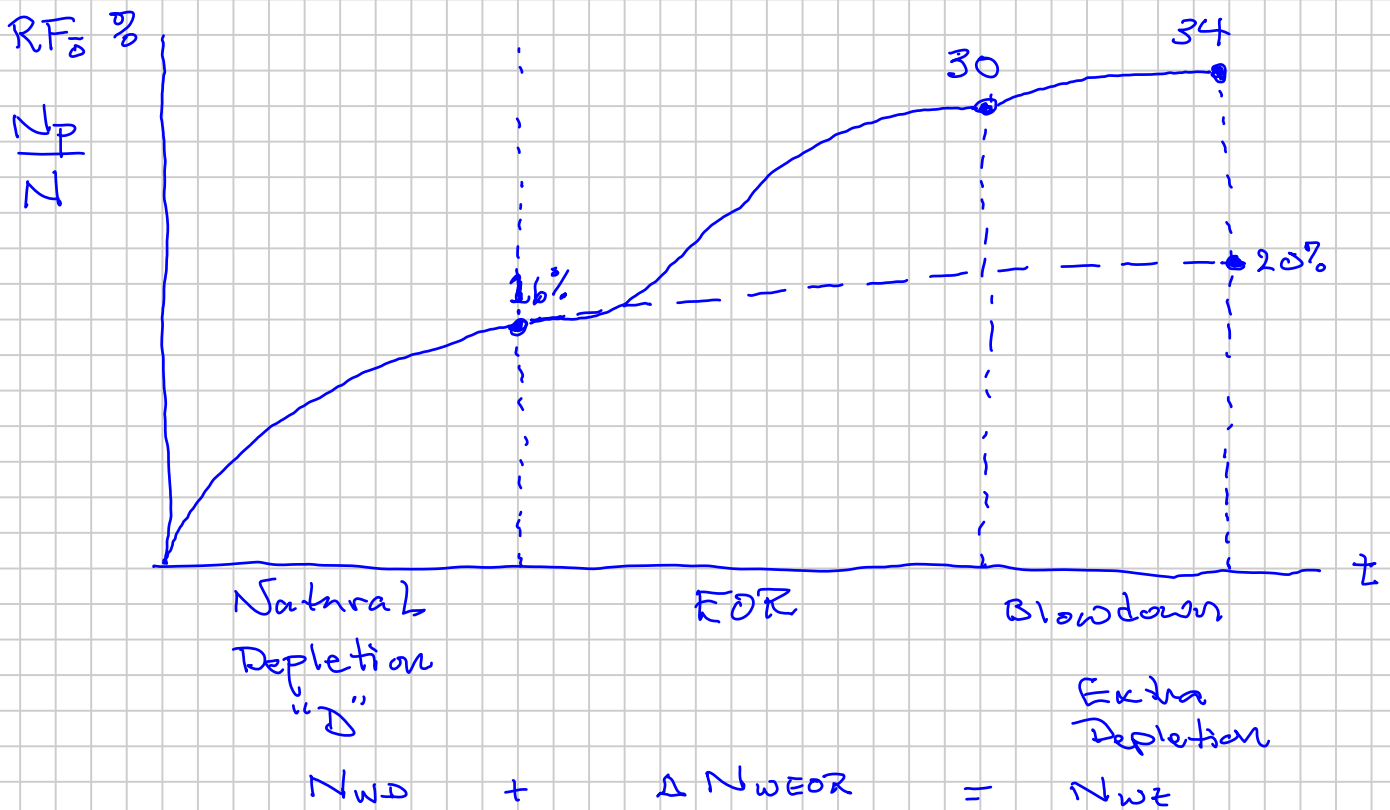


ENHANCED OIL RECOVERY (EOR)

"Enhanced"

- Recovery beyond what is expected by natural depletion: $C_f, C_w, \text{Aquifer SGD}$
 PUT (CVD)
 \downarrow

- Inject water, gas, (and/or chemicals)
 WAG



What is:

- EOR recovery %

- Depletion recovery %

What are:

- Depletion CAPEX & OPEX

- EOR CAPEX & OPEX

INCREMENTAL STO RECOVERY (%)

Initial STO In Place

$$N = \sum_{n=1}^{N_B} \Delta V_{pin} \left(\frac{S_{oi}}{B_{oi}} + \frac{S_{gi} \gamma_{si}}{B_{gdi}} \right)_n$$

STO (RO)

"B": Block (e.g. RFU, simulator grid cells)

$$\Delta V_p = (\Delta x \cdot \Delta y \cdot \Delta z \cdot \phi)$$

Remaining STO in Reservoir at time after start of production

$$N_R = \sum_{n=1}^{N_B} \Delta V_{pn} \left(\frac{S_o}{B_o} + \frac{S_g \gamma_s}{B_{gd}} \right)_n$$

$$N_p = N - N_R$$

$$= f \left(S_o, S_g, \underbrace{PVT}_{(B_o, B_{gd}, \gamma_s)}, C_f \right)$$

• $k_r(S)$: 2 ϕ , 3- ϕ , $f(PVT)$

• $PVT(p)$: depletion

• Injection (EOR)

- Displacement $S(x, y, z)$

- Gravity

- PVT $\underbrace{B_o, B_{gd}, \gamma_s, S_o}$

V | C | M

- Vaporization
- Condensation
- Miscibility
- Imbibition (Wettability)
- Diffusion
- Capillarity

EOR METHODS

All Methods - (Common Denominator)

(a) Pore-Level: Drive " S_{oi} " \rightarrow minimum $\rightarrow S_{or} \rightarrow 0$

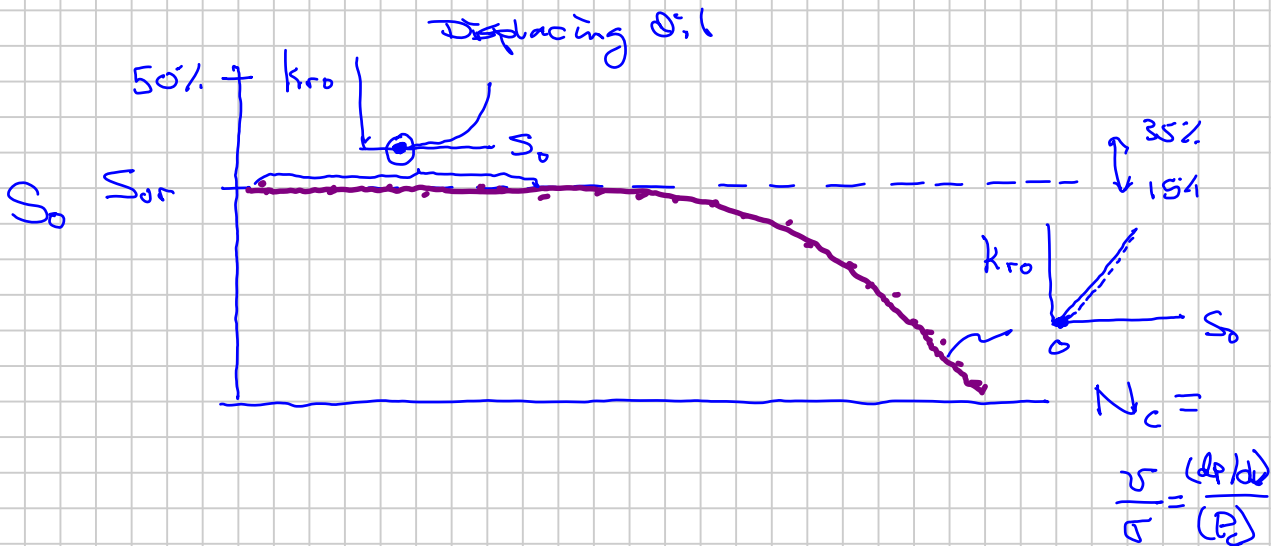
$\left(\frac{S_{oi}}{B_{oi}} + \frac{S_{oi} S_{ij}}{R_{gij}} \right) \rightarrow \text{minimum}$

$S_{or} \rightarrow 0$
 $S_{org} \rightarrow 0$
 $k_{ro} \rightarrow 0$ $\sigma \rightarrow 0$

Many WF projects

- Buckley-Leverett (BL) flow theory
 Water & Gas

$S_{oi} \rightarrow S_{or}$



$$P_{cgo} \propto \sigma_{go}$$

$$P_{cwo} \propto \sigma_{wo}$$

↑
IFT

(b) CONFORMANCE - Volumetric Sweep

Composite {

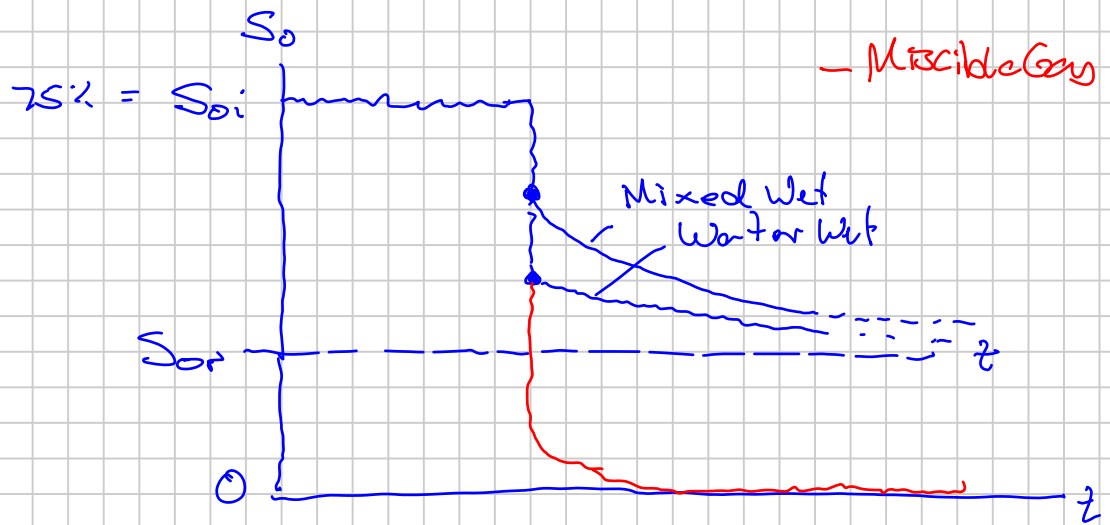
- Vertical (layering) z
- Areal (I-P well placement) x, y

"pattern"

* HCPV that has "seen" the injectant at seeing

- Usually the pore-level recovery ($\sim 1 - \frac{S_o}{S_{oi}}$) 50% → 100%

Microscopic
Displacement
Efficiency
MDE



EOR we use instead of time

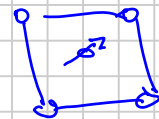
we use "pore volumes injected" PV_{inj} PV_i
"PVI"

- "Small scale (core lab test)

Well defined, fixed, "pattern" "Volume"

$$PVI = \frac{Q_{inj}}{\text{"PV"}}$$

Core / Pattern



- Dynamic "PU" (t) - real fields/wells

nobody seems
to talk about
this...

* VOIDAGE REPLACEMENT

$$q_{inj}(\bar{P}_R) \cong q_{FPR} = \underbrace{q_g B_g + q_o B_o + q_w B_w}_{@ \bar{P}_R}$$

$\Rightarrow \bar{P}_R(t) \sim \text{constant}$

