02.12.2019 ME683 Field development and operations

02.12 – 06.12 Prof Milan Stenko NTNU Norwegian University of science and Technology

09:00 – 14:00
3 breaks → 15 mins

Master program responsible: UDSM Joseph Kihedu
NTNU: Ole Jørgen Nydal

Evaluation:
10% homework (2019)
2x 15% Quizzes (2019, 2020)
60% Exam (2020)

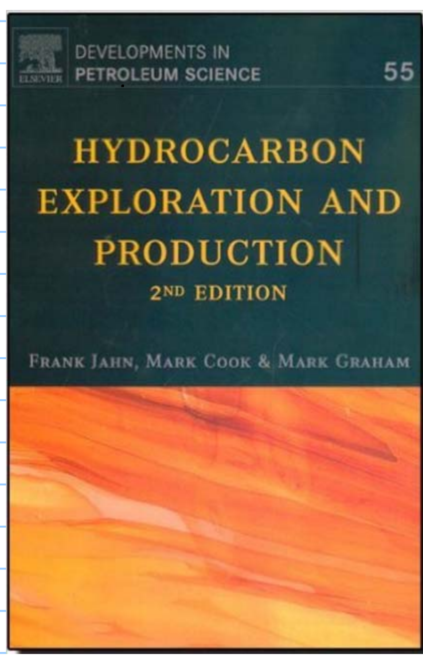
Supporting prof. @ UDSM: Liberato Haule
- Examination
- Exercises
- Quizzes

Students:
- Neema (petroleum)
- Wilfritus (chemical and process)
- Emmanuel (petroleum)
- Chrisostom (mechanical engineer)

Course information: http://www.ipt.ntnu.no/~stanko/files/Courses/ME683/2019
/2018 previous course material

youtube channel: https://www.youtube.com/channel/UCWMfsCe1NQMgx4UZWrVvFgA
↳ playlist:
ME683 - Field development and operation (2018)

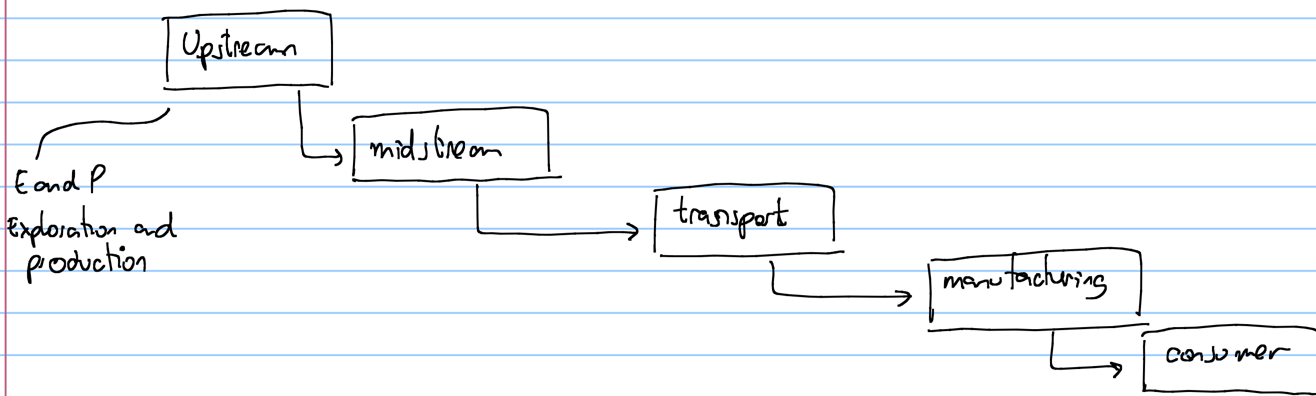
Book:



Authors: Frank Jahn, Mark Cook, Mark Graham

regular NTNU course: https://www.youtube.com/channel/UCWMfsCe1NQMgx4UZWrVvFgA
youtube channel: playlist: TPG4230 field development and operations (2019)

where are we?

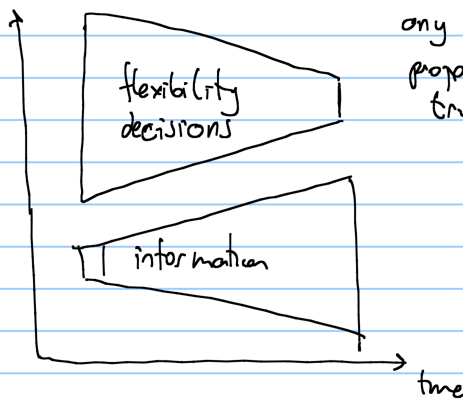


in E&P projects there are three distinct tasks:

field development and operations

- Understand the subsurface
  ↓
- commercialize the discovery / reservoir
  ↓
- optimize / effectivize the production
  - infill drilling
  - reduce maintenance and expenses
  - Enhanced oil recovery

  } HSE compliant

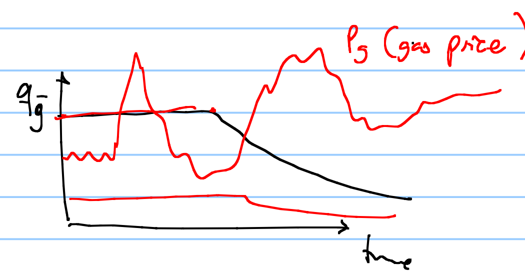


any oil and gas project. Specially true for offshore

topics to cover in the course

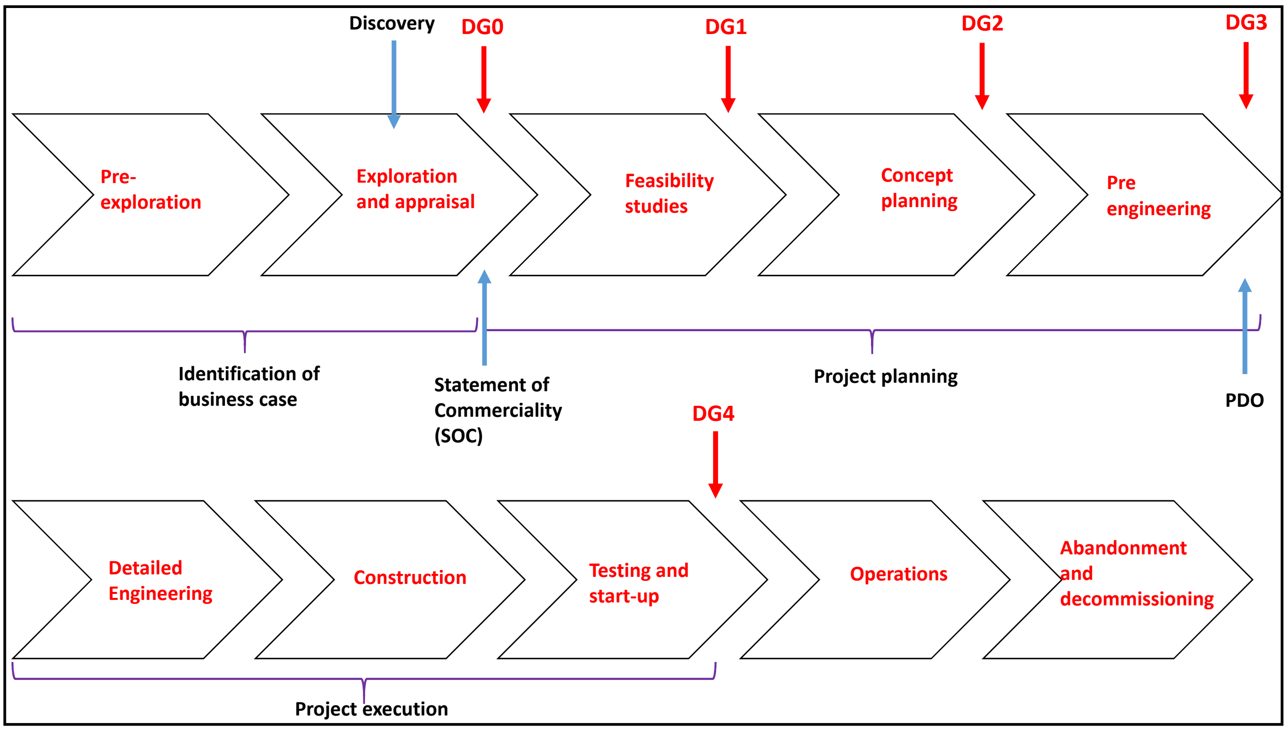
- Estimate and quantify reserve uncertainty
- Decision (probability) trees ~> appraisal
- flow assurance ~> hindrance to develop the field (multiphase transport Ole Jørgen Nydal) Corrosion, Roy Johnsen)
- offshore structure type and selection
- field production performance ~ q_{field} vs time
  Price vs. time

allows to compute: revenue
size of facilities → cost

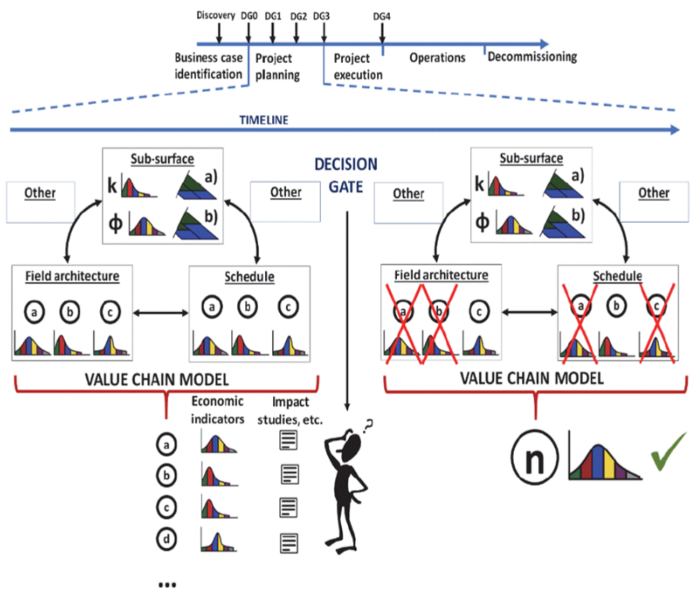


THE FIELD DEVELOPMENT PROCESS

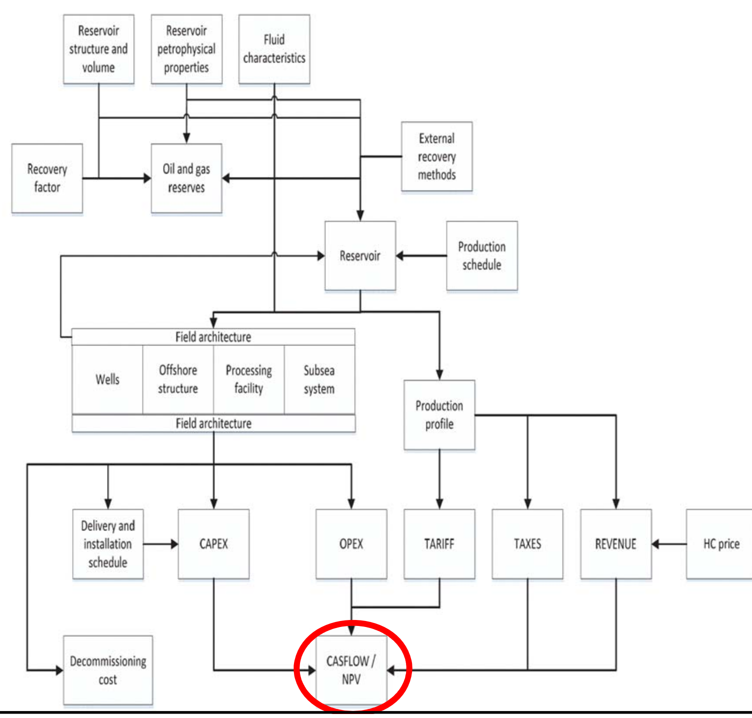
Prof. Milan Stanko (NTNU)

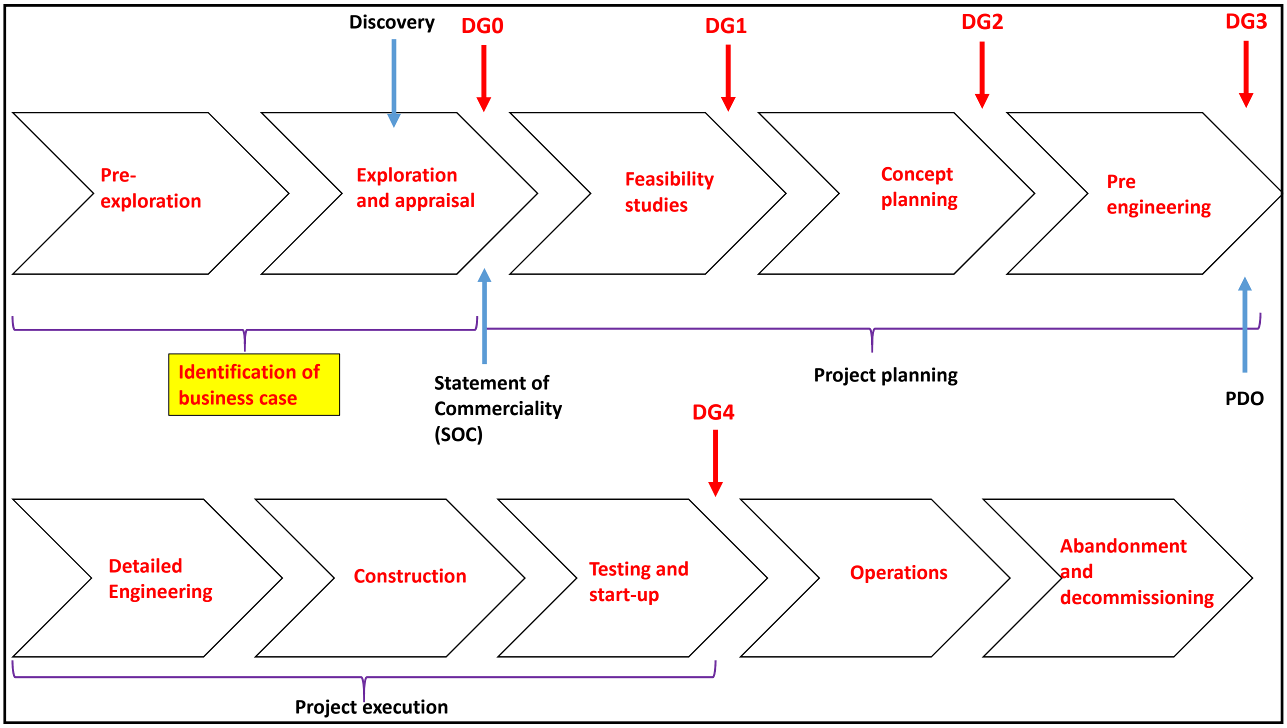


During the field development process a model of the value chain is made based on the disciplines involved and populated with information. Initially there are many alternatives and little information. As time progresses and decisions are taken, the model is expanded, there is more information but less flexibility.



Key performance indicators are computed with the value chain model and are used to take decisions in the decision gate process.





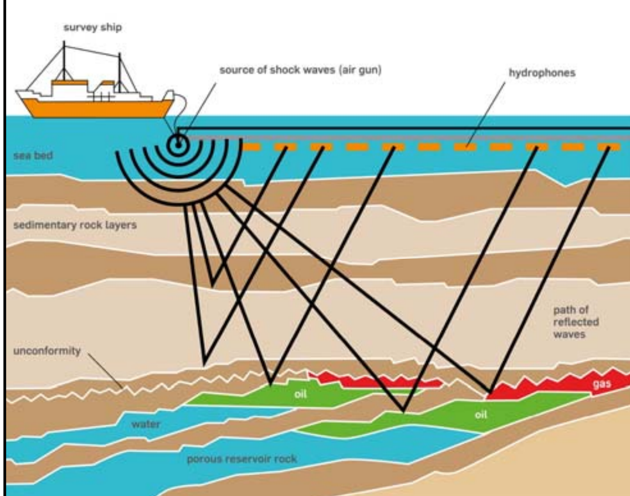
IDENTIFICATION OF BUSINESS CASE

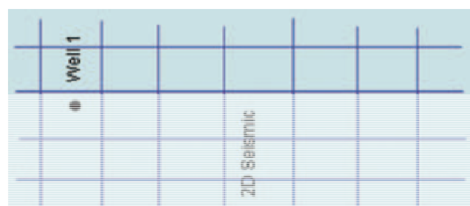
The main goal of this stage is to prove economic potential of the discovery and quantify and reduce the uncertainty in the estimation of reserves.

IDENTIFICATION OF BUSINESS CASE - TASKS

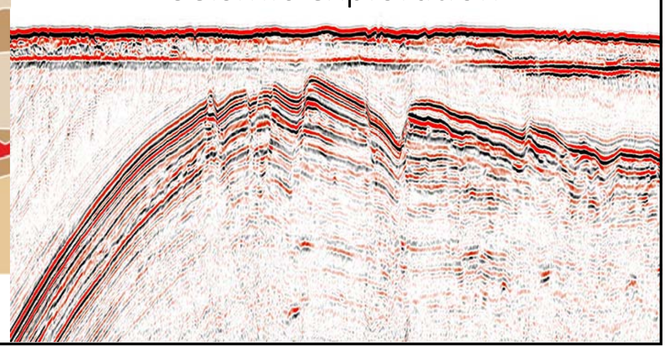
- Pre-exploration – scouting: collecting information on areas of interests. Technical, political, geological, geographical, social, environmental considerations are taken into account. E.g. expected size of reserves, political regime, government stability, technical challenges of the area, taxation regime, personnel security, environmental sensitivity, previous experience in the region, etc.
- Getting pre-exploration access – The exploration license (usually non-exclusive). In the NCS only seismic and shallow wells are allowed. This is usually done by specialized companies selling data to oil companies. Area: 500 Km^2
- Identify prospects.

IDENTIFICATION OF BUSINESS CASE - TASKS



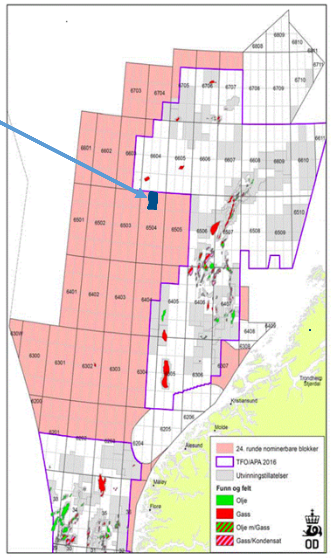


Seismic exploration



IDENTIFICATION OF BUSINESS CASE - TASKS

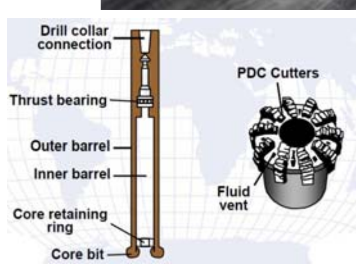
Ca 500 km^2

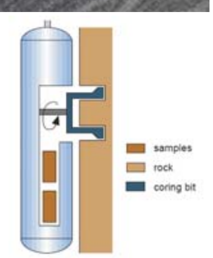


- Apply and obtain exclusive production license (6 years, possible to extend for 30 years). In the NCS: Licensing rounds (frontier areas) or Awards in predefined areas (APA). The current fees are 34 000 NOK/km^2 for the first year, 68 000 NOK/km^2 for the second year and 137 000 NOK/km^2 per year thereafter.

IDENTIFICATION OF BUSINESS CASE - TASKS

- Exploration. Perform geological studies, geophysical surveys, seismic, exploration drilling (Well cores, wall cores, cuttings samples, fluid samples, wireline logs, productivity test).
- Discovery!





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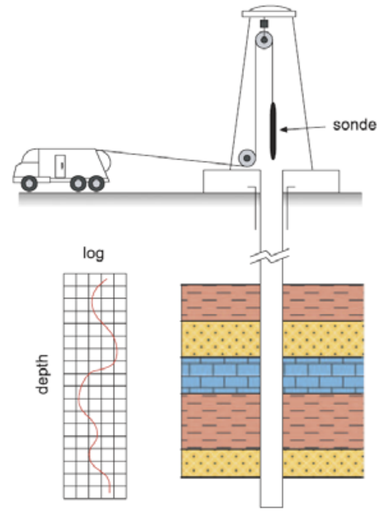


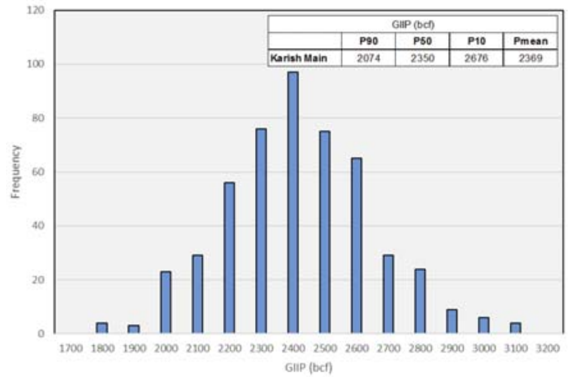
IDENTIFICATION OF BUSINESS CASE - TASKS

- Exploration. Perform geological studies, geophysical surveys, seismic, exploration drilling (Well cores, wall cores, cuttings samples, fluid samples, wireline logs, productivity test).

- Discovery!

IDENTIFICATION OF BUSINESS CASE - TASKS

- Assessment of the discovery and the associated uncertainty. Risk management:
  - o **Probabilistic reserve estimation.** Identify and assess additional segments.

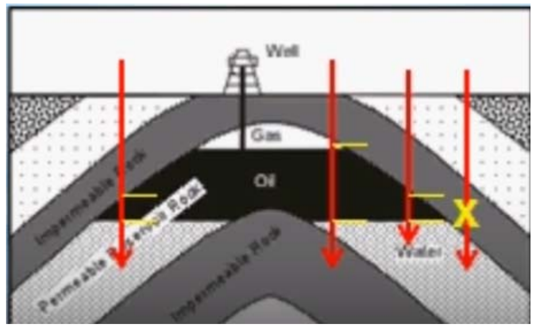


IDENTIFICATION OF BUSINESS CASE - TASKS

- Assessment of the discovery and the associated uncertainty. Risk management:
  - o **Probabilistic reserve estimation.** Identify and assess additional segments.
  - o Perform **simplified economic valuation** of the resources.
  - o Field **appraisal** to reduce uncertainty: more exploration wells and seismic to determine for example: fault communication, reservoir extent, aquifer behavior, location of water oil contact or gas oil contact.

IDENTIFICATION OF BUSINESS CASE - TASKS

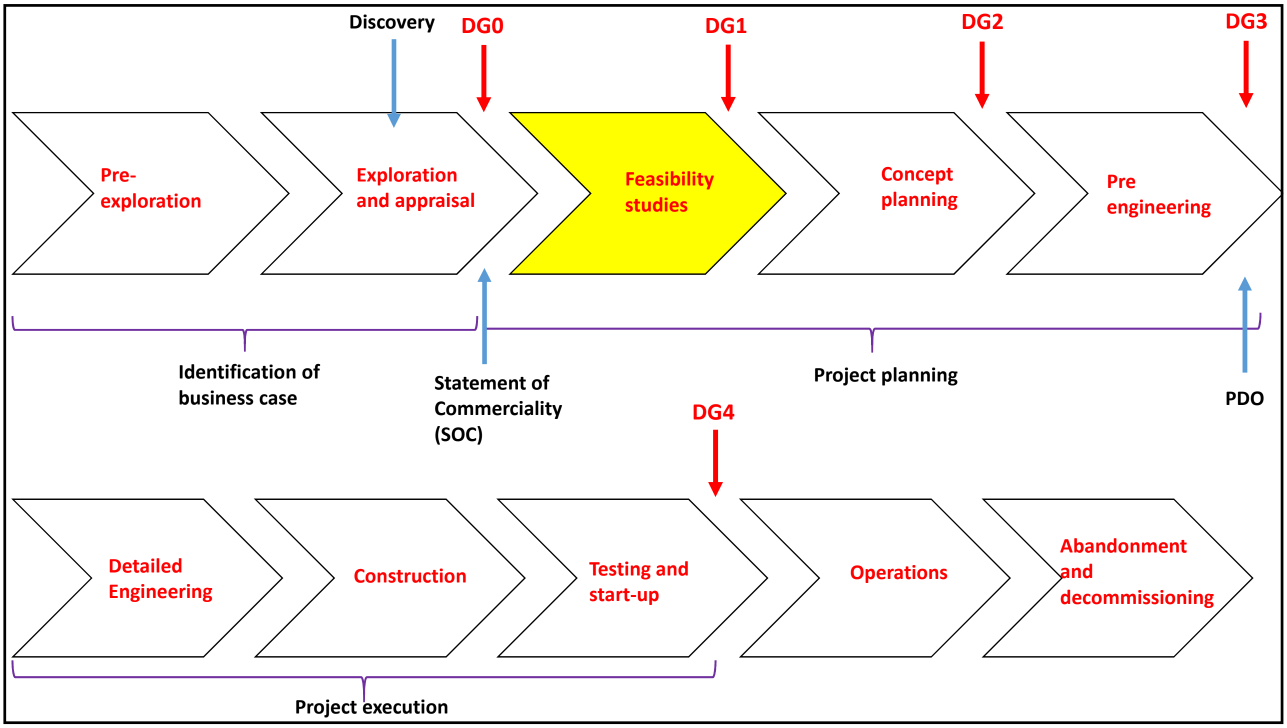
o Appraisal



IDENTIFICATION OF BUSINESS CASE - TASKS

DG0:

- Issue a SOC (Statement of Commerciality) and proceed with development.
- Continue with more appraisal
- Sell the discovery.
- Do nothing (wait)
- Relinquish to the government

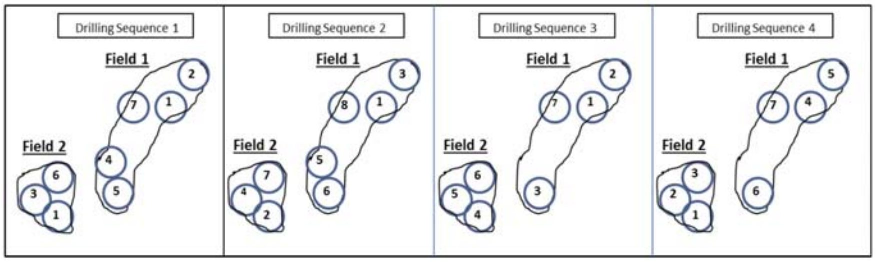


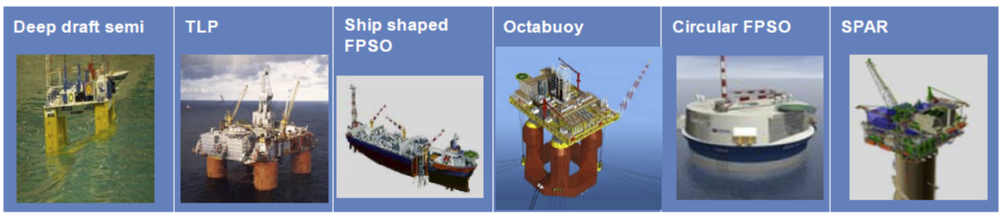
FEASIBILITY STUDIES - TASKS

OBJECTIVE: Justify further development of the project, finding one or more concepts that are technically, commercially and organizationally feasible

- Define objectives of the development in line with the corporate strategy.
- Establish feasible development scenarios.
- Create a project timeline and a workplan.

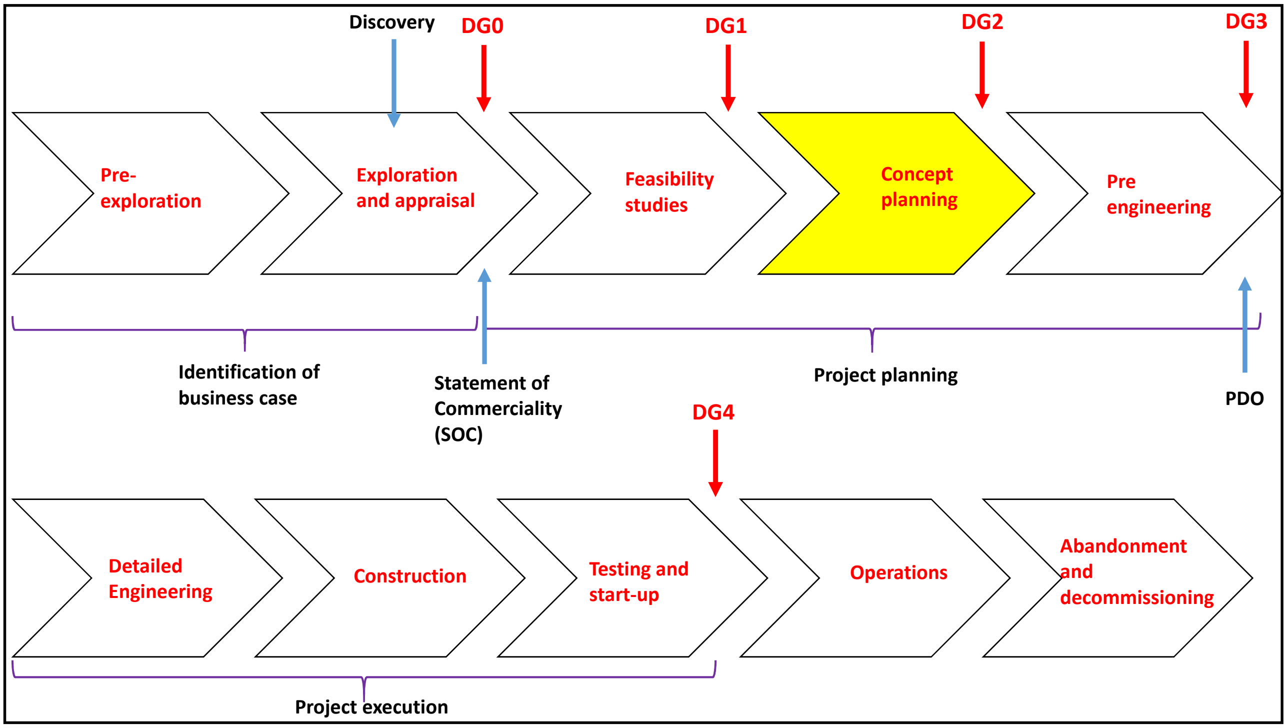
FEASIBILITY STUDIES - TASKS





FEASIBILITY STUDIES - TASKS

- Identify possible technology gaps and blockers.
- Identify the needs for new technology.
- Identify added value opportunities.
- Cost evaluation for all options (at this stage, cost figures are ±40% uncertain)



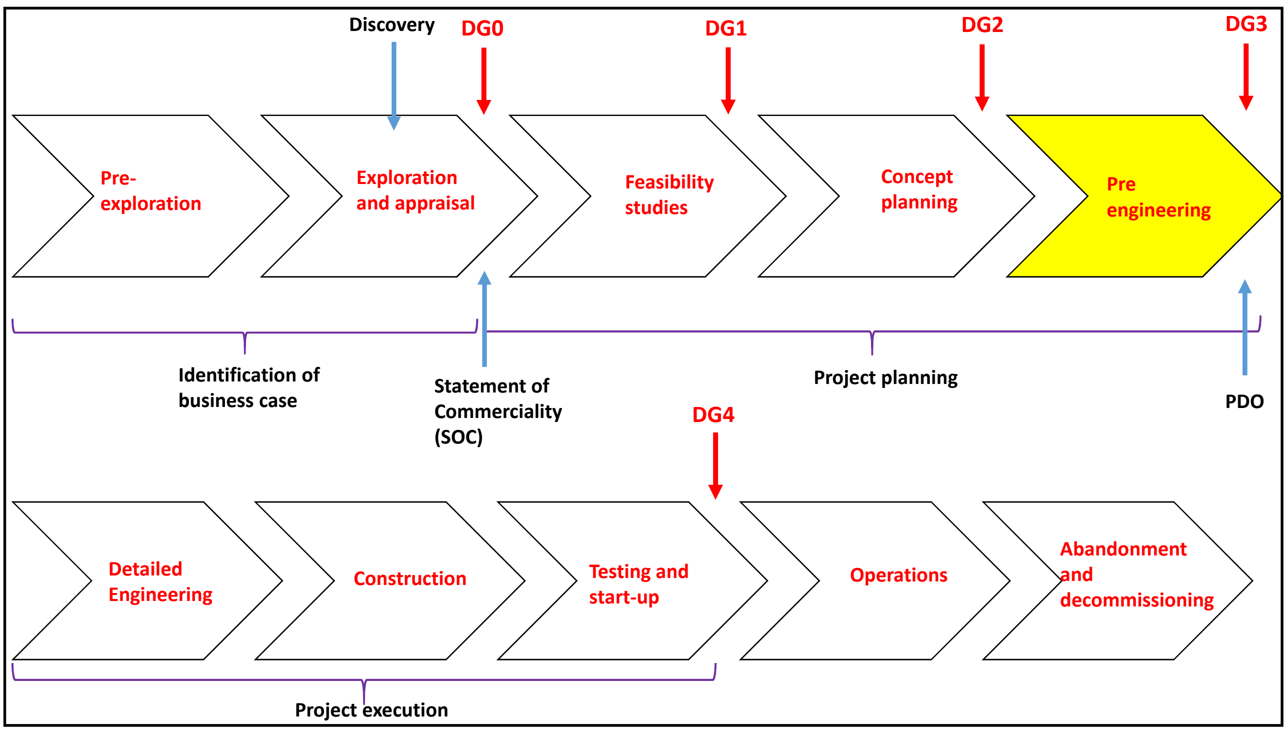
CONCEPT PLANNING - TASKS

OBJECTIVE: Identify development concepts, rank them and select and document a viable concept (Base Case Scenario).

- Evaluate and compare alternatives for development and screen out non-viable options.
- Elaborate a Project Execution Plan (PEP) which describes the project and management system.
- Define the commercial aspects, legislation, agreements, licensing, financing, marketing and supply, taxes.

CONCEPT PLANNING - TASKS

- Create and refine a static and a dynamic model of reservoir. **Define the depletion and production strategy.**
- Define an HSE program
- **Flow assurance evaluation.** Identification of challenges related with fluid properties, multiphase handling and driving pressure.
- Drilling and well planning
- Pre-design of facilities
- Planning of operations, start-up and maintenance
- Cost and manpower estimates of the best viable concept.



PRE-ENGINEERING - TASKS

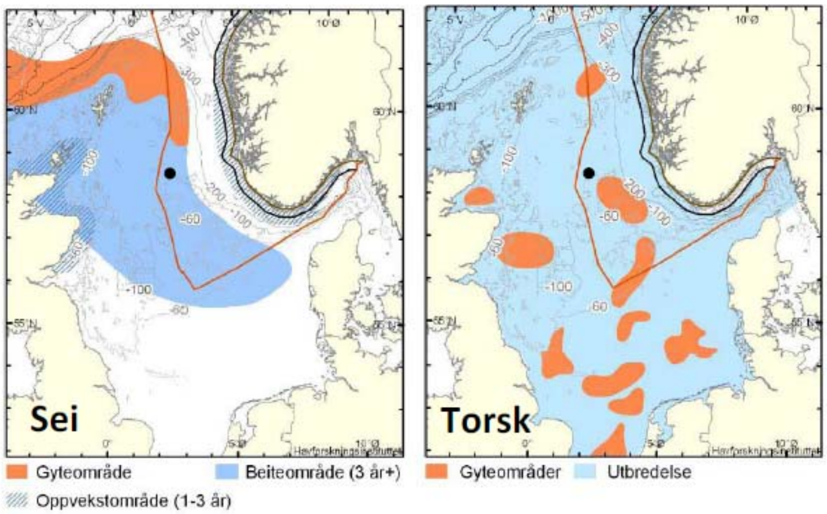
OBJECTIVE: Further mature, define and document the development solution based on the selected concept.

- Selection of the final technical solution. Decide and define all remaining critical technical alternatives.
- Execute Front End Engineering Design (FEED) Studies: determine technical requirements (arranged in packages) for the project based on the final solution chosen. Estimate cost of each package.
- Plan and prepare the execution phase.

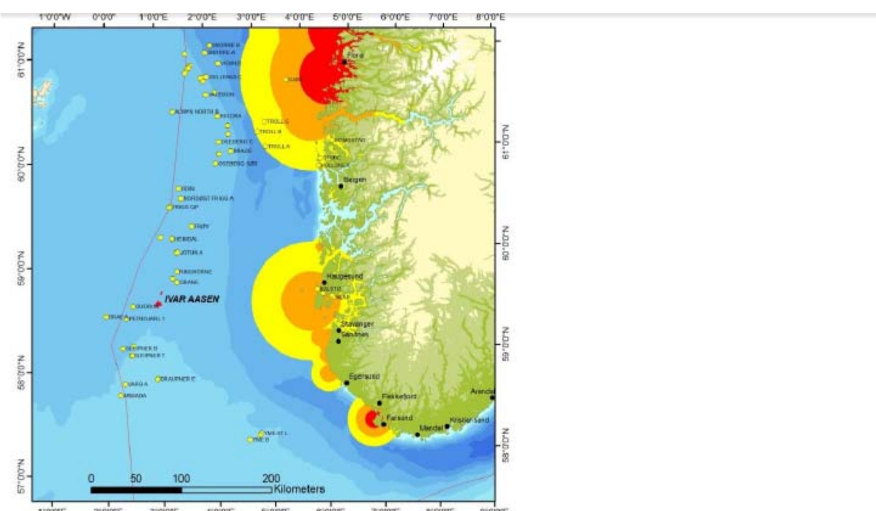
PRE-ENGINEERING - TASKS

- Prepare for submission of the application to the authorities.
- Perform the Environmental impact assessment.
- Establish the basis for awarding contracts.
- Issue:
  - Plan for development and operations
  - Plan for installation and operations of facilities for transport and utilization of petroleum (PIO)
  - Impact assessment report

PRE-ENGINEERING - TASKS

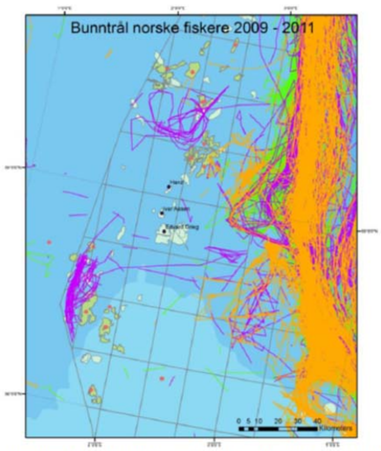


PRE-ENGINEERING - TASKS



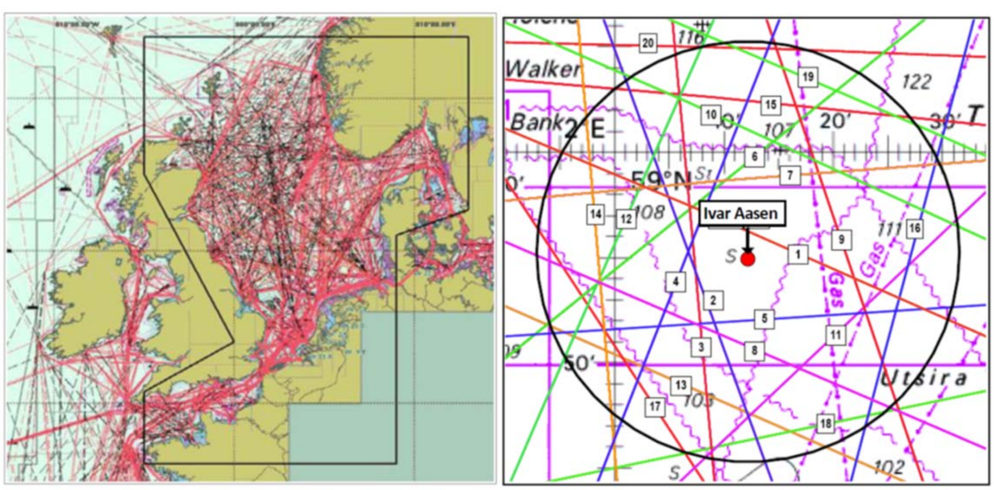
Figur 18. Svært viktige (rød), viktige (oransje) og nokså viktige (gule) leveområder for sjøfugl langs kysten av Nordsjøen i hekketiden. Kartet markerer buffersoner rundt de viktige hekkelokalitetene (NINA)

PRE-ENGINEERING - TASKS



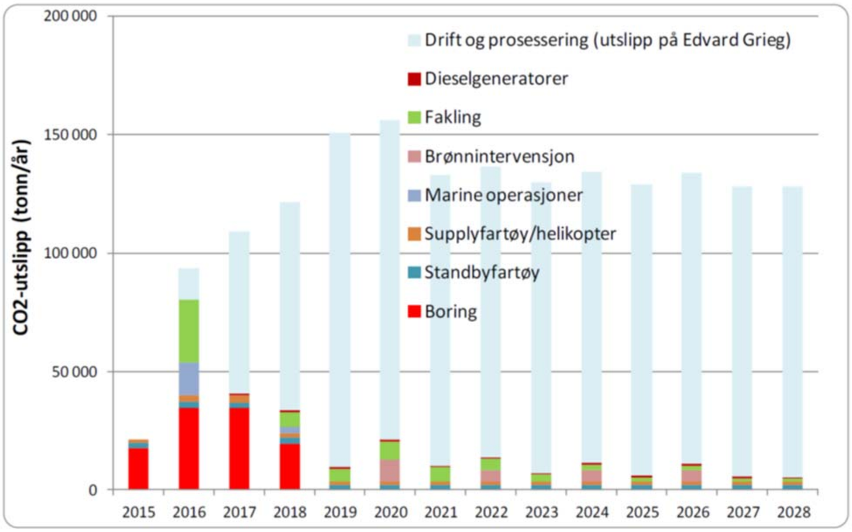
Figur 23. Registrert norsk fiskeriaktivitet med bunntrål i området omkring Aasen i 2009 (grønn), 2010 (fiolett) og 2011 (oransje). Figur utarbeidet på grunnlag av data fra Fiskeridirektoratets satellittsporing av større fiskefartøyer

PRE-ENGINEERING - TASKS



Figur 24. Trafikkompleksitet i Nordsjøen (venstre) og skipsleder for handels- og offshorefartøy innenfor en radius på 10 nautiske mil fra Aasen (høyre)

PRE-ENGINEERING - TASKS



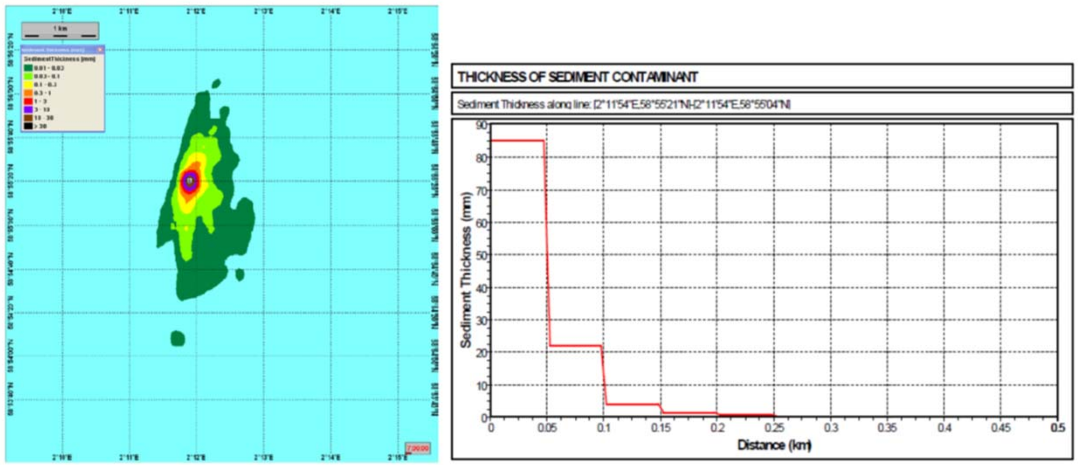
Figur 25. Samlede utslipp av CO_2 fra Aasenfeltet i perioden 2015 – 2028

PRE-ENGINEERING - TASKS

Tabell 5-1. Foreløpig oversikt over estimerte mengder kaks for typiske produksjonsbrønner på Aasen, West Cable og Hanz

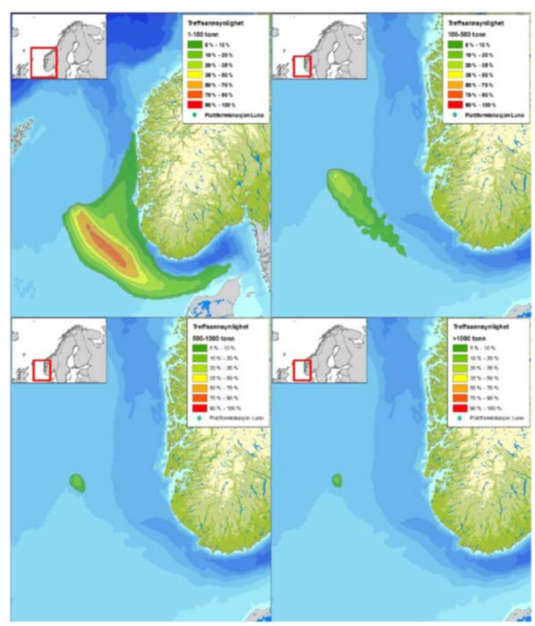
Seksjon	Borevæske	Boret lengde (m)			Mengde borekaks (tonn)		
		Aasen	West Cable	Hanz	Aasen	West Cable	Hanz
36”	WBM	88	88	86	70	70	70
26”	WBM	370	370	400	150	150	160
17 ½”	OBM	1 550	1 020	990	310	205	200
12 ¼”	OBM	860	3 890	1 700	90	390	170
8 ½”	OBM	1 390	1 530	90	70	80	5
SUM (avrundet)		**4 300**	**6 900**	**3 300**	**690**	**895**	**605**
SUM WBM kaks					**220**	**220**	**230**
SUM OBM kaks					**470**	**675**	**375**

PRE-ENGINEERING - TASKS



Figur 29. Sedimentering ved utslipp av vannbasert kaks ved havbunnen (sommersituasjon)

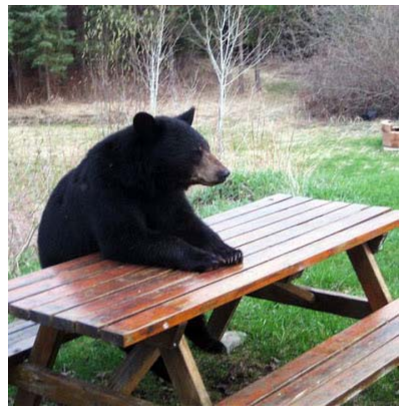
PRE-ENGINEERING - TASKS

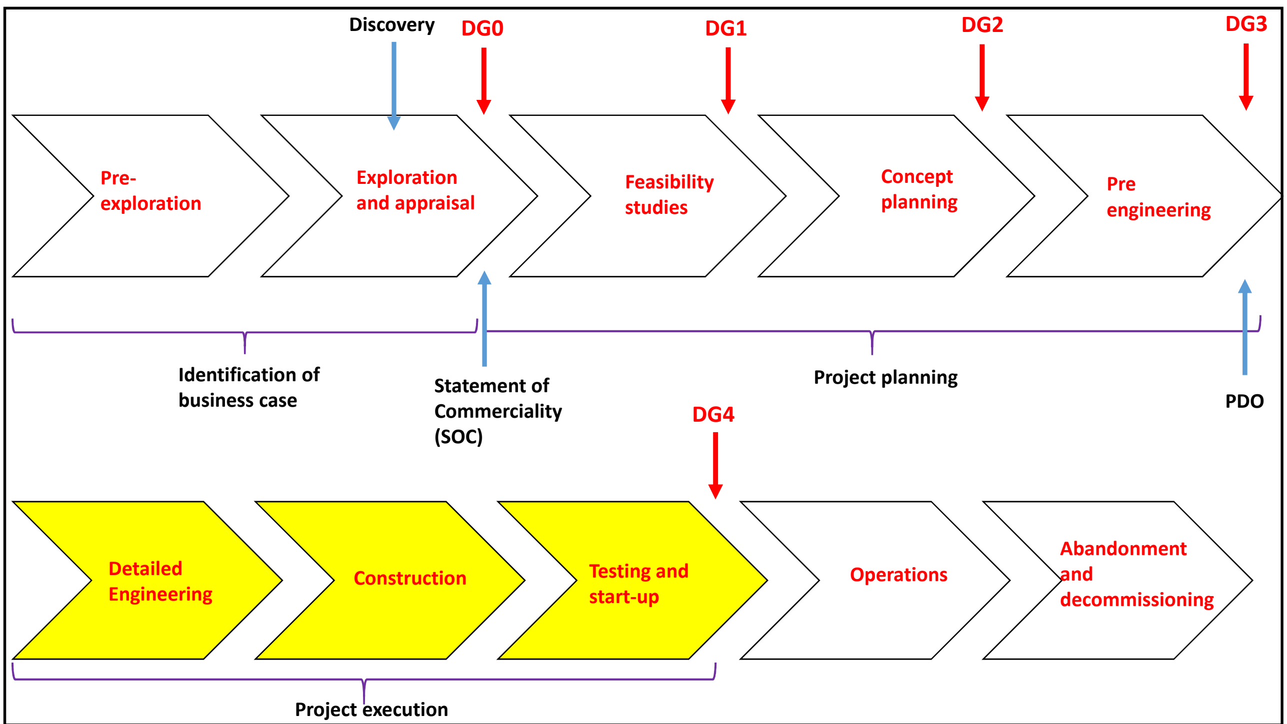


Figur 37. Sannsynligheten for treff av ulike mengdekategorier av olje i 10 × 10 km ruter gitt en sjøbunnsutblåsning fra Aasen/Grieg (helårsstatistikk). Influensområdet er basert på alle utslippsrater og varigheter og deres individuelle sannsynligheter. Merk at det markerte området ikke viser omfanget av et enkelt oljeutslipp, men er det området som berøres i mer enn 5 % av enkeltsimuleringene av oljens drift og spredning (Lundin 2011).

PRE-ENGINEERING - TASKS

- Wait for the government to study the proposal





DETAILED ENGINEERING, CONSTRUCTION, TESTING AND STARTUP

OBJECTIVE: Detailed design, procurement of the construction materials, construction, installation and commissioning of the agreed facilities.

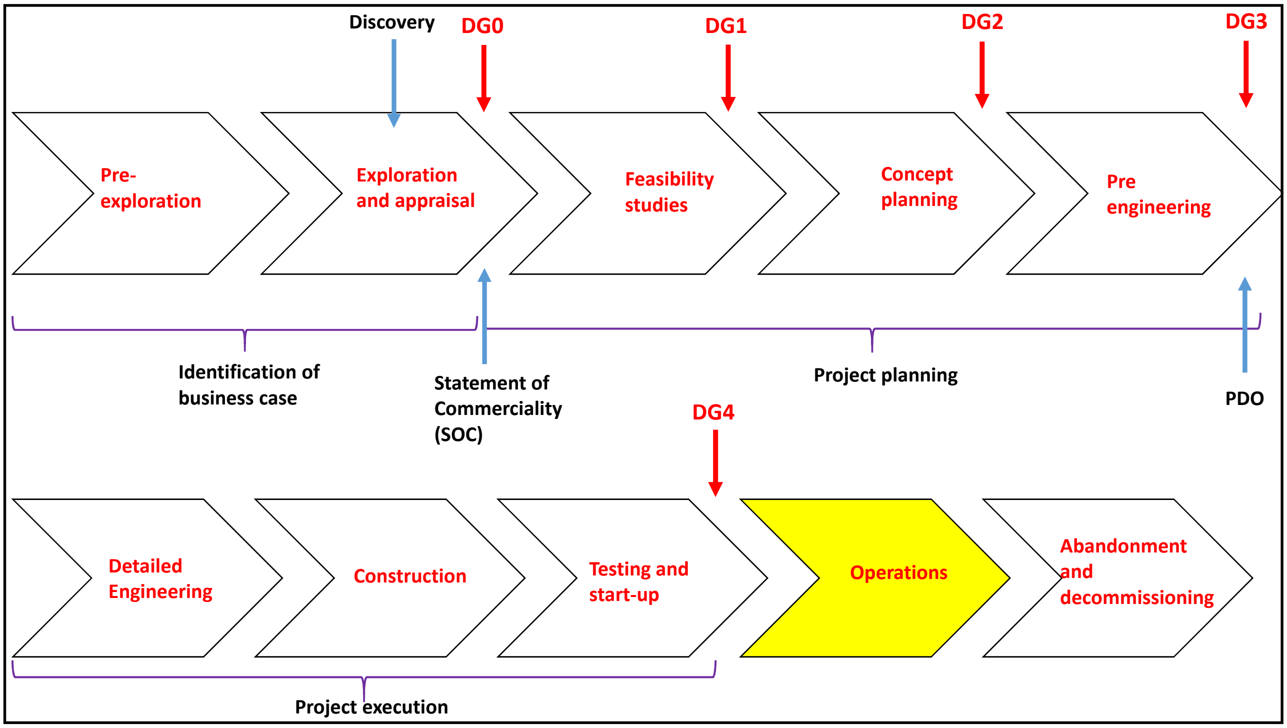
Individual contracts

- Detailed engineering
- Bids, contracts
- Construction, fabrication
- Installation
- Commissioning (Cold or Hot)

EPCM (Engineering, procurement, construction, and management contract) with one main contractor.

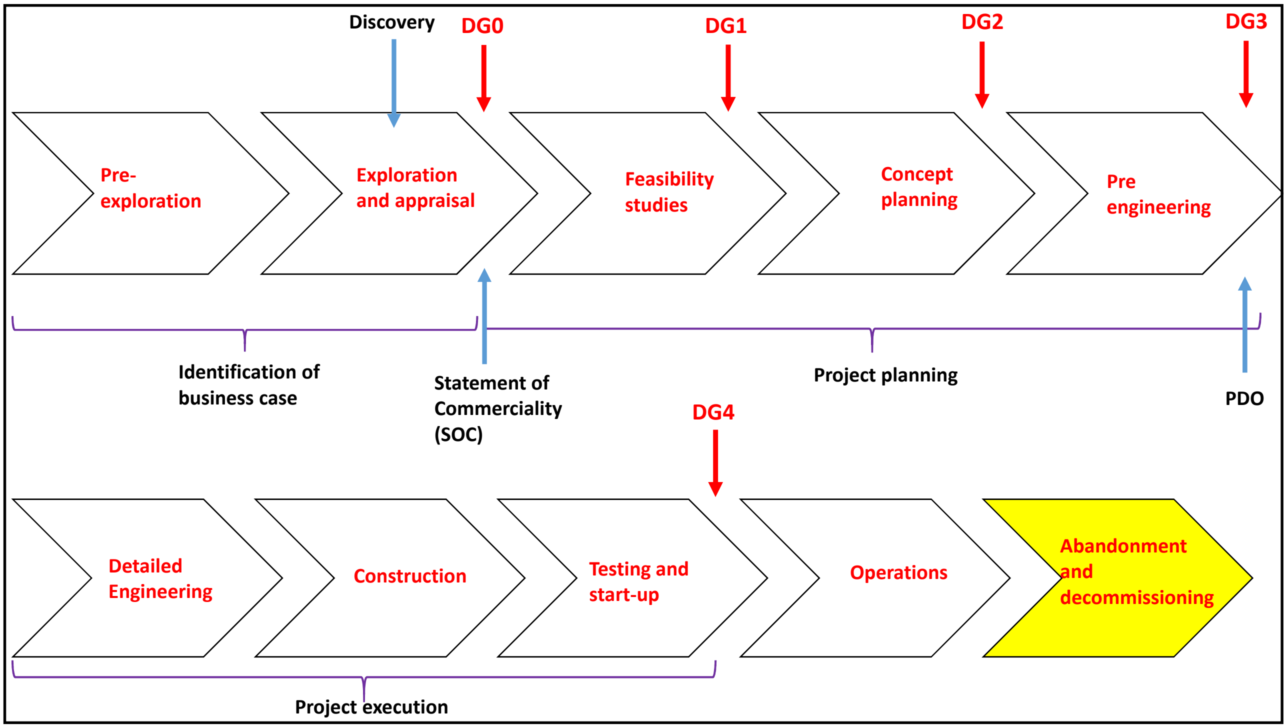
DETAILED ENGINEERING, CONSTRUCTION, TESTING AND STARTUP

- Constructing wells.
- Perform hand over to asset, operations
- Prepare for start-up, operation and maintenance



OPERATIONS

- Production startup, Build-up phase, Plateau phase, Decline phase, Tail production, Field shut-down.
- Maintenance.
- Planning Improved Oil recovery methods.
- Allocation and metering.
- De-bottlenecking.
- Troubleshooting.



DECOMISSIONING AND ABANDONMENT

- Engineering “down and clean”: flushing and cleaning tanks, processing equipment, piping.
- Coordinate with relevant environmental and governmental authorities.
- Well plugging and abandonment (P&A)
- Cut and remove well conductor and casing.
- Remove topside equipment.

DECOMISSIONING AND ABANDONMENT

- Removal of the offshore structure: Lifting operations and transport
- Remove or bury subsea pipelines
- Mark and register leftover installations on marine maps
- Monitoring
- Recovery of material: Scrap (steel) and recycling equipment (Gas turbines, separators, heat exchangers, pumps, processing equipment)
- Disposal of residues

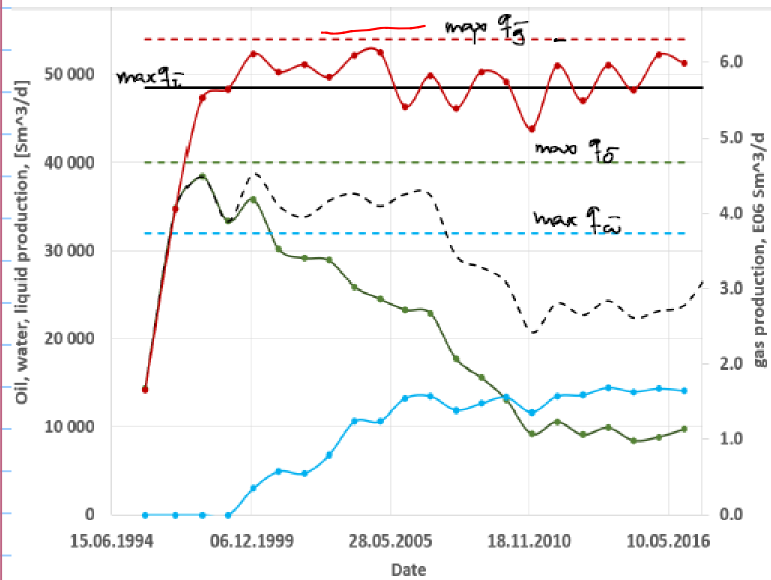
DECOMISSIONING AND ABANDONMENT

DECOMISSIONING AND ABANDONMENT

typical production profile (phases) of a field:

continue production as long as operating expenditures < revenue

↳ as short as possible (pre-drilled wells, platform wells versus subsea wells)



bottlenecked? (gas capacity)

for oil field q_o

$q_g = \underline{GOR} \cdot \underline{q_o}$

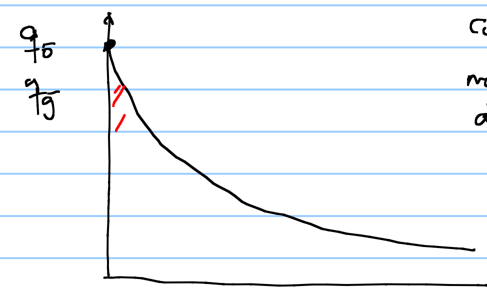
GOR changes with time

Predicting and quantifying field production performance

two production modes

constant rate mode
plateau mode

mode A



constant pressure mode
decline mode

mode B

$q_o \cdot P_o$ –
NPV – $\underline{\text{CAPEX}}$!

$$NPV = \frac{\text{cash flow}}{(1+i)^t}$$

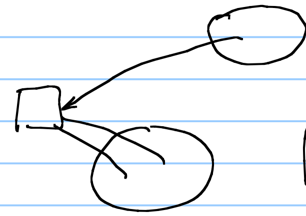
t: years
i: discount rate

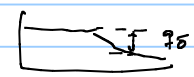
Used for:

- standalone fields that require new infrastructure to be built from scratch
- medium to large fields

Used for

- satellite fields that can be tied in to existing infrastructure (medium – small size)





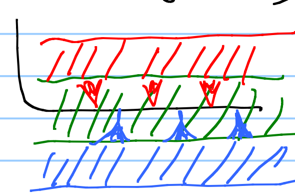
why not to produce as much as possible as early as possible?

- trade off / balance between CAPEX and revenue.

higher plateau rate gives ↑ revenue

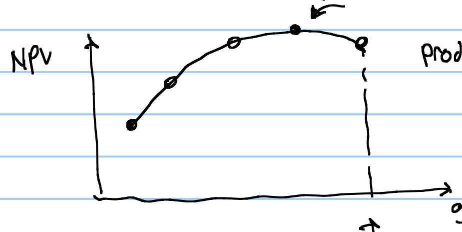
higher plateau rates give ↑ capital expenses → bigger processing facilities
↳ bigger offshore structure
↳ drill more wells (to avoid sand production, formation damage gas coning or water cusping)

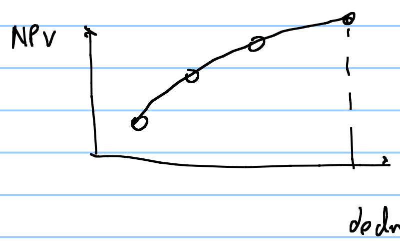
to study this dependency, we typically run analysis with different plateau rates



produce mode A

decline from beginning





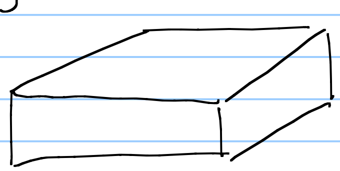
produce in mode B

rule of thumb to define plateau rates for standalone fields:

for oil 10% of TRR per year
↳ total recoverable reserves

N – OOIP original oil in place

only oil and water

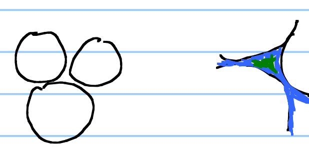


m^3 – bbls

$$N = \frac{V_R \cdot \phi \cdot S_{oi}}{B_o} = \frac{V_R \cdot \phi \cdot (1 - S_{wc})}{B_o @ P_R^i, T_R^i}$$

$V_R \cdot \phi$ → V_{fluid}

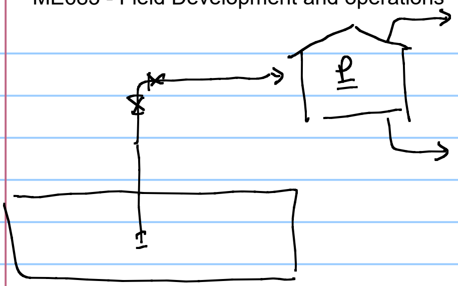
$$\phi = \frac{\text{pore volume}}{\text{rock volume}}$$



$$S_o = \frac{V_o}{V_{pore}}$$

$$S_w = \frac{V_w}{V_{pore}}$$

connate water S_{wc}



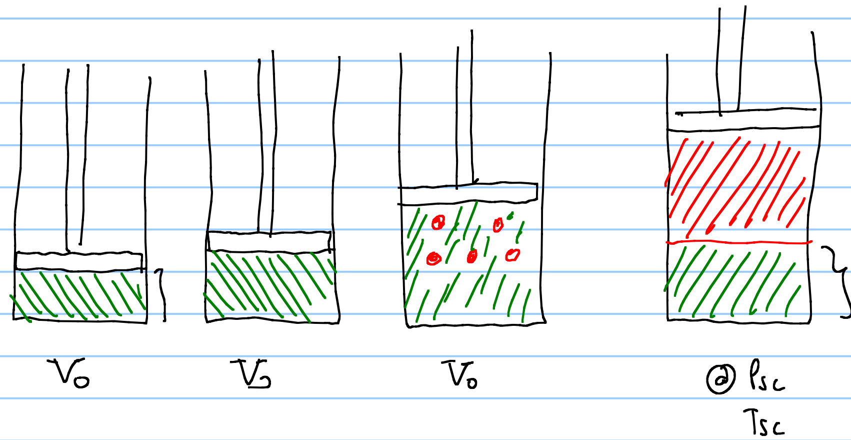
oil volume factor $B_o = \frac{V_o @ p,T \; [m^3]}{V_o @ p_{sc}, T_{sc} \; [Sm^3]}$ } greater than 1

1 – 1.7 (heavy oil, low GOR – light oil, high GOR)

standard conditions depend

$p_{sc} = 1.01325$ bara

$T_{sc} = 15.56$ °C



$$TRR = N_{pu} = RF_u \cdot N = V_R \frac{\Phi (1 - S_{wc})}{B_o} \cdot RF_u$$

RF_u: for gas (0.5 – 0.8), for oil (0.2 – 0.6)

N_{pu}: ultimate cumulative production

RF_u: ultimate recovery factor

an example. a field with

$N = 100\,000\,000$ stb   10% of TRR in every year

assume $RF_u = 0.4$

$TRR = N_{pu} = 40E06$ stb

$$q_{plateau} = \frac{0.1 \, N_{pu}}{365} = \frac{0.1 \cdot 40E06 \text{ stb}}{365 \text{ days}}$$

$$q_{plateau} = \underline{10958 \text{ stb/day}}$$

for gas   IGIP, G   2% – 5% of TRR (G_{pu}) per year

differences between oil and gas production:

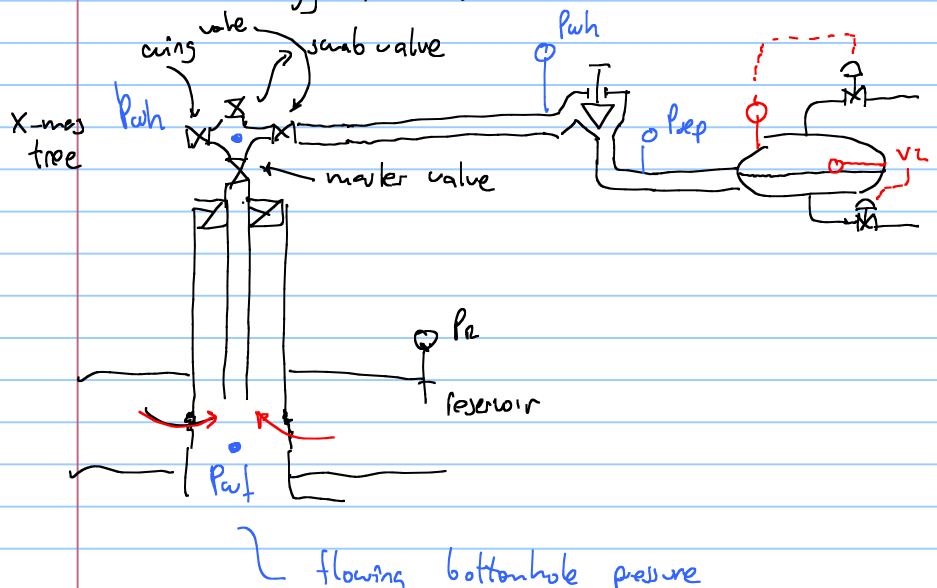
- oil can be sold in the spot market, with tanker. gas must be sold to a customer with a pre-existing contract, infrastructure
- Gas contracts are typically long term, they specify a plateau rate, swing factor

because of this, plateau duration of gas fields is much longer than oil fields (1–5 years) ↳ (5–30 years)

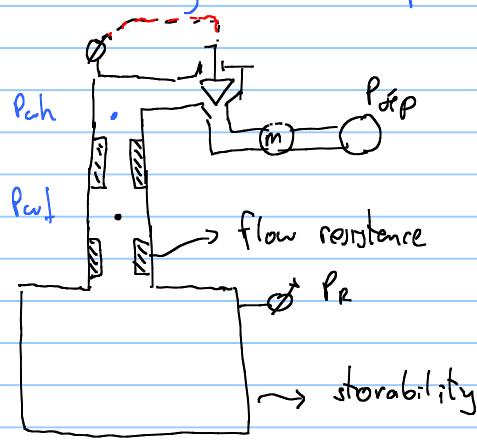
LNG Liquified natural gas CH_4 methane C_2H_6 ethane → liquid
−160°C

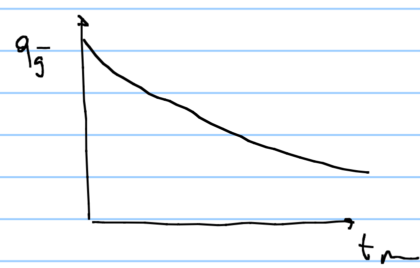
Mechanical analogy of a field

always P_{sep} is constant no matter the rate q_o, q_g, q_w

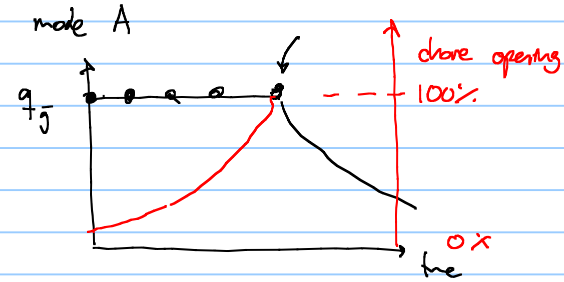


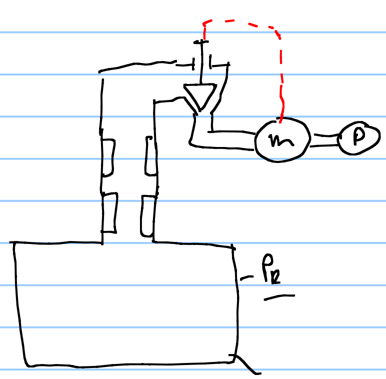
mode B (decline mode)
keep the choke opening fixed





mode A

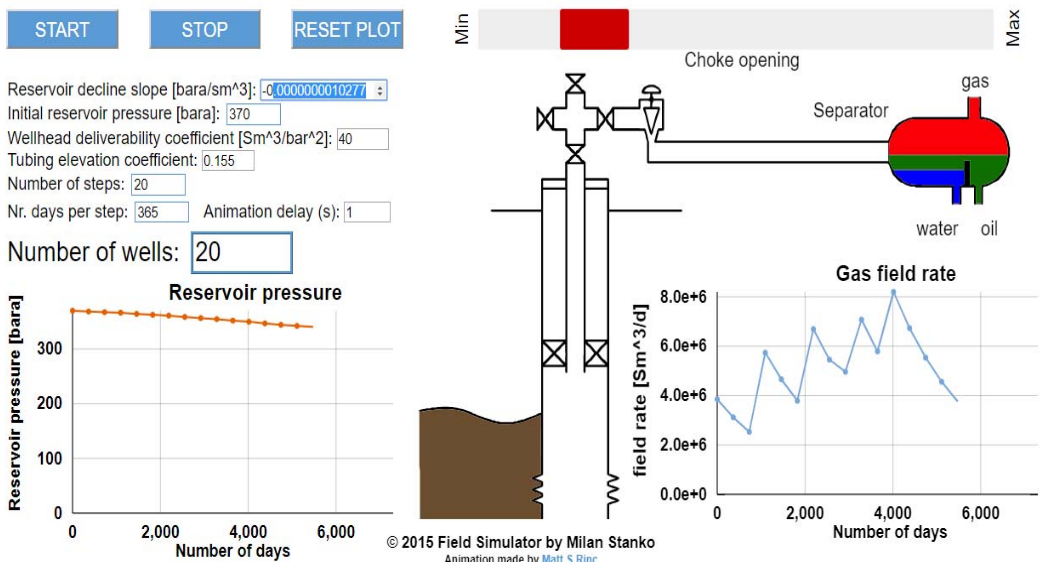




$\underline{q} \propto (\underline{P_R} - P_{sep})$

P_R vs G_p

http://www.ipt.ntnu.no/~stanko/Field_Simulator.html



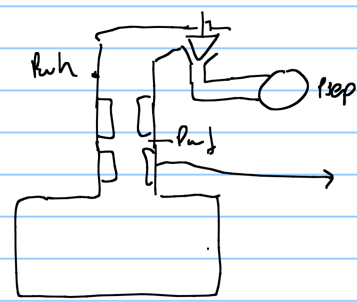
Dry gas ⟶

material balance

$P_R = f(G_p)$

cumulative production

$G_p = \int_0^t q_g \, dt$



$P_{wf} = f(P_R, q_g)$

↳ Inflow performance relationship (IPR)

$P_{wh} = f(P_{wf}, q_g)$

tubing performance relationship (TPR)

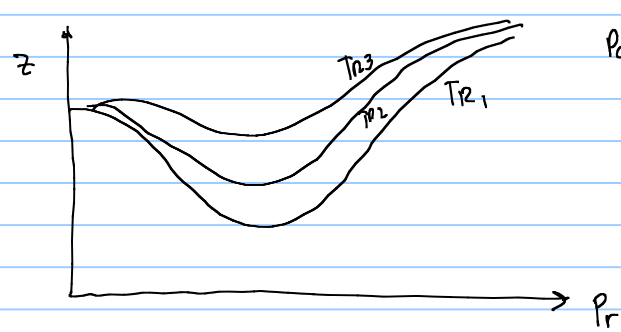
initial pressure

$P_R = \frac{P_i}{Z_i} Z_R \left(1 - \frac{G_p}{G}\right)$

G → initial gas in place

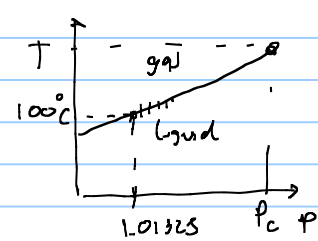
↳ gas deviation factor $PV = ZRT$

$RF = \frac{G_p}{G}$ $(0 \rightarrow RF_u)$



$P_c, T_c = f(\gamma_g)$

reduced pressure $\frac{P}{P_c}$ ~ critical pressure gas



$$p_R = p_i \frac{z_R}{z_i}\left(1 - \frac{G_p}{G}\right)$$

$$z_R = f\left(\frac{p_R}{p_c}, \frac{T_R}{T_c}\right)$$

1: Assume p_R

2: from chart, read z_R with p_r, T_r ($\frac{p_R}{p_c}$, $\frac{T_R}{T_c}$)

3: verify

$$p_R^{\text{assumed}} - p_i \frac{z_R^{\text{assumed}}}{z_i}\left(1 - \frac{G_p}{G}\right) = 0 \ ?$$

if not → go back to step 1

if yes ↓

p_R is the solution!