Evaluation of exercise set 1:

- 100%

| 20% | 20% | 20% | 25% | 15% |
|---|---|---|---|---|
| report / presentation | problem 1 | problem 2 | problem 3 | problem 4 |

for future deliveries 20% deduction for every day delivered late!

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## Production potential

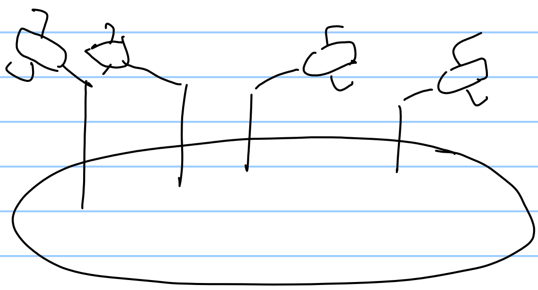
Dry gas reservoir → uniform reservoir pressure

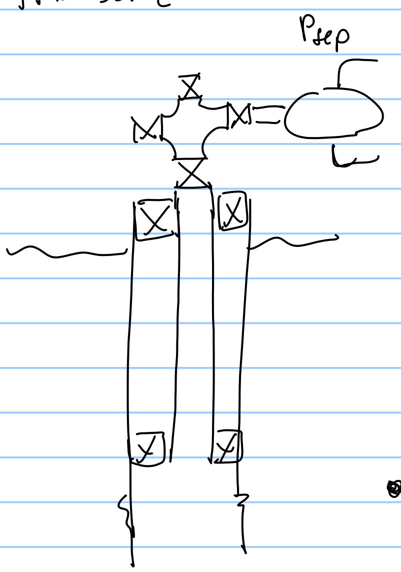
Standalone well →

N wells

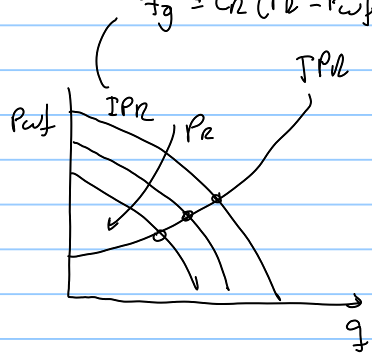
all wells are identical, IPR, TPR same

$$q_g = C_R (P_R^2 - P_{wf}^2)^n$$



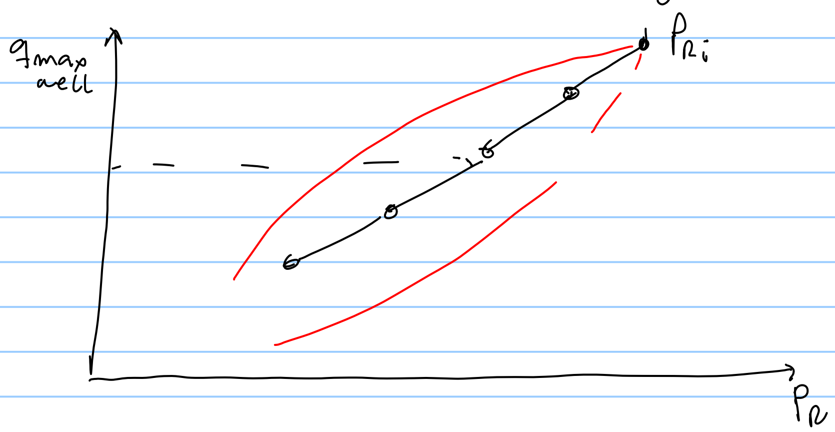




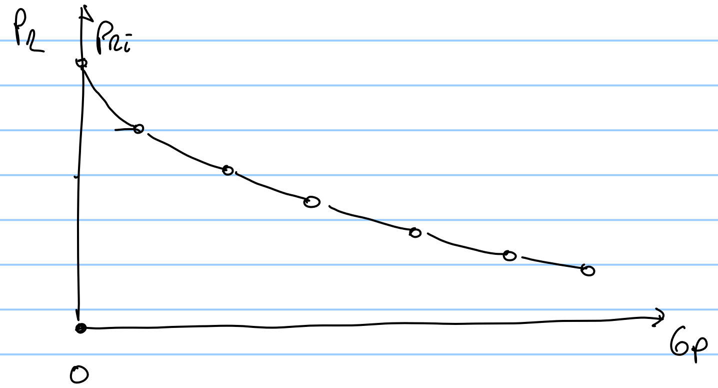


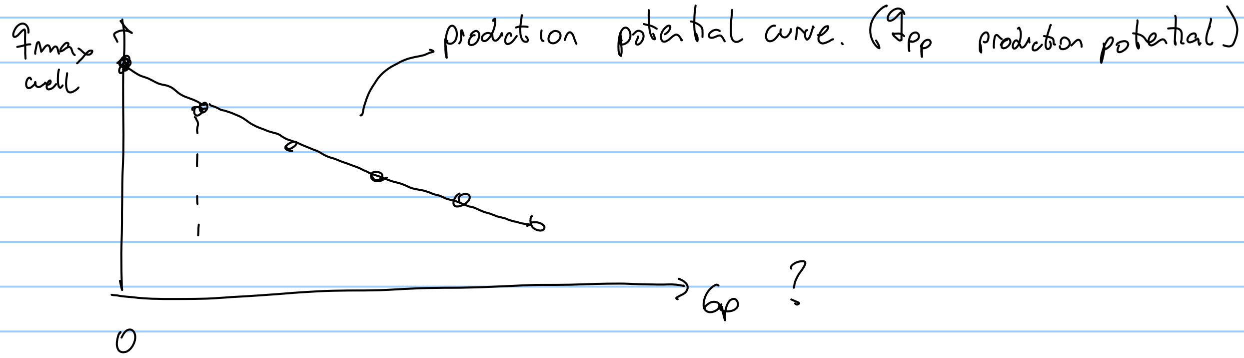


maximum rate from the well will go down with reservoir pressure

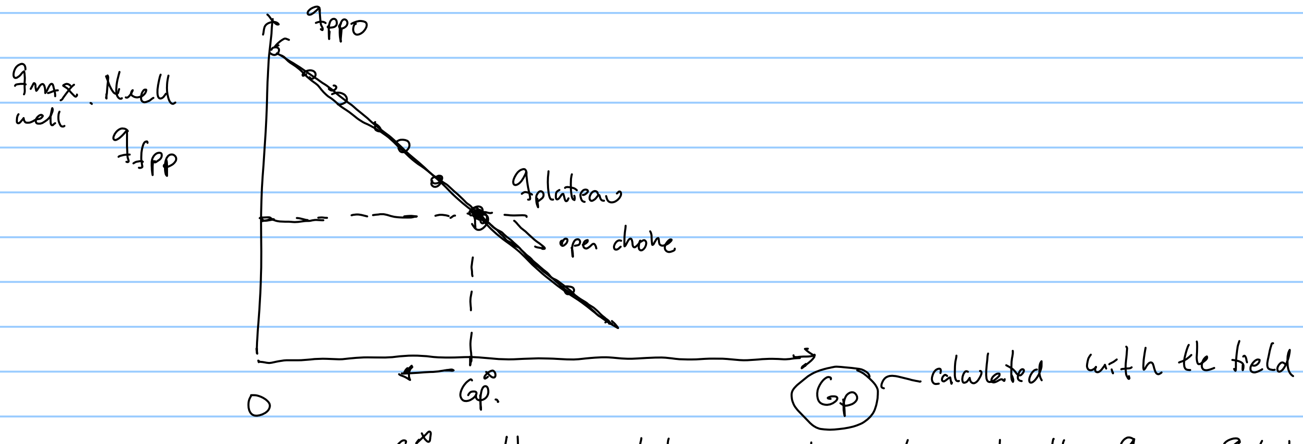


$P_R$ according to material balance $P_R(t) = f(G_p)$ $\qquad G_p = \int_0^t q_g \, dt$




for the field :




$G_p^*$ is the cumulative production at which the $q_{fpp} = q_{plateau}$

$$t_{plateau} = \left( \frac{G_p^*}{q_{plateau} \cdot N_{day/year}} \right).$$

Until now, to find plateau length you perform a stepwise calculation in time

| time | $q_{open\ choke}$ | $q_{produced}$ | if $q_{open\ choke} > q_{produce}$ → plateau |
|---|---|---|---|
| $t_1$ . | | | |
| $t_2$ . | - | - | — |
| $t_3$ . | | | |
| $t_4$ | | | |

Deriving the production profile using the production potential. always open choke

for dry gas $\boxed{q_{fpp} = q_{ppo} - m\, G_p}$ (1) $q_f = q_{fpp}$

$\boxed{G_p = \int_0^t q_f \, dt}$ (2)

$$q_f = q_{ppo} - m \int_0^t q_f \, dt$$

derive with respect to time

$$\frac{dq_f}{dt} = -m\, q_f$$

$$\int_{q_{ppo}}^{q(t)} \frac{dq_f}{q_f} = \int_0^t -m \, dt$$

$q_{ppo}$ — production potential @ $t=0$, @ $P_R = P_{Ri}$

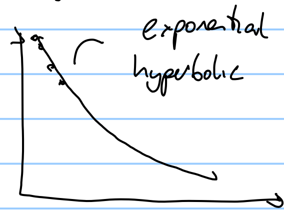
$$\ln q_f \Big|_{q_{ppo}}^{q(t)} = -m(t-0)$$

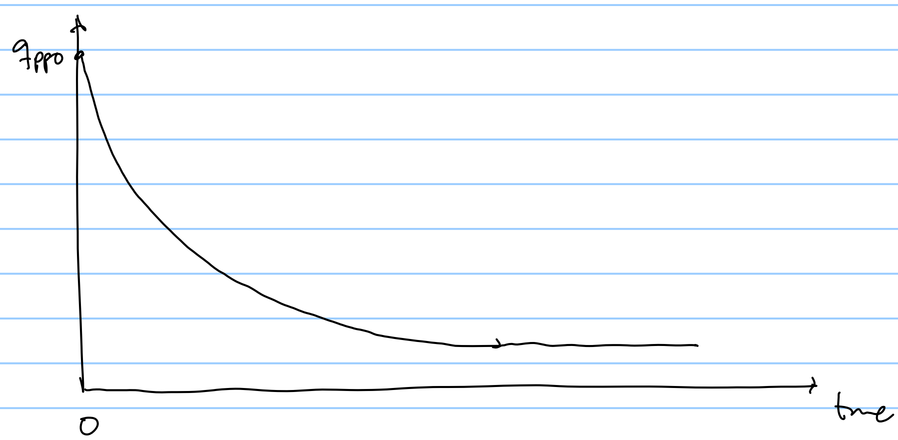
$$\boxed{q_f = q_{ppo} \cdot e^{-mt}}$$ eq (1)

material balance

res simulator

DCA




eq 1 gives you a decline shape for the rate

it can be applied for decline periods (producing at open choke) using appropriate bounds in the integral

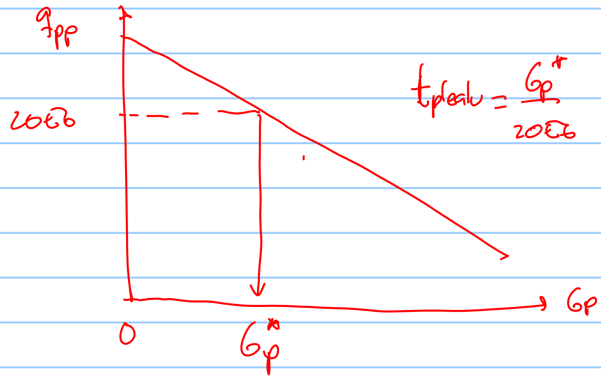
$$\int_{q_{ppo}}^{q(t)} \frac{dq_f}{q_f} = \int_0^t -m \, dt$$

$P_{wf} = BHP$

$(P_{wf}^{avail} - P_{wf}^{req})^2$ $q_{plateau}$ = desired

$q_{plateau1}$ 10E6 Sm3/d

| time | Gp | PR | q field (open choke) | Pwf avail (co-current (IPR)) | Pwf requ (counter current TPR) | Pxp | Error | (q field) |
|---|---|---|---|---|---|---|---|---|
| $t_1$ | 10 | $P_{Ri}$ | □ | | | | □ = | if $q^{open\ choke} > q_{desired}$: $q_{desired}$; else $q_{open\ choke}$ |
| $t_2$ | □ + ($q_{field} \cdot (t_2 - t_1)$ Ndays/year) | | | | | | | |
| $t_3$ | | | | | | | | |
| $t_4$ | | | | | | | | |

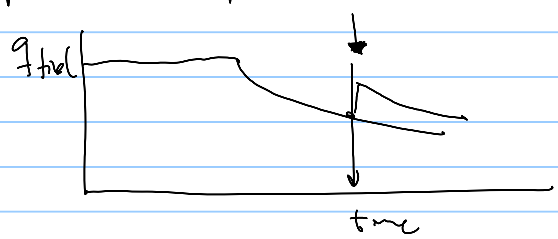


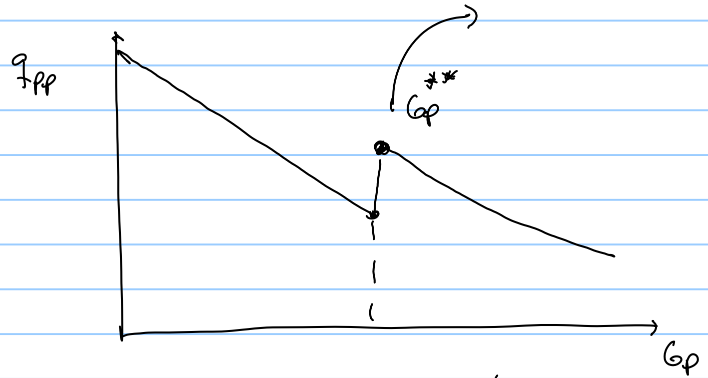

$t_{plateau} = \frac{Gp^*}{20E6}$

what happens if $q_{plateau} = q_{plateau2}$ (20 E6 Sm3/d)

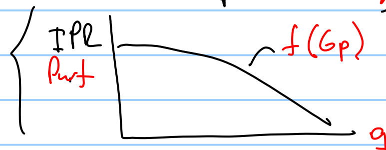
what are the limitations?

- changes in the production system → change no. wells
  - are applied at a particular day

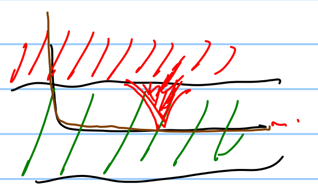


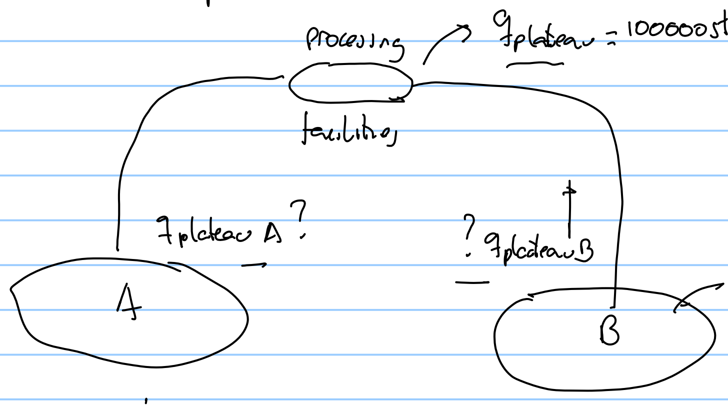

- IPR f(Pr), f(Gp)

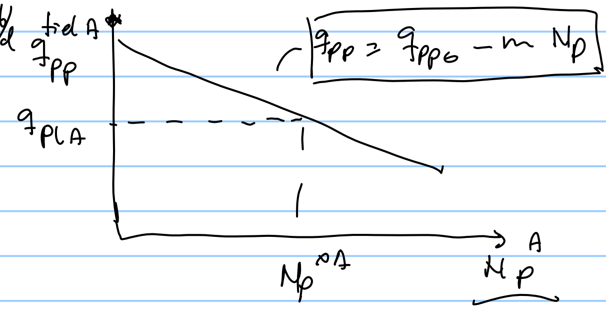


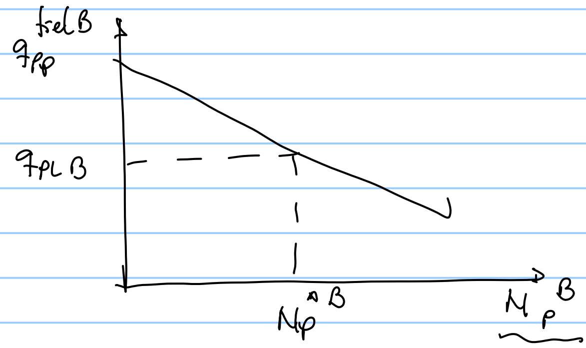

$P_{wf} > P_c$ critical coning pressure



take a example with two reservoirs




if $t_{plateau}$ field is to be maximixed
then $t_{plateau}^{A} = t_{plateau}^{B}$

iterative procedure

assume $q_{plateau\,A}$

calculate $q_{pleau\,B} = \overset{100000}{q_{pleateau}} - q_{plateau\,A}$

go to the production potential curve
read $N_p^{*A}$, $N_p^{*B}$

calculate $t_{plateau\,A}$, $t_{plateau\,B}$

$$\frac{N_p^{*A}}{q_{plateau\,A} \cdot N_{day/year}}$$

is $t_{plateau\,A} = t_{plateau\,B}$ ? NO

yes

$q_{plateau\,A}$, $q_{plateau\,B}$ is the optimum solution

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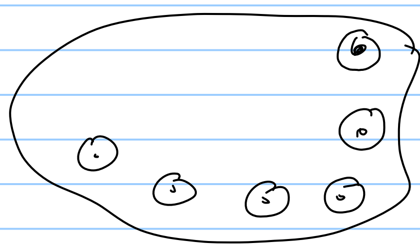
in big reservoirs $q_{pp\,well} \neq f(N_{p\,field})$

$q_{pp\,well} = f(N_{p\,well})$



**Example 1: Production potential of a system with two standalone wells**

Assume that there is a field with two (2) standalone wells, and that the production potential of each well can be expressed as a function of the cumulative production of each individual well:

$$q_{pp}^{i} = f\left(Q_P^{i}\right) \quad \text{Eq. 11}$$

In this case the production profile can be computed separately for each well from the production potential curve and then add them up to obtain the field production profile. Please note that the field production potential for a given field cumulative production is not unique. This is because there are different ways to achieve the same field cumulative production (e.g. in a two well system, produce more from well 1 than 2, produce equal, or produce more from well 2 than 1).

As an example, consider the production system with 2 standalone wells shown in Fig. 14.a. The production potential of each well is presented in Fig. 14.b. Wells will be produced at constant rate initially, with plateau rates $q_{P1}$ and $q_{P2}$ and, when the plateau rate is no longer feasible, they will be produced at the production potential.

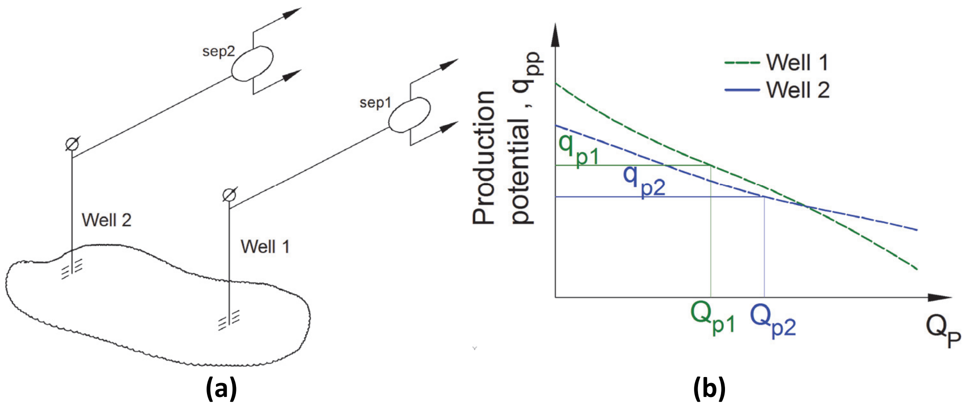



**Fig. 14. Example case: 2 standalone wells**

The plateau duration of each well can be very easily calculated by intersecting the individual plateau rate with the production potential curve of each well. This yields a plateau duration of $t_{p1}=Q_{P1}/q_{P1}$, for well 1 and $t_{p2}=Q_{P2}/q_{P2}$ for well 2. After the plateau ends, the production profile of each well follows the potential.

A typical reservoir management problem consists of how to define well rates to maximize field plateau duration when a fixed field rate is desired. If individual well plateau rates are to be kept constant, this can be achieved by finding the plateau rates for which the plateau end occurs at the same time. If the production potential curves are straight lines the following procedure is suitable:

The production potential curve for well 1:

$$q_{pp1} = -m_1 \cdot Q_{P1} + q_{ppo1} \quad \text{Eq. 12}$$

The cumulative production at which the production potential ($q_{pp1}$) is equal to the plateau rate ($q_{p1}$), i.e. $Q_{Pp1}$, is:

$$Q_{Pp1} = \frac{q_{ppo1} - q_{p1}}{m_1} \quad \text{Eq. 13}$$

Similarly for well 2:

$$Q_{Pp2} = \frac{q_{ppo2} - q_{p2}}{m_2} \quad \text{Eq. 14}$$

Then the plateau duration has to be the same for both wells:

$$t_{p1} = \frac{Q_{Pp1}}{q_{p1}} = t_{p2} = \frac{Q_{Pp2}}{q_{p2}} \quad \text{Eq. 15}$$

Substituting Eq. 13 and 14 in Eq. 15:

$$\frac{q_{ppo1} - q_{p1}}{m_1 \cdot q_{p1}} = \frac{q_{ppo2} - q_{p2}}{m_2 \cdot q_{p2}} \quad \text{Eq. 16}$$

$$\frac{q_{ppo1}}{q_{p1}} - 1 = \frac{m_1}{m_2} \cdot \left( \frac{q_{ppo2}}{q_{p2}} - 1 \right) \quad \text{Eq. 17}$$

Eq. 17 has two unknowns, therefore one more equation is needed. Clearing $q_{p2}$ from the expression of the total plateau rate:

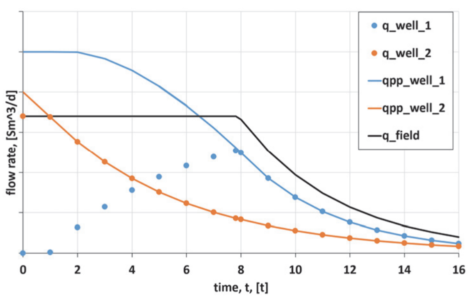
$$q_{p2} = q_p - q_{p1} \quad \text{Eq. 18}$$

Substituting Eq. 18 in Eq. 17 yields:

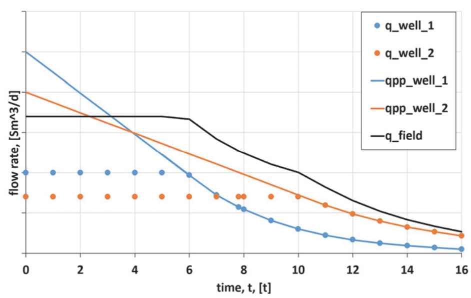
$$q_{p1}^2 \cdot (m_1 - m_2) + q_{p1} \cdot (q_{ppo1} \cdot m_2 + m_2 \cdot q_p - m_1 \cdot q_p + m_1 \cdot q_{ppo2}) - q_{ppo1} \cdot m_2 \cdot q_p = 0 \quad \text{Eq. 19}$$

Eq. 19 can be solved with the quadratic formula to find $q_{p1}$.

Please note that there are infinite alternatives to produce the field at plateau rate as shown in Fig. 15. Each option will yield a different field plateau duration.



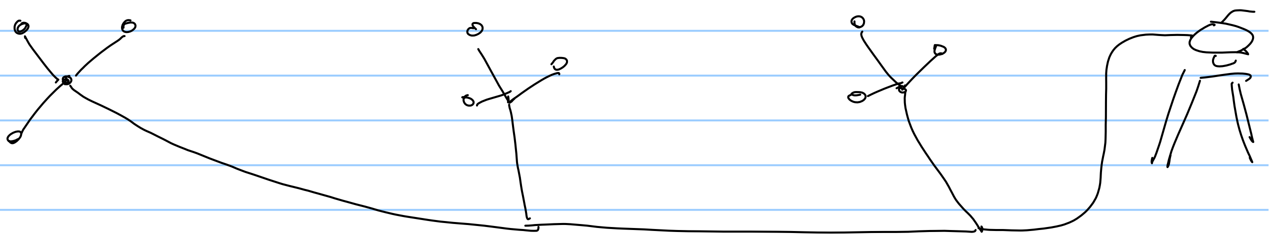
(a)



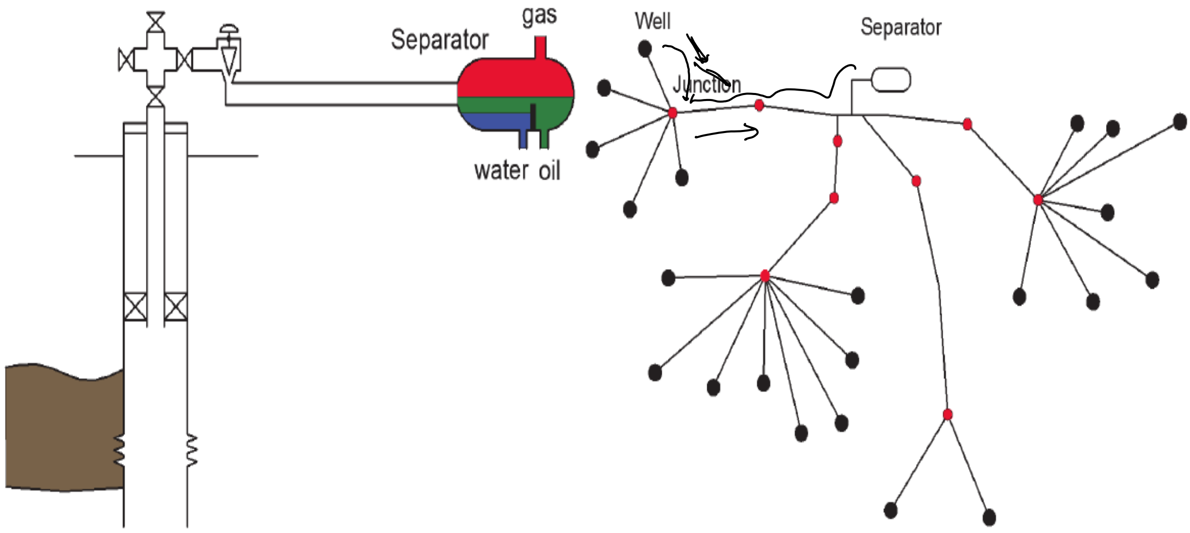
(b)

## Production networks

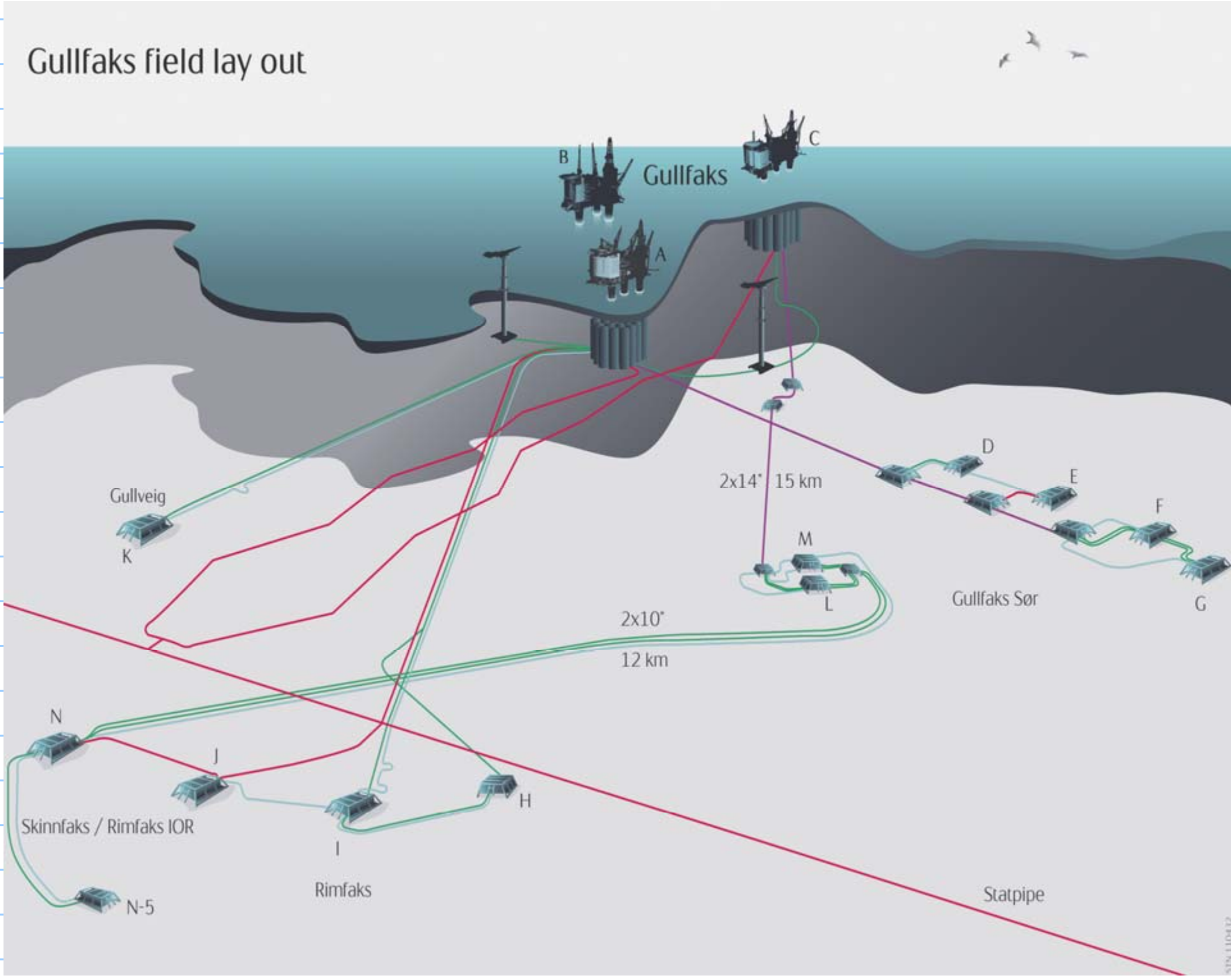
system of flowlines that commingle the production from the individual well and take it to processing facilities



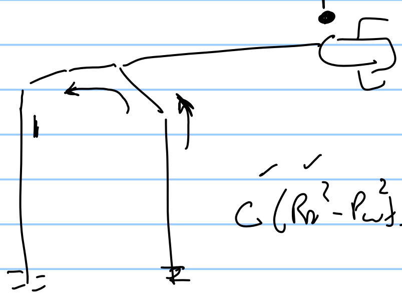
Subsea wells



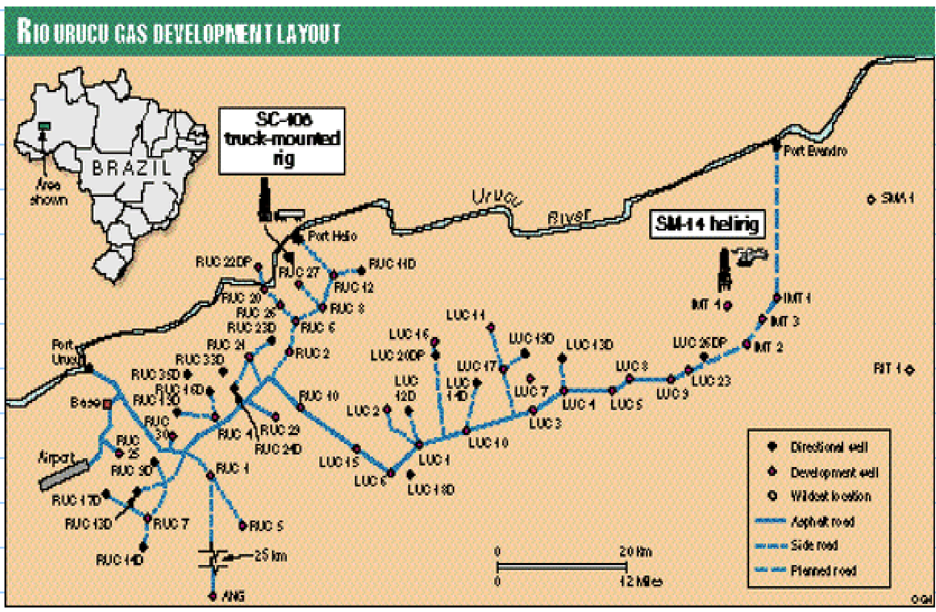

(a) (b)



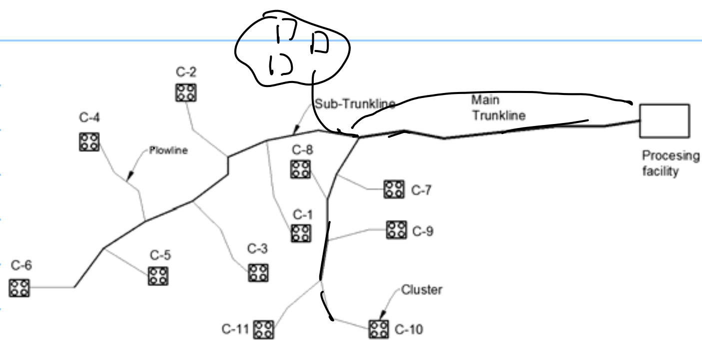

in networks there is interdependence between wells



$C(P_R^2 - P_{wf}^2)$




Rubiales field


60m
60m


Bahrain
Qatar
Sharjah
Riyadh
Al Hofuf
Al Majmaah
Ar Rass
Al Duwadimi
Saudi Arabia
Kharj
Mesaieed
Abu Dhabi
Fujairah
Hatta
Al Ain
Ghayathi
United Arab Emirates
Al Qua'a
Ibri
Al Aflaj
SHAYBAH OIL FIELD
Wadi Addawasir
Bishah
Sabt Alalayah
Oroug Bani M'aradh Wildlife Sanctuary
Khamis Mushait
Abha
Oman


10m /120m

(sabkah)