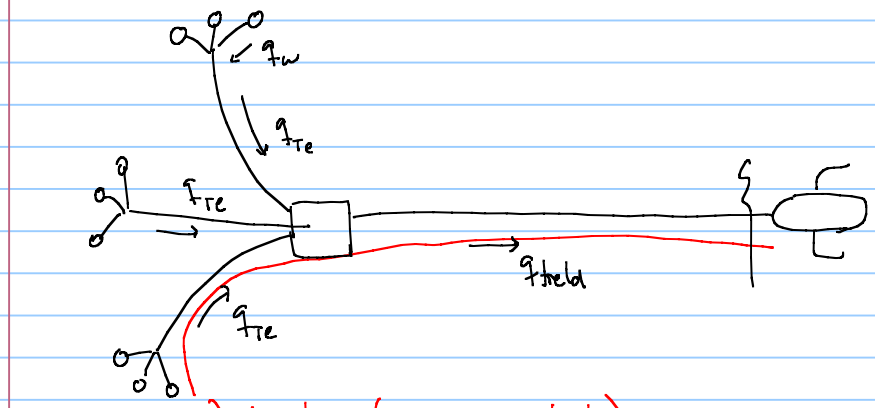
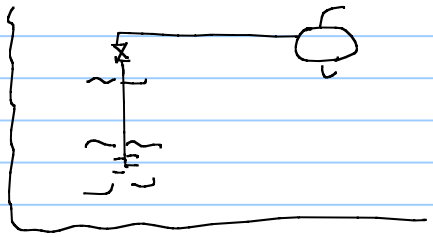
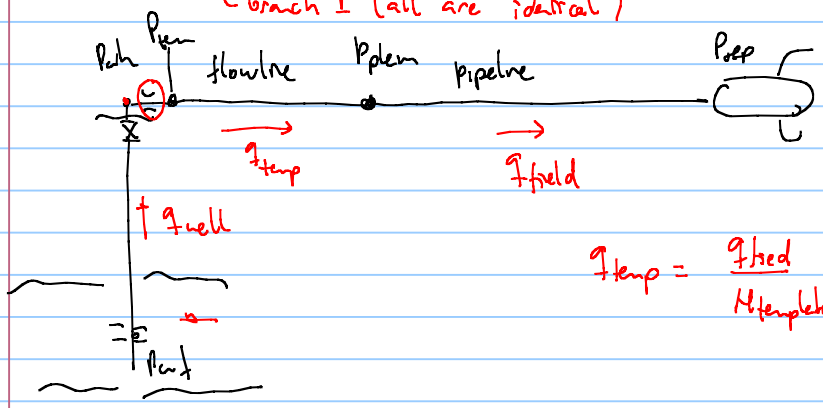
Plan:
- comments on exercise set 2.
- Review of last lecture topics
- Reservoir – Production simulators integration
- Asset / field value chain model
- NPV calculations





commingling / gathering network
- all wells are identical
- all templates are symmetrically position with respect to plem
- same nr. wells on each template

branch 1 (all are identical)

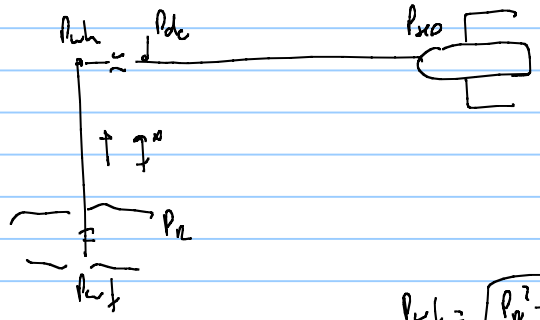


$$q_{temp} = \frac{q_{field}}{M_{templates}} \qquad q_w = \frac{q_{field}}{N_{wells}}$$

Uptime	347	d
Ct, Tubing coefficient (2100 MDx0.15 ID m)	4.03E+04	Sm3/bar
Tubing Elevation coeff, S	0.155	
$C_{FL\ Flowline}$. Template-PLEM (5000x0.355 ID m)	2.83E+05	Sm3/bar
$C_{PL\ Pipeline}$ PLEM-Shore (158600x0.68 ID m)	2.75E+05	Sm3/bar
Separator (slug catcher) pressure	30	bara
Number of wells	6	
Number of templates	2	
$q_{field\_plateau}$	2.00E+07	[Sm^3/d]
Field gas rate for abandonment	5.00E+06	[Sm^3/d]

IPR, tubing, flowline, pipeline

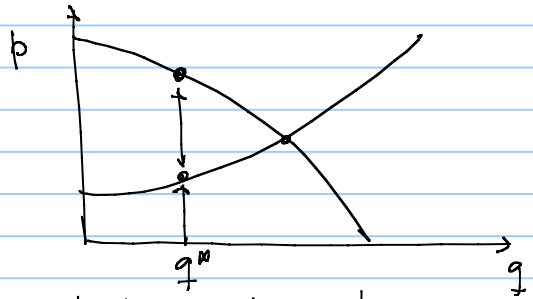
time	qfield	qtemp	qwell	Gp	RF	ZR	PR	Pwf	Pwh avail	Ptemp req	Pplem req	Psep	DeltaPchol
[years]	[Sm^3/d]	[Sm^3/d]	[Sm^3/d]	[Sm^3]	[-]	[-]	[bara]	[bara]	[bara]	[bara]	[bara]	[bara]	[bara]
0				0	0	0	0						( )
1													
2													
3													
4													



$$P_{wf} = \sqrt{P_w^2 - \left(\frac{q}{C}\right)^2}$$

Two modeling options

1: Remove controllable element
compute available pressure upstream
compute required pressure downstream



if $\Delta p > 0$ then rate is feasible

if $\Delta p < 0$ then rate is not feasible

- Include choke model (adjustable equipment)

- $q_{target} = q^*$

- $q_g = C\left(P_w^2 - P_{wf}^2\right)^n$

$$q_g = C_T \left(\frac{P_{wf}^2}{e^s} - P_{wh}^2\right)^{0.5}$$

$$q_g = C_d A_2 P_1 \left(\frac{P_{sc}}{T_{sc}}\right) \sqrt{\frac{2k}{Z_1 T_1 m_w} \frac{k}{k-1} \left(\left(\frac{P_{dc}}{P_{wh}}\right)^{2/k} - \left(\frac{P_{dc}}{P_{wh}}\right)^{\frac{k+1}{k}}\right)}$$

$$q_g = C_{PI}\left(P_{dc}^2 - P_{sep}^2\right)^{0.5}$$

1: Assume choke opening (A_2)

2: Solve system of equations (iterative process), network solving

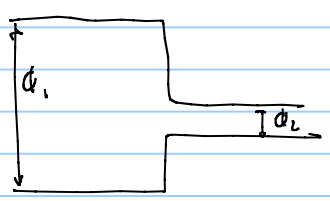
3: Result q_1

4: Compare $q_1 = q^*$?

not ↩ (back to 1)

yes ↓

A_2 is solution, rate is feasible

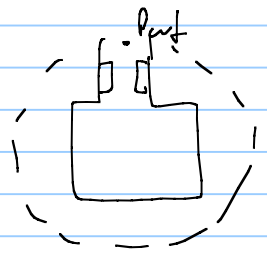


$$A_2 = \pi \frac{\phi_2^2}{4}$$

1-4 is also an iterative process often called "optimization"

If $A_2 \rightarrow A_{2max}$ without meeting the target rate, then the rate is not feasible

So far we have reservoir simulator and production simulator in the same "platform" software, tool



In industry

typically developed, updated and run by reservoir simulation department

- ECLIPSE
- MBAL
- SENSOR
- Intersect
- OPM
- MRST
- CMG

} commercial tools

typically developed, updated and run by production simulation department

- GAP/PROSPER
- Pipesim
- OLGA
- LEDA flow
- Reo
- pipeflow

} commercial tools

typical industrial workflow to get production profiles:

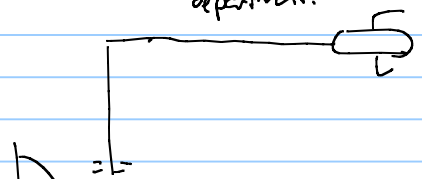
Reservoir simulator department

- increase RF
- well placement
- pressure maintenance strategy
- enhanced oil recovery
- assure Perform

results

tme	p_R	q_w	GOR	wc

production simulator department.



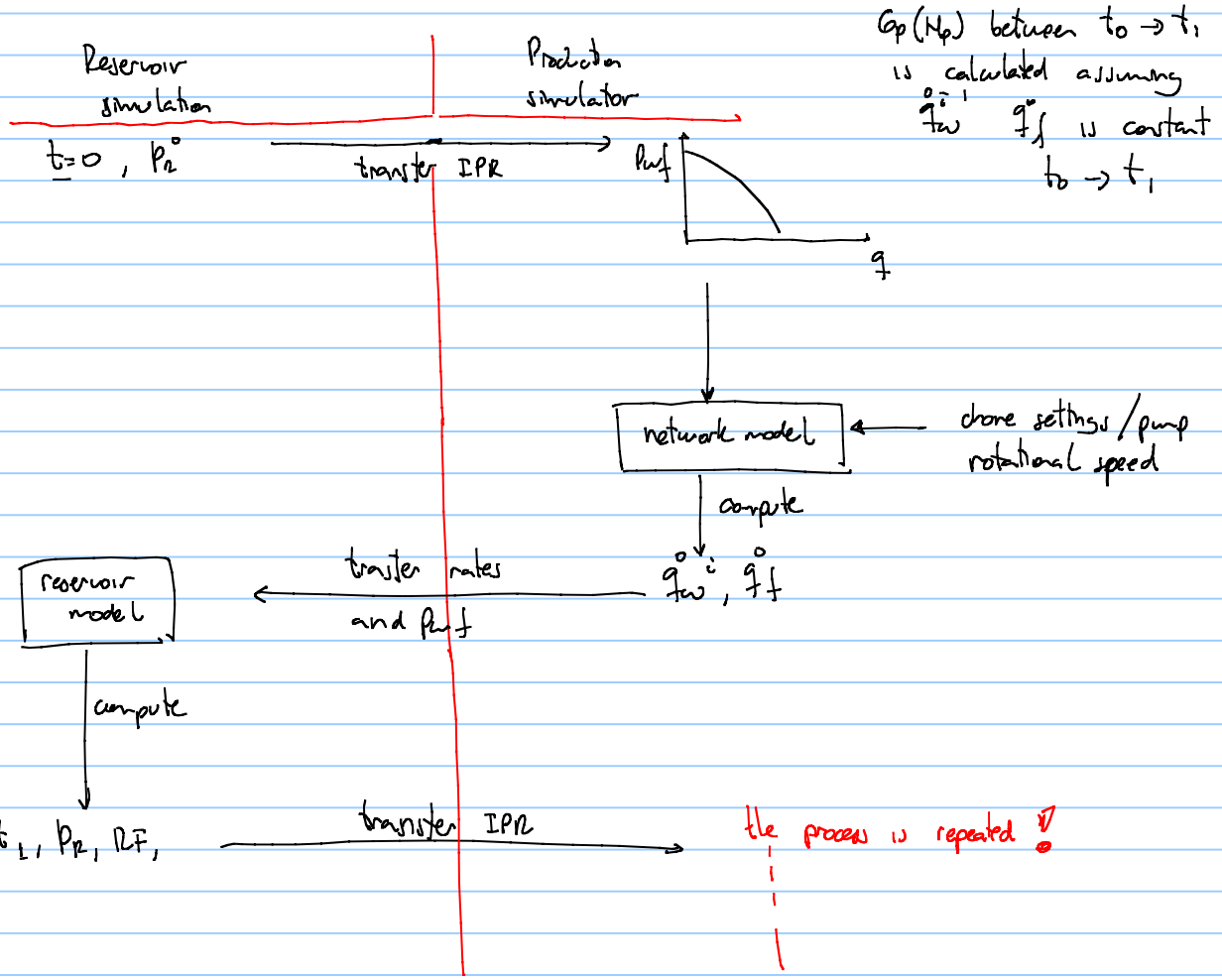
results

rate feasibility

tme	q_w	GOR	wc	feasibility (yes, no)	Action.
t_1					↑7, ↓9
t_2					
t_3					

feedback

Coupling reservoir and production simulators. Example of an explicit strategy

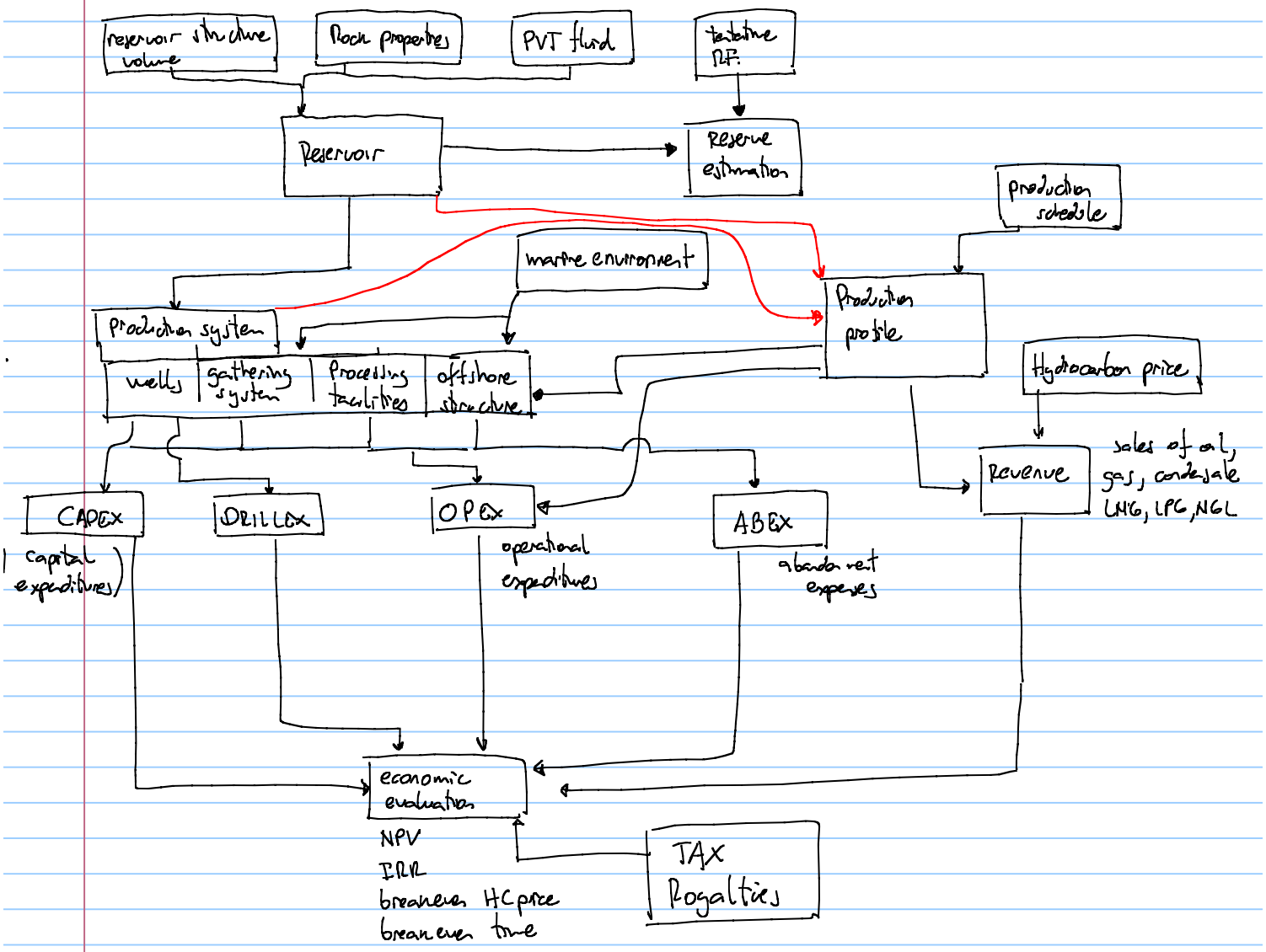


for an implicit coupling, the reservoir simulation step must be re-run,

typically explicit coupling with small Δt_i is equivalent to implicit coupling

Commercial software to couple reservoir + production models → IAM Avocet (Schlumberger)
(Integrated asset modeling)
→ Resolve.
→ Pipe-it

to take decisions about field development, the company establishes value chain model of asset



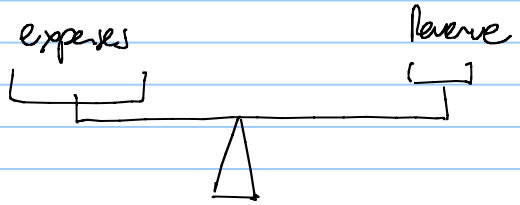
CAPEX:
- engineering studies (salaries, consultants, contractors)
- processing facilities (separators, pumps, compressors, water injection, gas injection, water/oil/gas treatment)
- offshore structure (cost of platform, FPSO, TLP, GBS → gravity based structure)
  - living quarters
  - auxiliary equipment (power system)
- subsea system (template, X-mas tree, flowline, pipelines, metering, risers, umbilical, control system)
- export system

design, manufacturing, installation

DRILLEX :
- drilling rate of drilling vessel
- materials → well completion
- well head
- test while drilling (DST, logging, pressure test, sampling)
- drilling tools

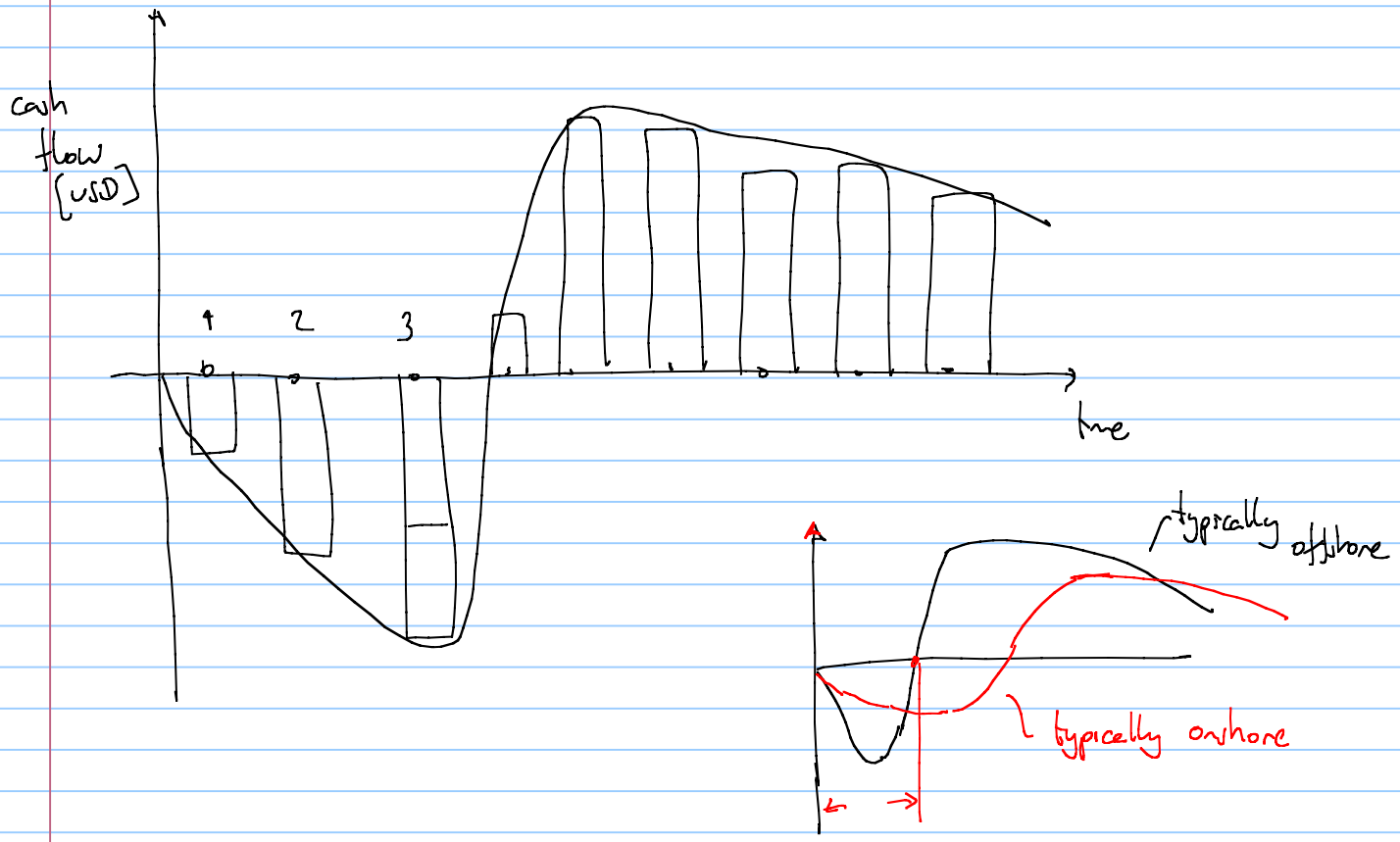
OPEX :
- salaries of workers
- insurance
- maintenance
- equipment
- well intervention
- Power
- Production chemical
  - hydrate inhibitor
  - demulsifier
  - wax inhibitor
  - corrosion inhibitor
- pigging
- transportation and export

ABEX :
- well plugging
- removal of facilities, structure, pipeline
- cleaning



Cash flow calculations

Year	Gas/oil volumes	Revenue	CAPEX	OPEX	DRILLEX	Cash flow.	Cummulative CF	DCF
1	0	0	—	0	—	Revenue − expenses →	→	
2	0	0	—	0	—			
3	0	0	—	0	—			
4	0	0	—	0	—			
⋮	—	—	0	—	—			
⋮	—	—	0	—	0			
⋮	—	—	0	—	0			
⋮		—	0	—	0			
								NPV = ΣDCF



Discounted cash flow

$$PV = FV \frac{1}{(1+i)^t}$$

t ~ year counter

i ~ discount rate (6 - 15 %)

$$DCf = Cf \cdot \frac{1}{(1+i)^t}$$

$$NPV = \sum_{t=1}^{N_{years}} \frac{CF_t}{(1+i)^t}$$