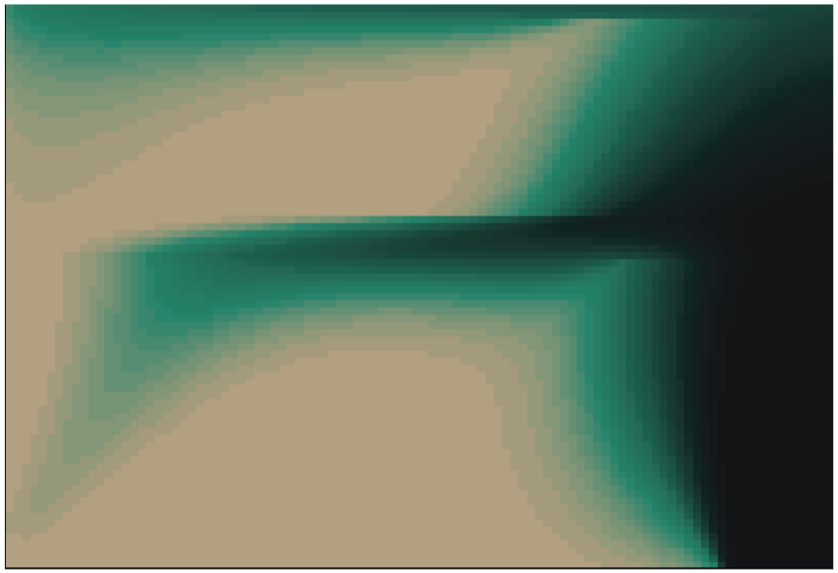


Summary

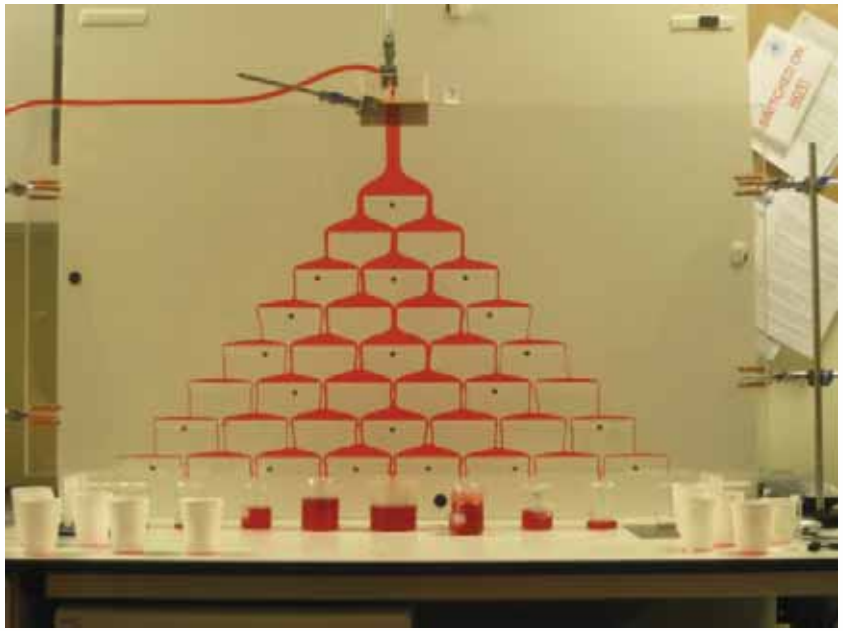
- Maestro is an established methodology providing an efficient framework for selection and ranking of candidate fields for EOR processes by focusing on most promising processes at an early stage
- The methodology continues to be relevant for today's EOR screening requirements
- New chemicals and processes require developments to the methodology
- Research ongoing to improve analytical methods for WAG processes

RPS Energy

Thank You

Modelling Flow across Baffles

Hele – Shaw experiment



Flux ⇒ Pascal's triangle

1
1 1
1 2 1
1 3 3 1
1 4 6 4 1
1 5 10 10 5 1
1 6 15 20 15 6 1