Class 5

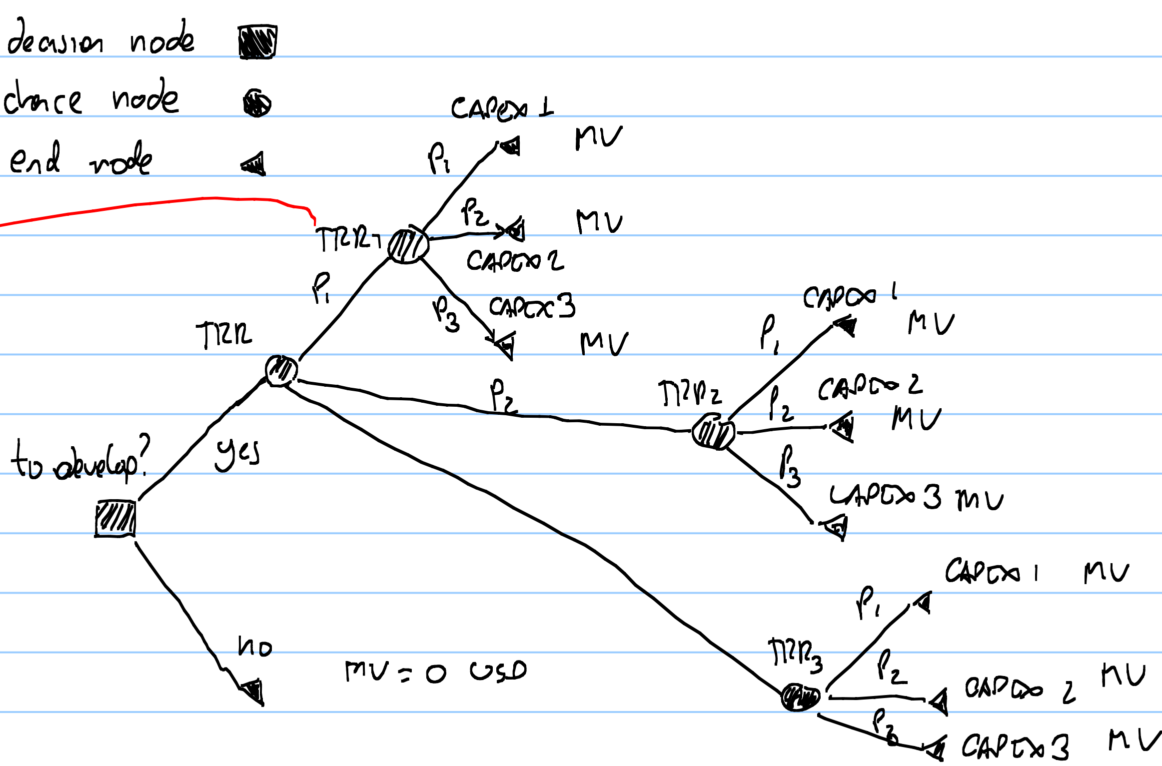
- Probability trees
- Field development
- Offshore structures for HC production

Probability trees
- → traditional approach requires less computing power
- → discrete variables: vessel type, decision variable, sequence
- → when simulations take a long time

Probability trees → is used often in appraisal

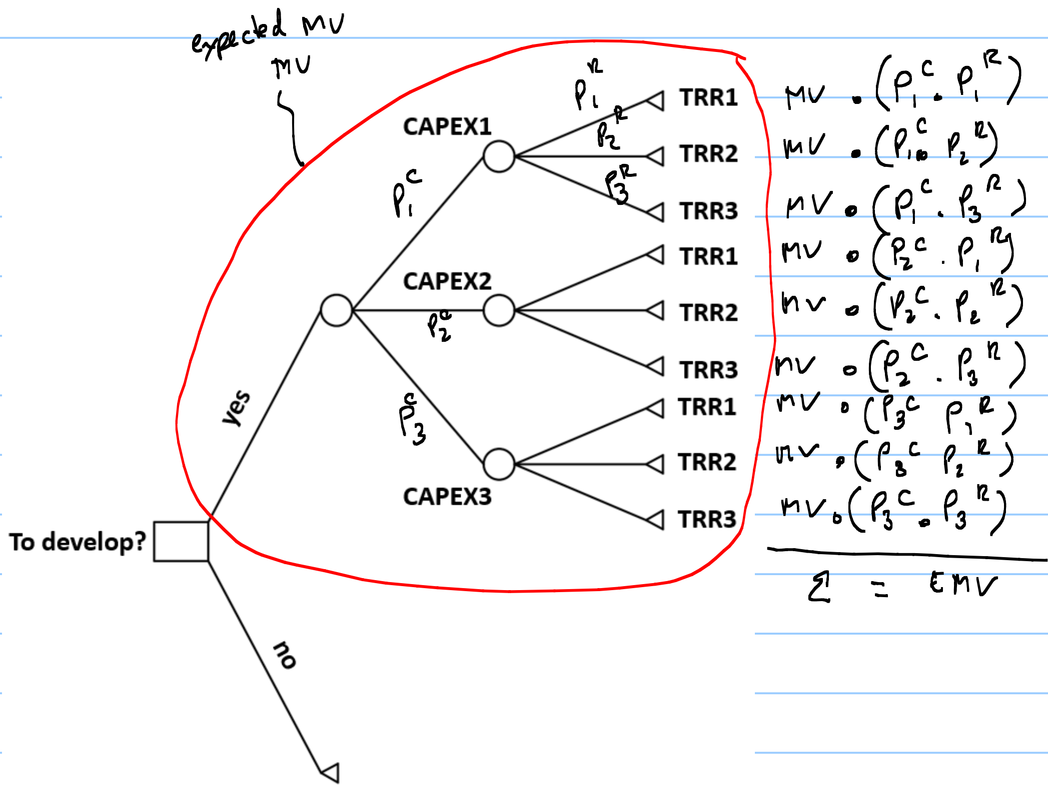
- Identify how many variables the probability tree has
  - (1) develop or not (2)
  - TRR (3)
  - CAPEX (3)

requires discretizing continuous distribution



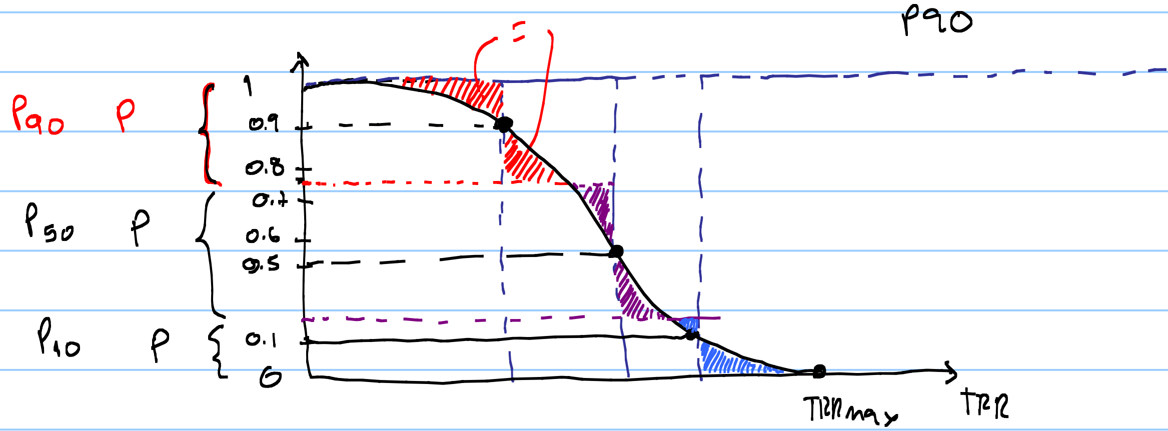
Cost values (OPEX, CAPEX, DRILLEX) usually display a Gaussian/Normal distribution

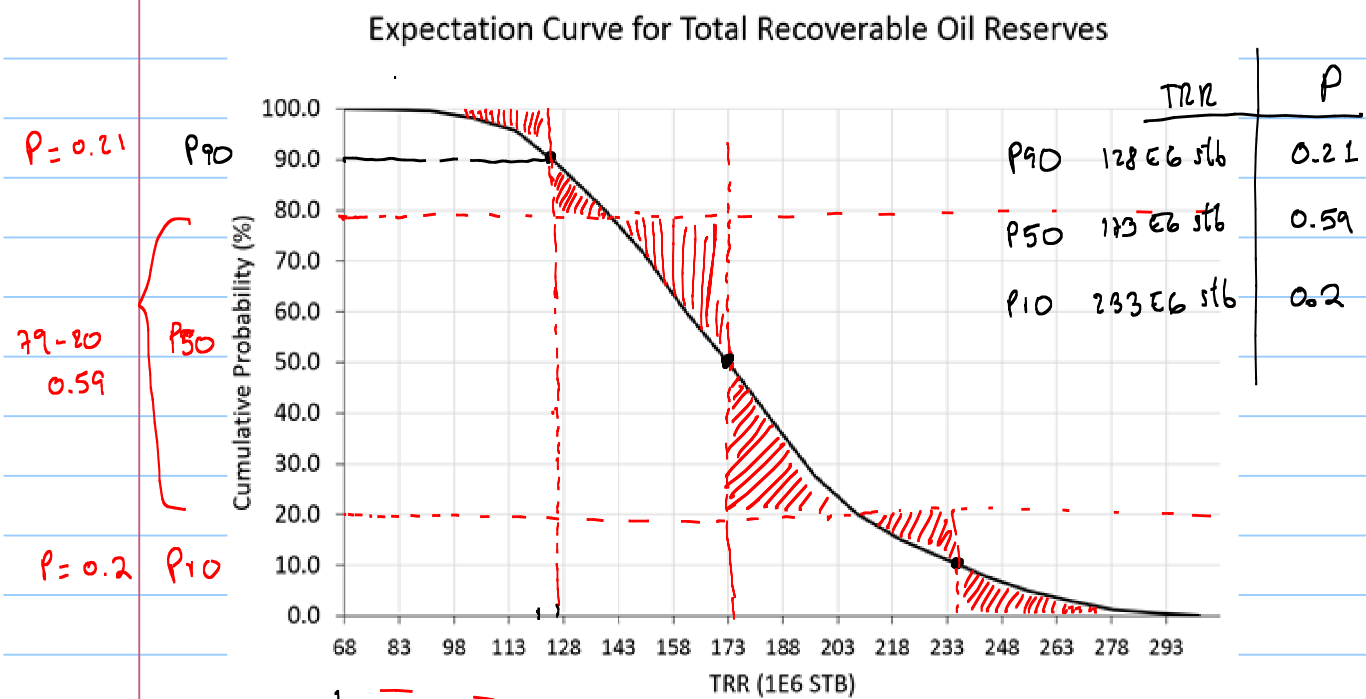
$\sigma = \pm 20$ (mean)

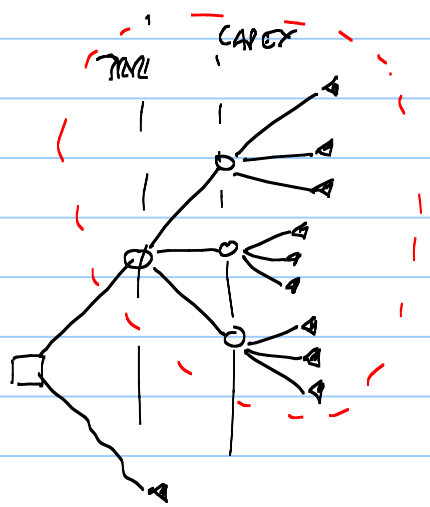


How do we get discretized values of TRR, CAPEX from a continuous function

for TRR, people like to use P10 P50 P90





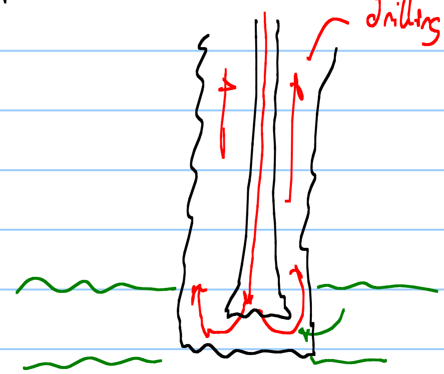


EMV = 3.11 E9 USD !

OPTION	TRR	P_TRR	CAPEX	P_capex	MV = TRR*60*0.4-CAPEX	P=P_capex*P_TRR	MV*P		
[-]	[stb]	[-]	[USD]	[-]	[USD]	[-]	[USD]		
1	1.28E+08	0.21	7.00E+08	0.3	2.37E+09	0.063	1.49E+08		
2	1.28E+08	0.21	1.10E+09	0.4	1.97E+09	0.084	1.66E+08		
3	1.28E+08	0.21	1.50E+09	0.3	1.57E+09	0.063	9.90E+07		
4	1.73E+08	0.59	7.00E+08	0.3	3.45E+09	0.177	6.11E+08		
5	1.73E+08	0.59	1.10E+09	0.4	3.05E+09	0.236	7.20E+08		
6	1.73E+08	0.59	1.50E+09	0.3	2.65E+09	0.177	4.69E+08		
7	2.33E+08	0.2	7.00E+08	0.3	4.89E+09	0.06	2.94E+08		
8	2.33E+08	0.2	1.10E+09	0.4	4.49E+09	0.08	3.59E+08		
9	2.33E+08	0.2	1.50E+09	0.3	4.09E+09	0.06	2.46E+08	EMV	3.11E+09

Answer: yes to development!

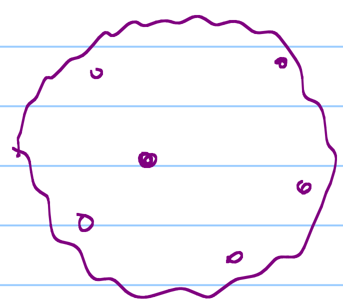
field development process

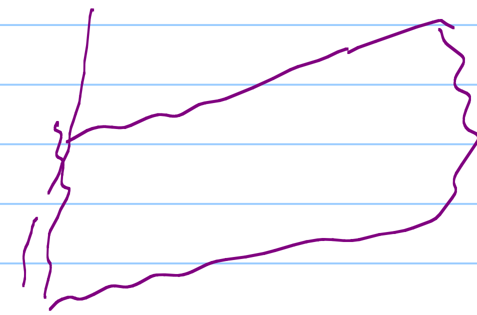


drilling mud : functions :

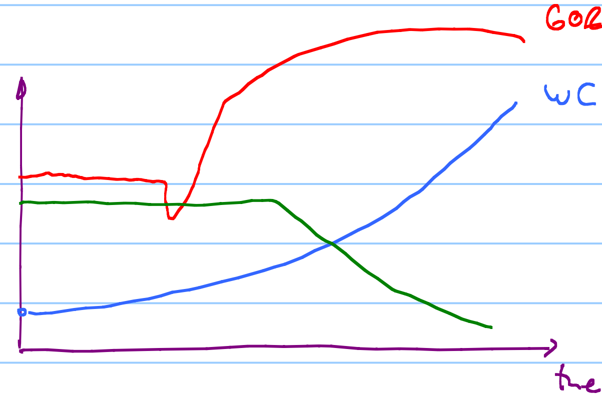
- carry cuttings to surface
- cool the bit
- lubricate
- pressure control of reservoir fluid

top view of reservoir

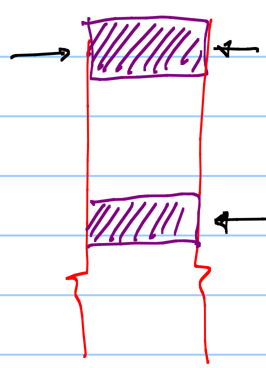


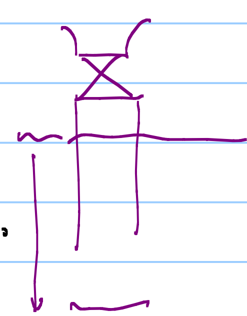


Debottlenecking



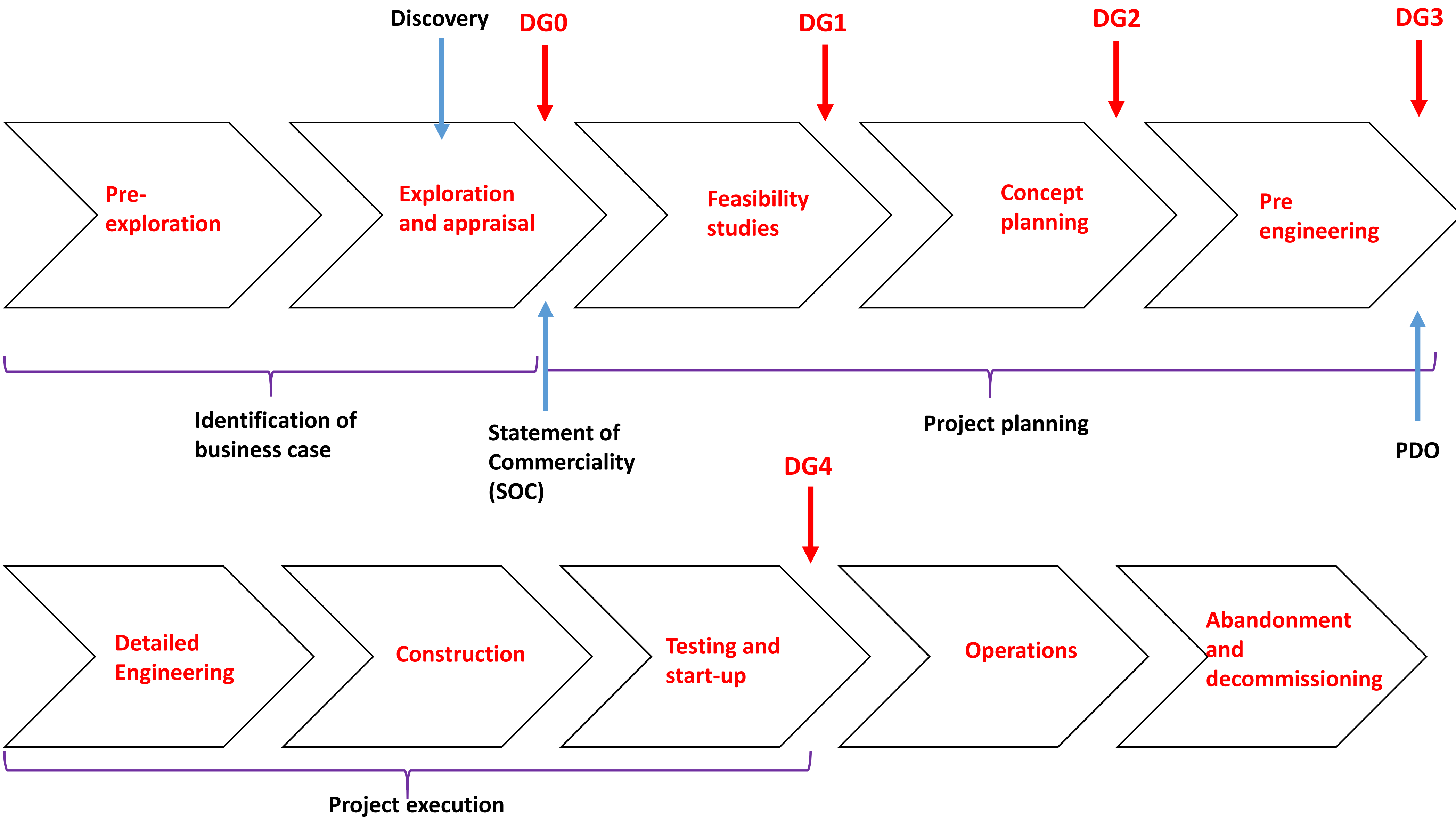
Plug and abandonment





THE FIELD DEVELOPMENT PROCESS

Prof. Milan Stanko (NTNU)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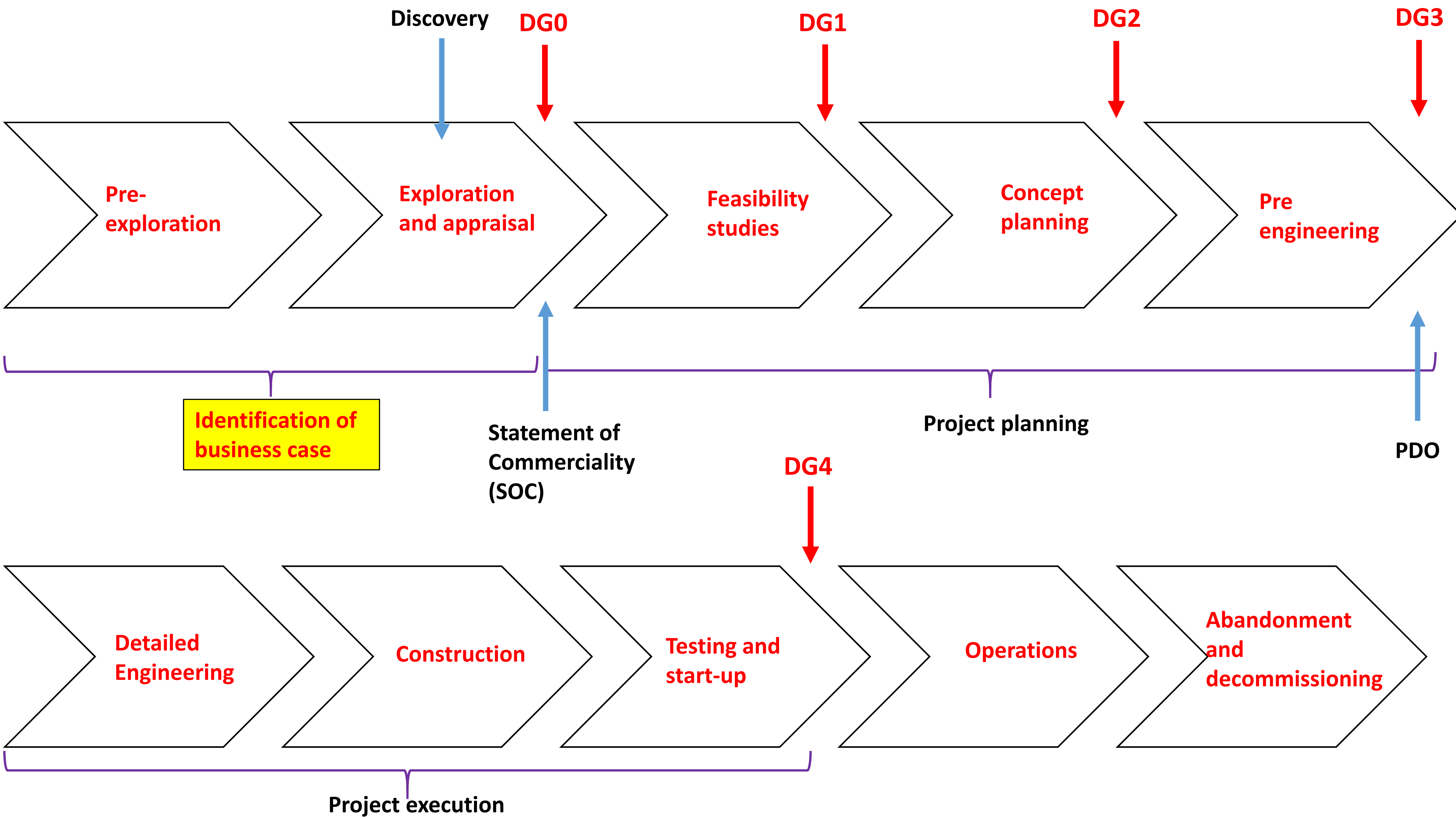
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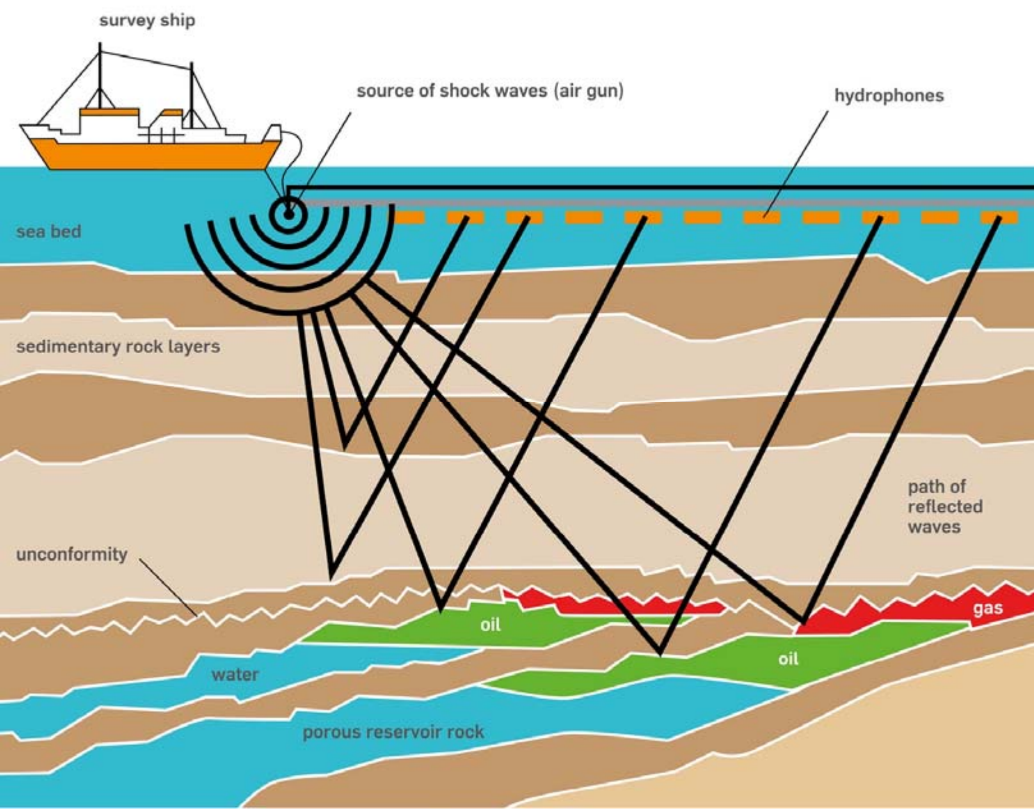
IDENTIFICATION OF BUSINESS CASE

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.

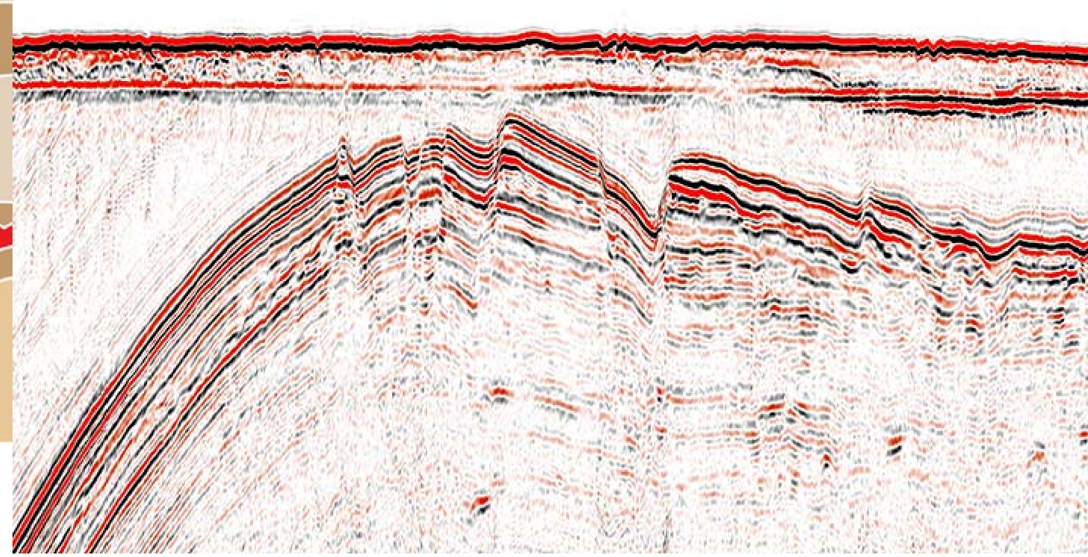
IDENTIFICATION OF BUSINESS CASE - TASKS

- 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.
- Identify prospects.

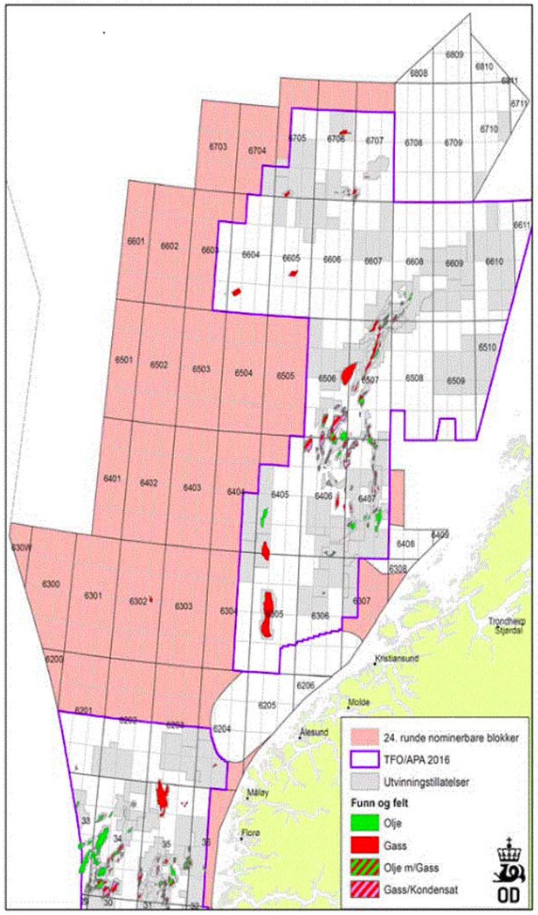
IDENTIFICATION OF BUSINESS CASE - TASKS



Seismic exploration



IDENTIFICATION OF BUSINESS CASE - TASKS



- Apply and obtain exclusive production license. 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!**

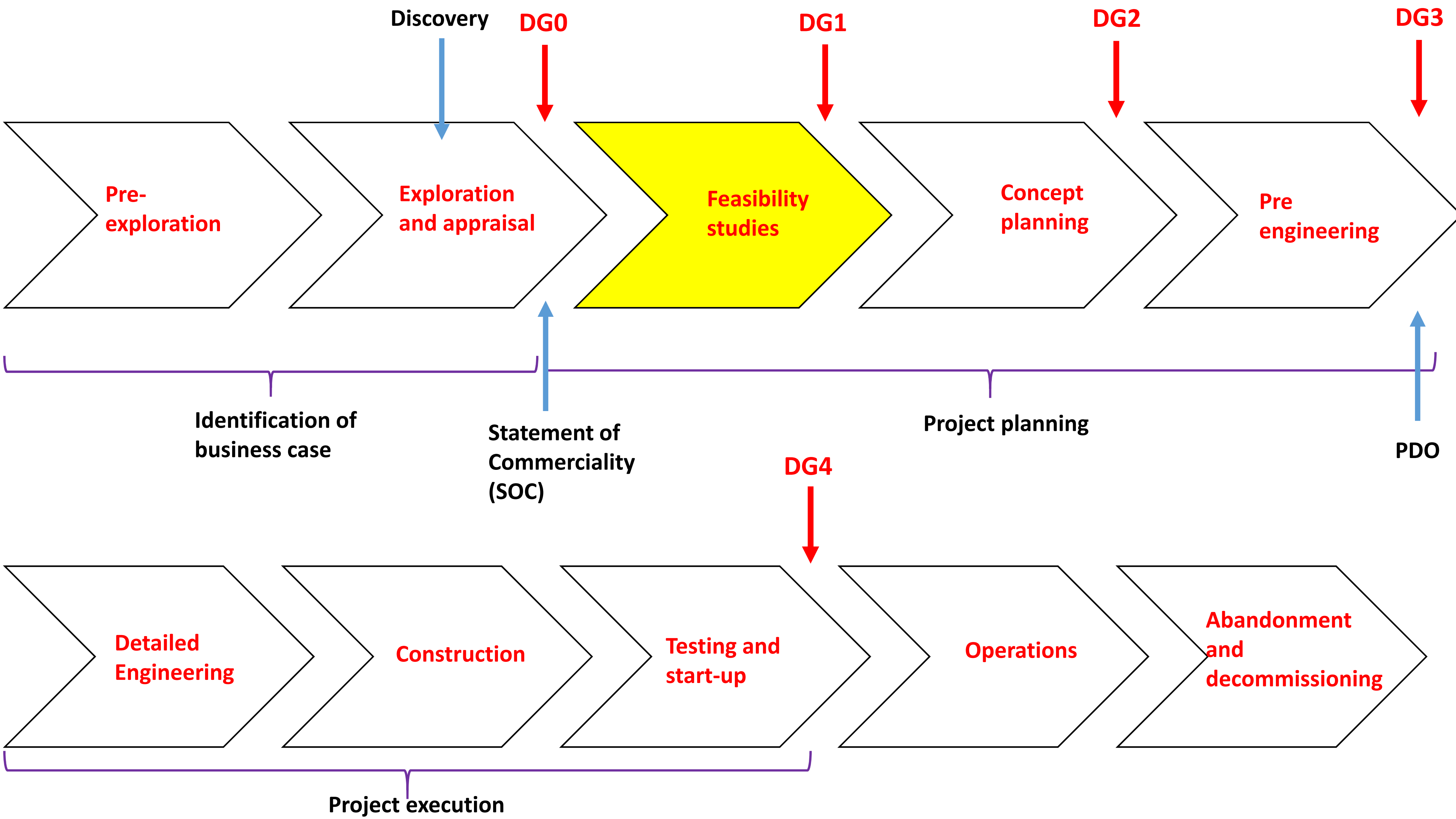
IDENTIFICATION OF BUSINESS CASE - TASKS

- Assessment of the discovery and the associated uncertainty. Risk management:
  - **Probabilistic reserve estimation.** Identify and assess additional segments.
  - Perform **simplified economic valuation** of the resources.
  - 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

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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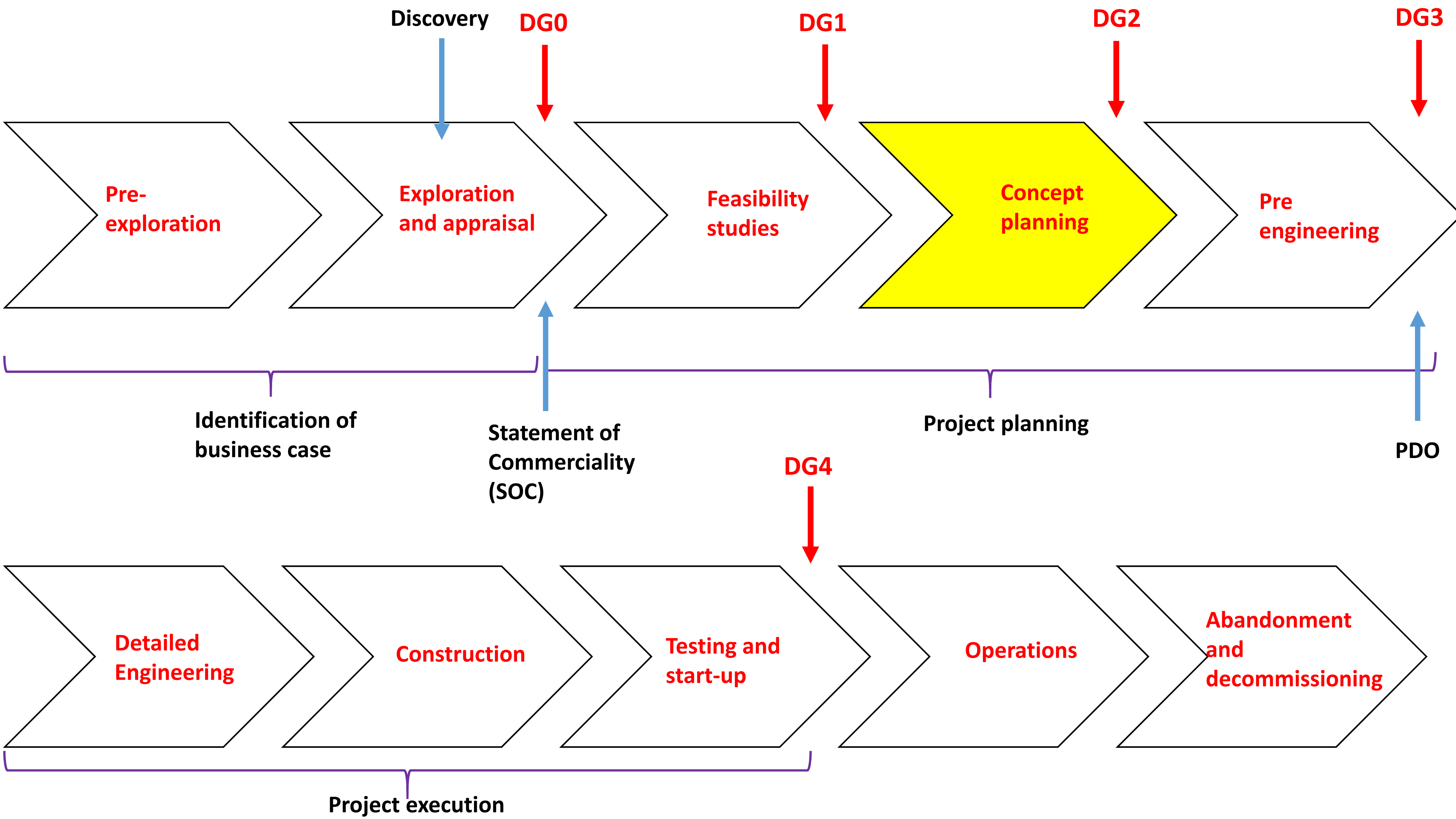
FEASIBILITY STUDIES - TASKS

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

- 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)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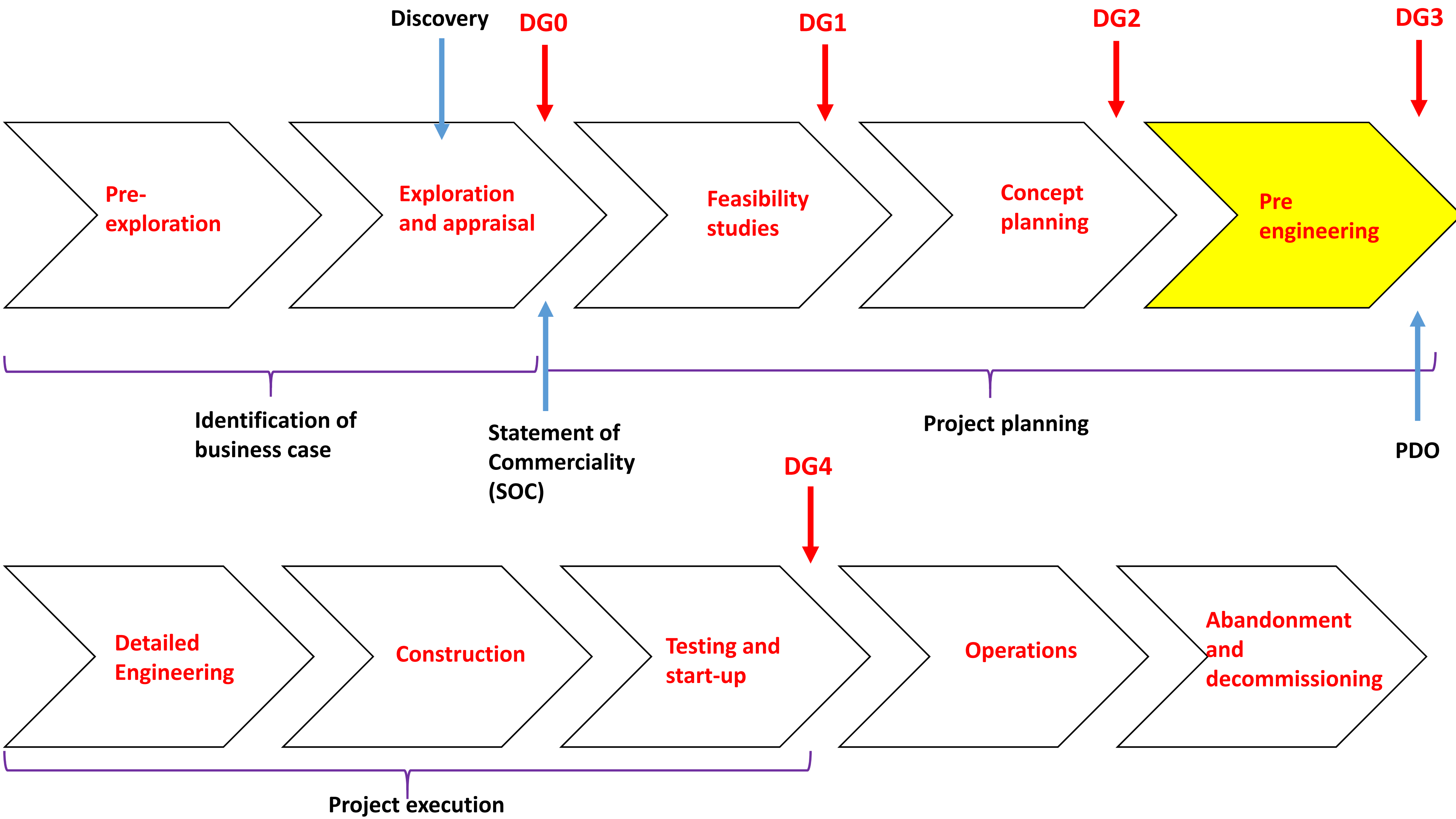
CONCEPT PLANNING - TASKS

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.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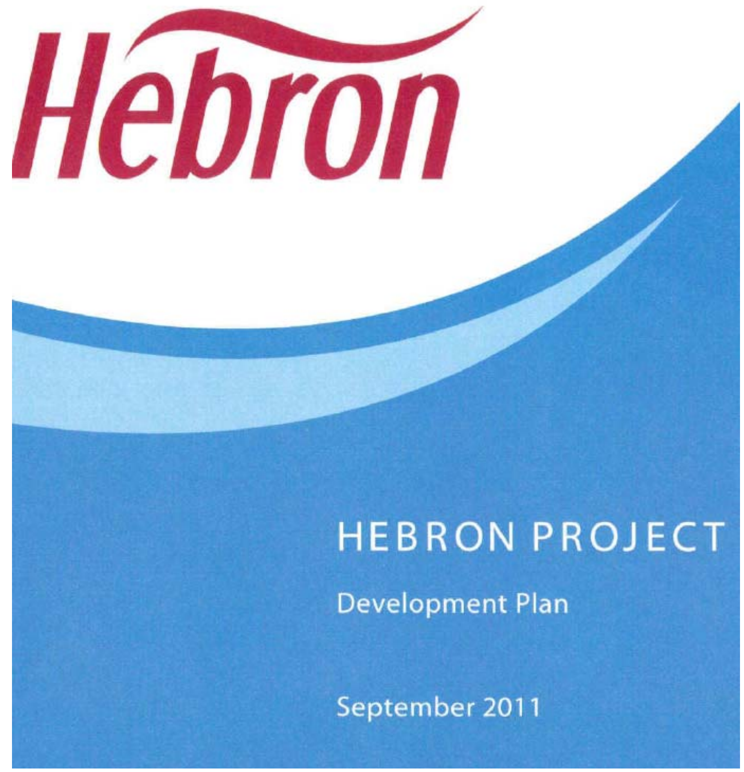
PRE-ENGINEERING - TASKS

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

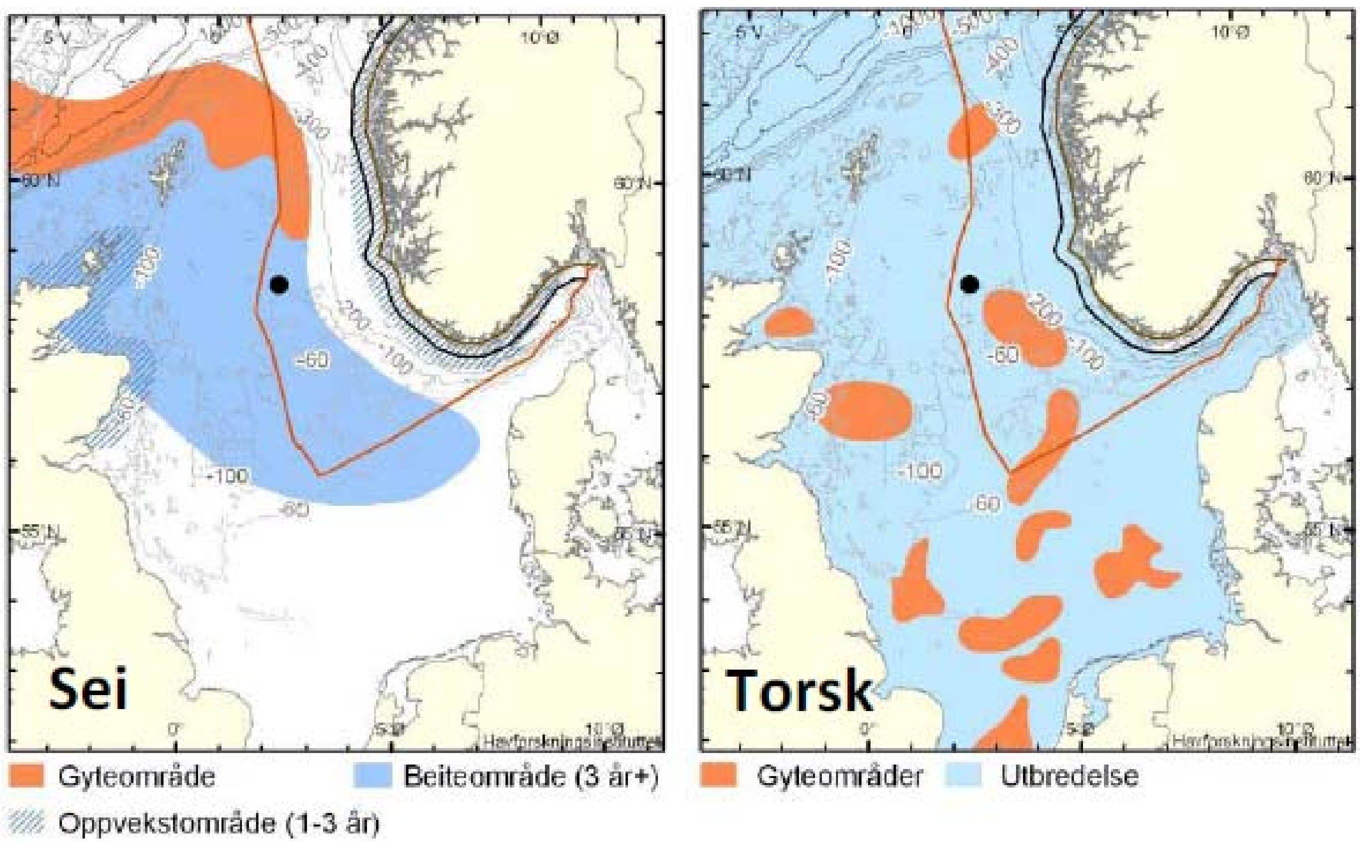
- Selection of the final technical solution. Decide and define all remaining critical technical alternatives.
- Execute Front End Engineering Design (FEED) Studies: determine technical requirements (arranged in packages) for the project based on the final solution chosen. Estimate cost of each package.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

PRE-ENGINEERING - TASKS

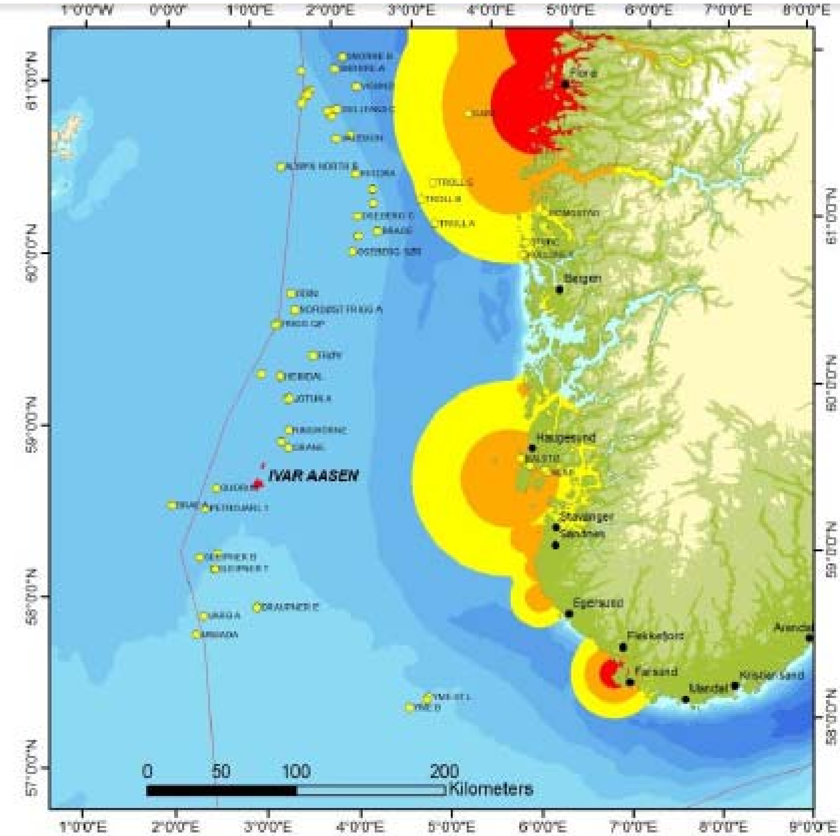
- Prepare for submission of the application to the authorities.
- Perform the Environmental impact assessment.
- Establish the basis for awarding contracts.
- Issue:
  - Plan for development and operations
  - Plan for installation and operations of facilities for transport and utilization of petroleum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



PRE-ENGINEERING - TASKS

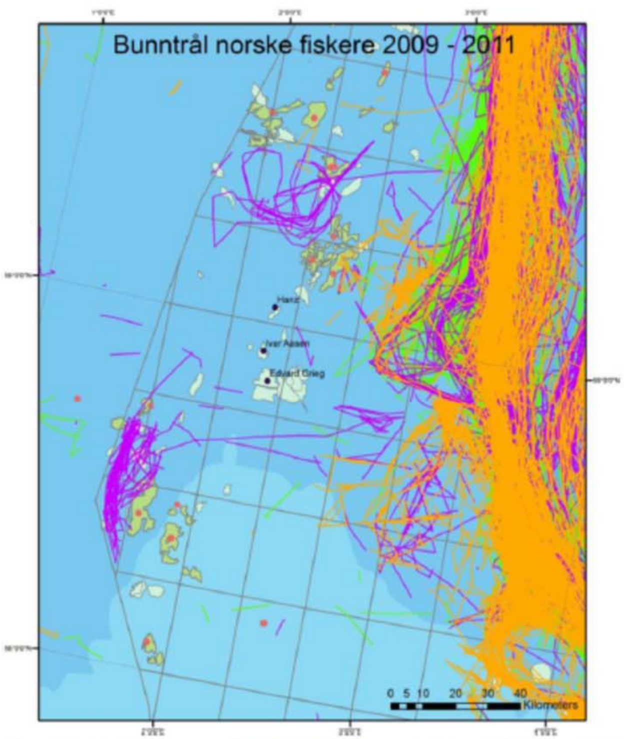


PRE-ENGINEERING - TASKS



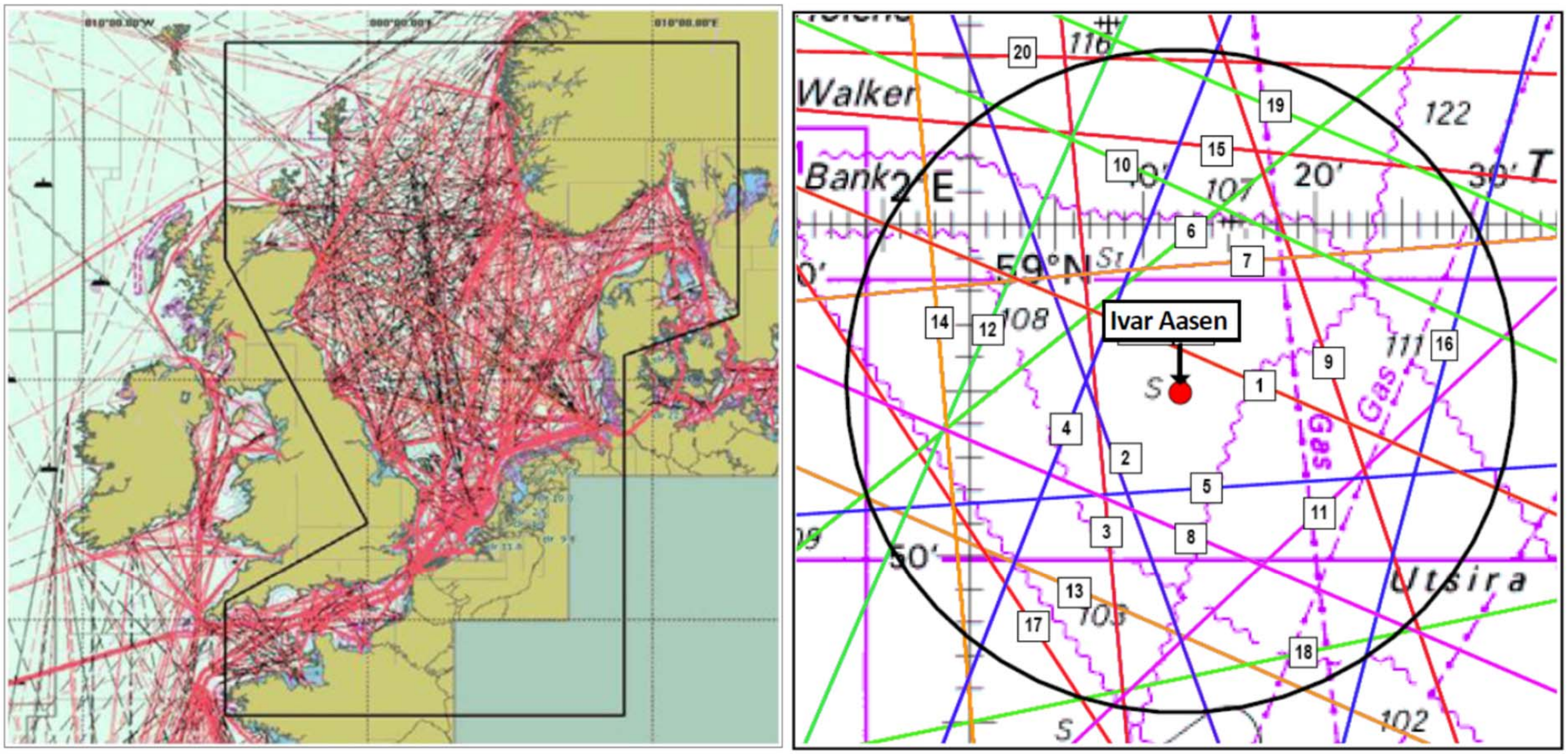
Figur 18. Svært viktige (rød), viktige (oransje) og nokså viktige (gule) leveområder for sjøfugl langs kysten av Nordsjøen i hekketiden. Kartet markerer buffersoner rundt de viktige hekkelokalitetene (NINA)

PRE-ENGINEERING - TASKS



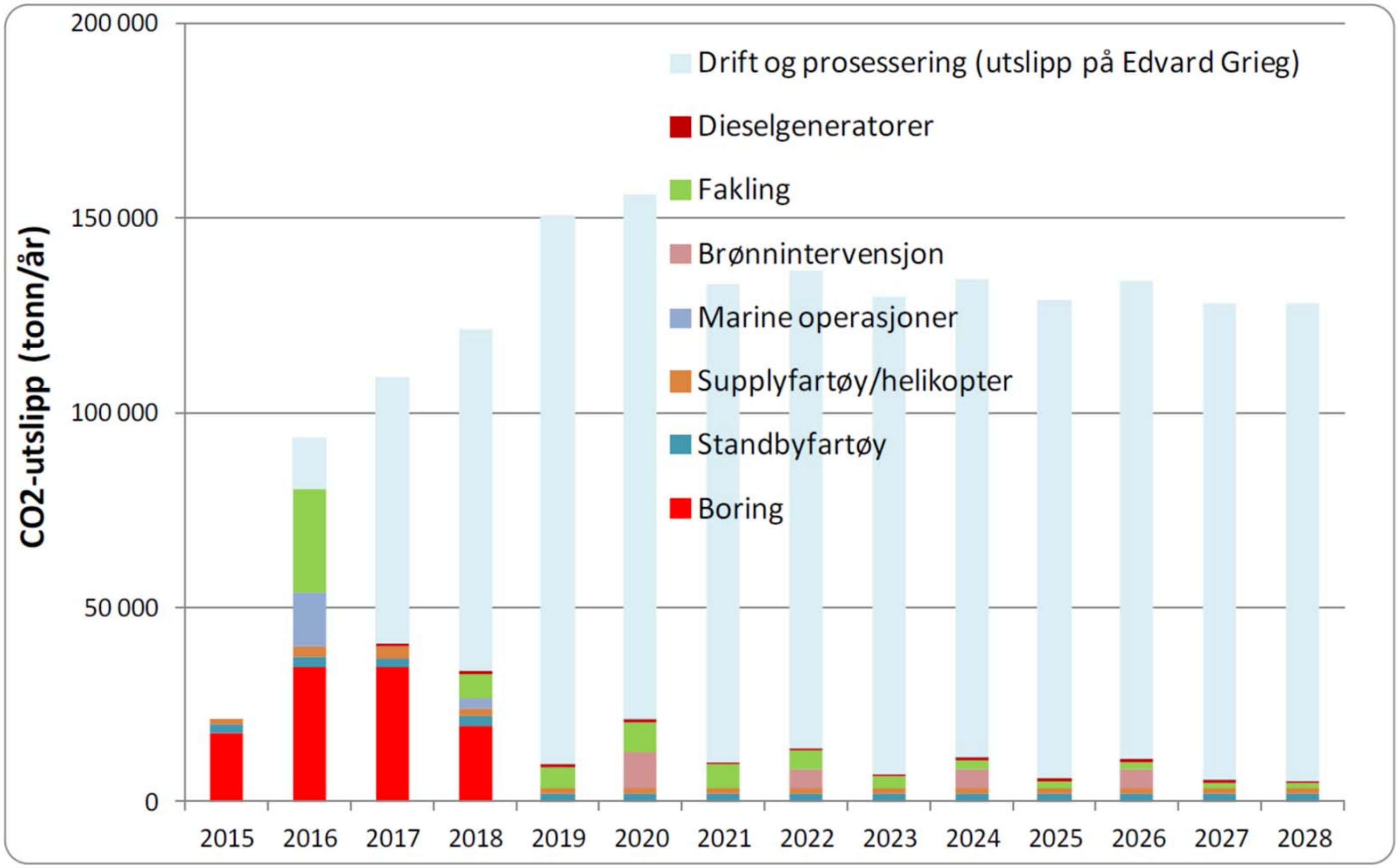
Figur 23. Registrert norsk fiskeriaktivitet med bunntrål i området omkring Aasen i 2009 (grønn), 2010 (fiolett) og 2011 (oransje). Figur utarbeidet på grunnlag av data fra Fiskeridirektoratets satellittsporing av større fiskefartøyer

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



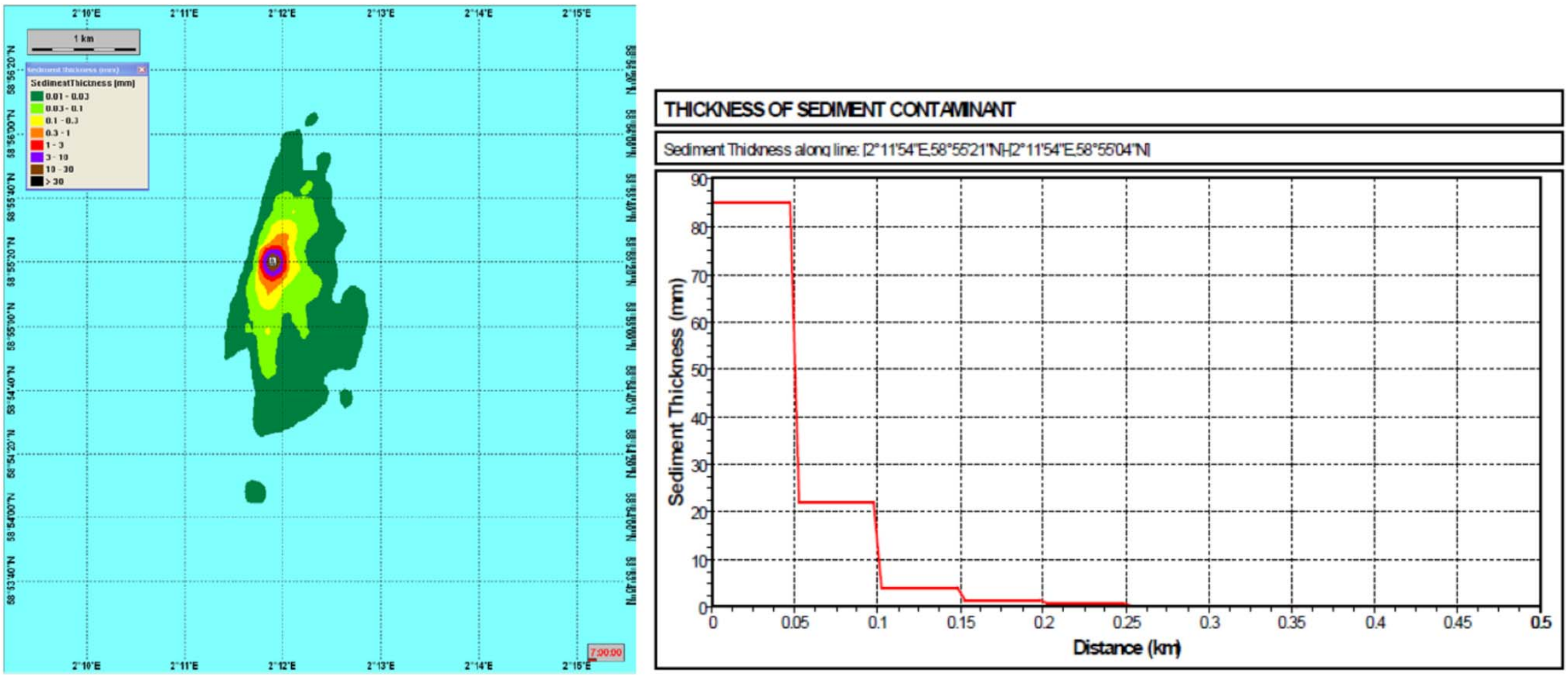
Figur 25. Samlede utslipp av CO_2 fra Aasenfeltet i perioden 2015 – 2028

PRE-ENGINEERING - TASKS

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

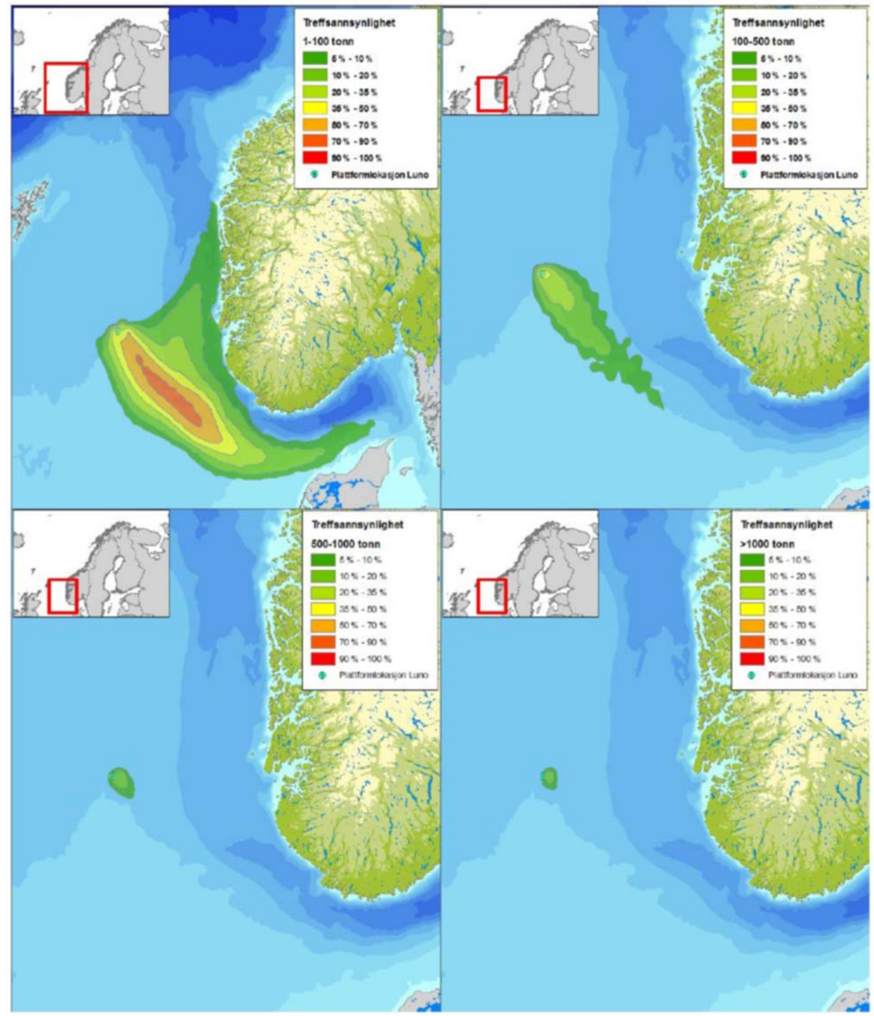
Seksjon	Borevæske	Boret lengde (m)			Mengde borekaks (tonn)		
		Aasen	West Cable	Hanz	Aasen	West Cable	Hanz
36”	WBM	88	88	86	70	70	70
26”	WBM	370	370	400	150	150	160
17 ½”	OBM	1 550	1 020	990	310	205	200
12 ¼”	OBM	860	3 890	1 700	90	390	170
8 ½”	OBM	1 390	1 530	90	70	80	5
SUM (avrundet)		**4 300**	**6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

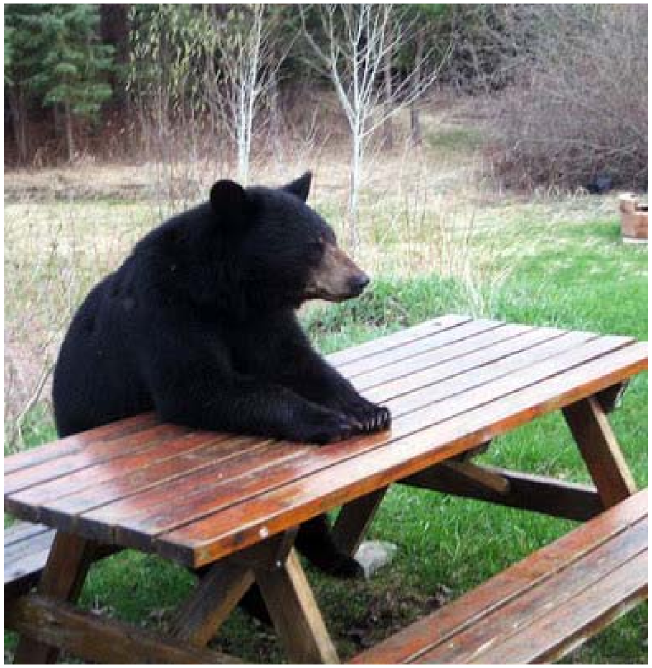
PRE-ENGINEERING - TASKS

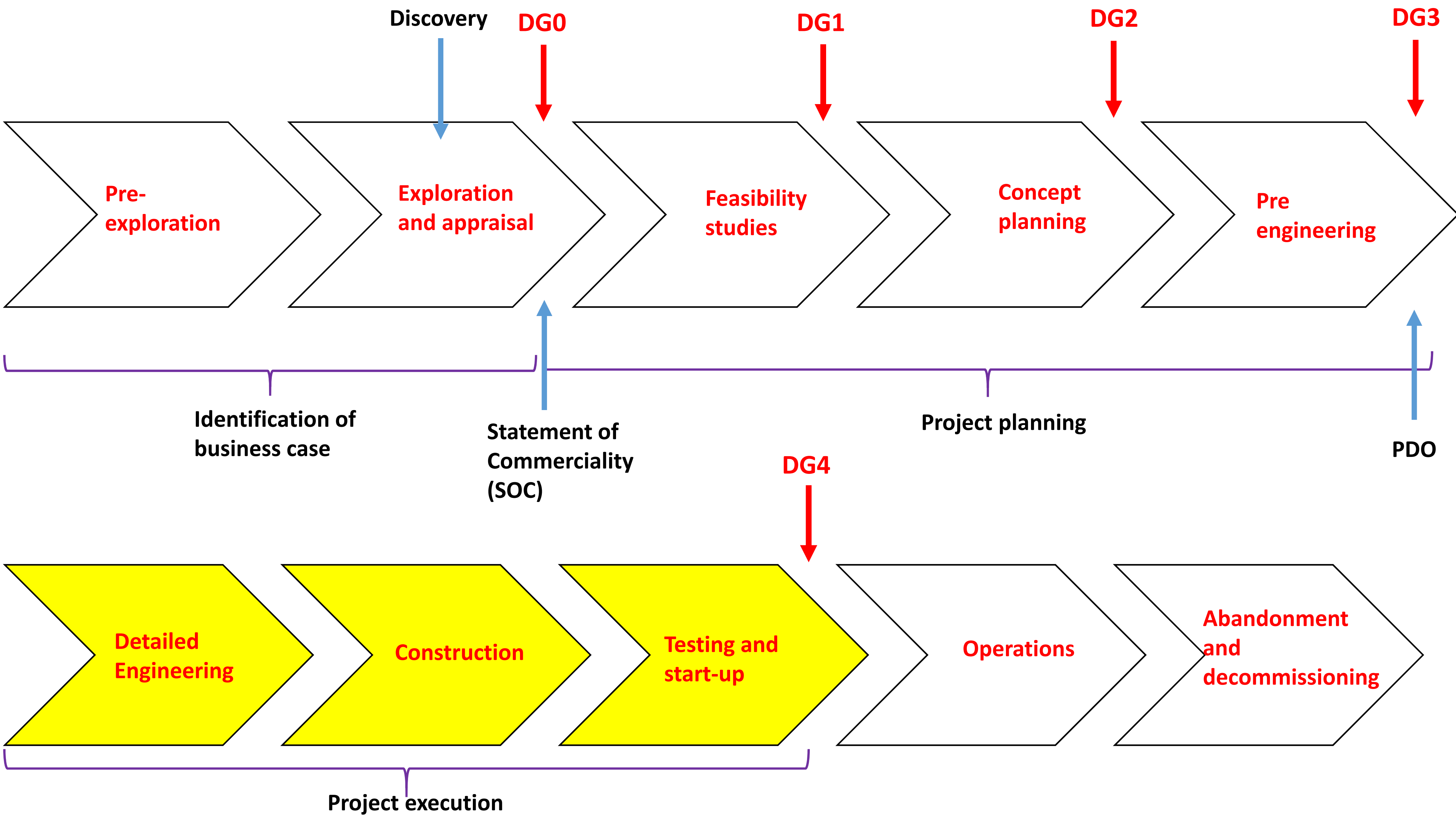


Figur 37. Sannsynligheten for treff av ulike mengdekategorier av olje i 10 × 10 km ruter gitt en sjøbunnsutblåsning fra Aasen/Grieg (helårsstatistikk). Influensområdet er basert på alle utslippsrater og varigheter og deres individuelle sannsynligheter. Merk at det markerte området ikke viser omfanget 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

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DETAILED ENGINEERING, CONSTRUCTION, TESTING AND STARTUP

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

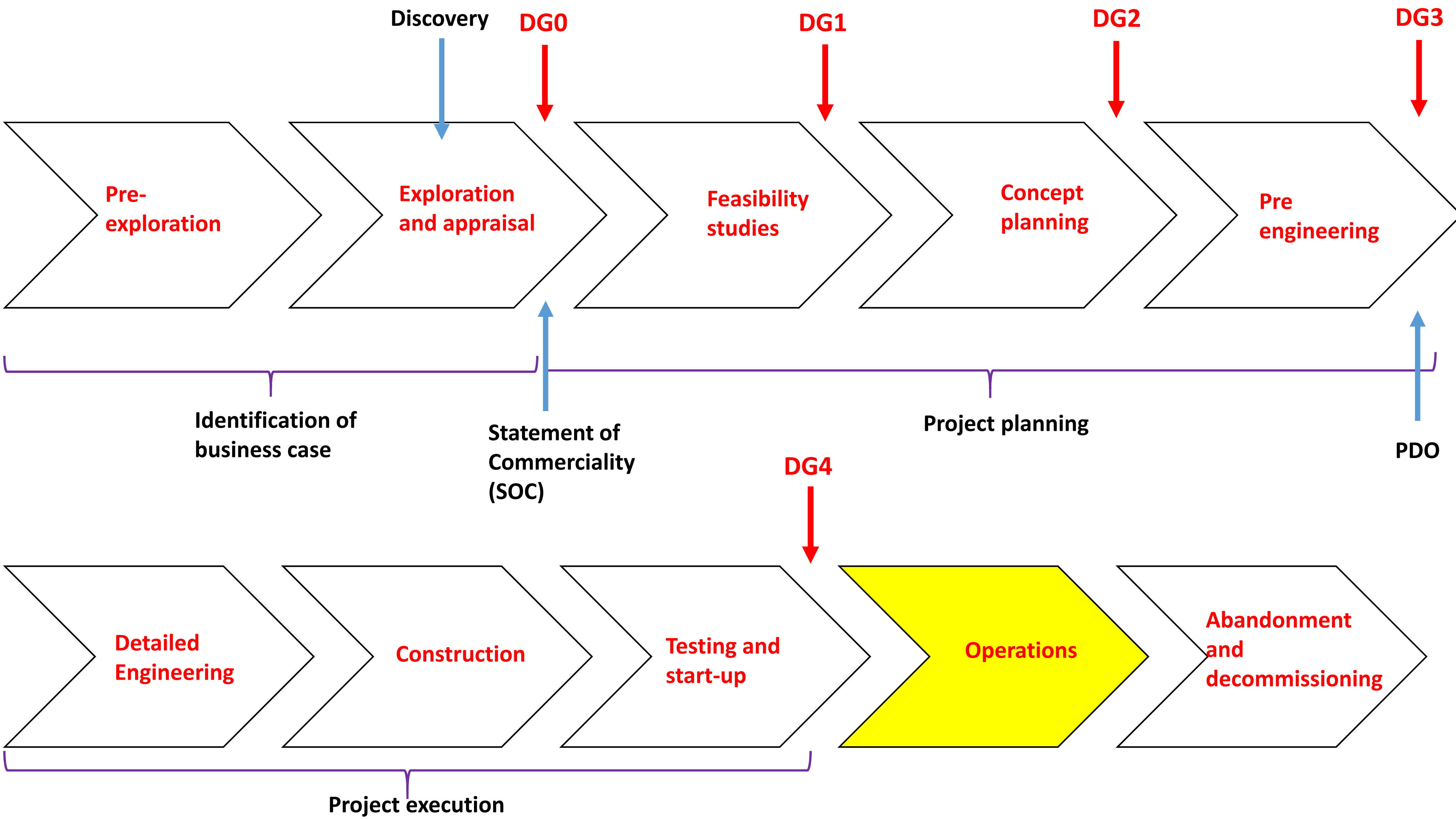
Individual contracts

- 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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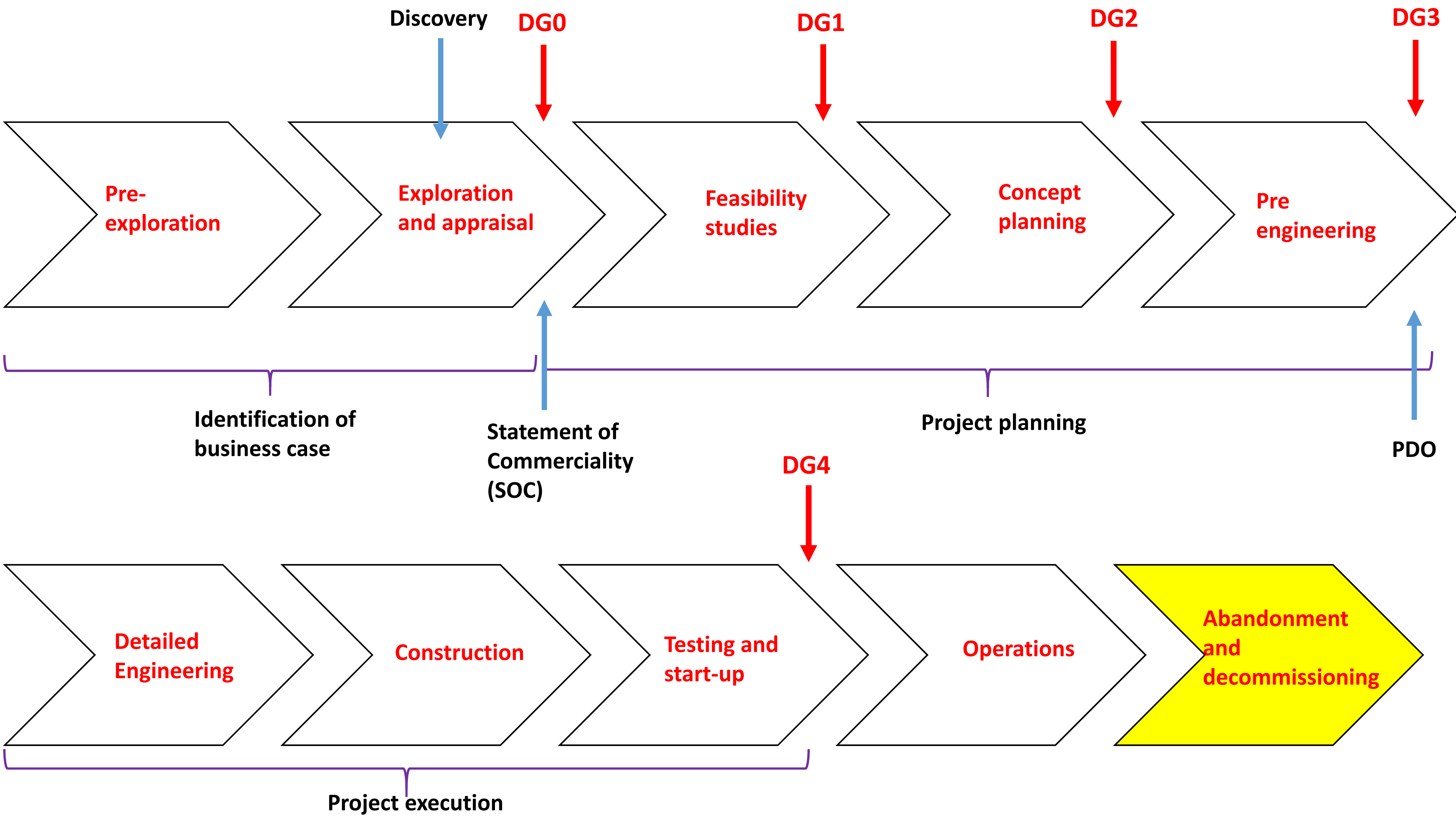
OPERATIONS

- 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.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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

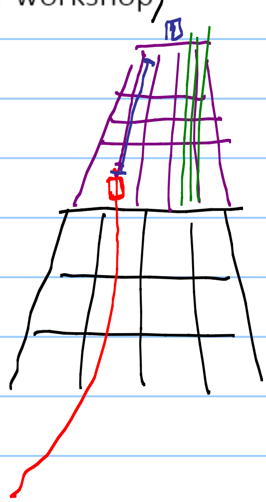
DECOMISSIONING AND ABANDONMENT

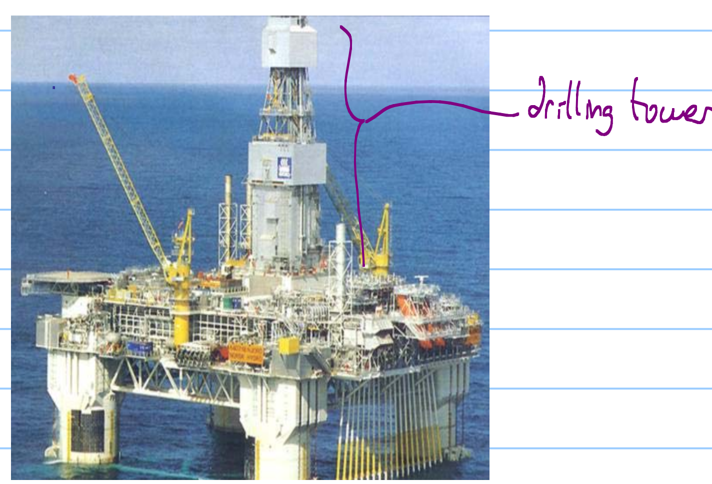
DECOMISSIONING AND ABANDONMENT

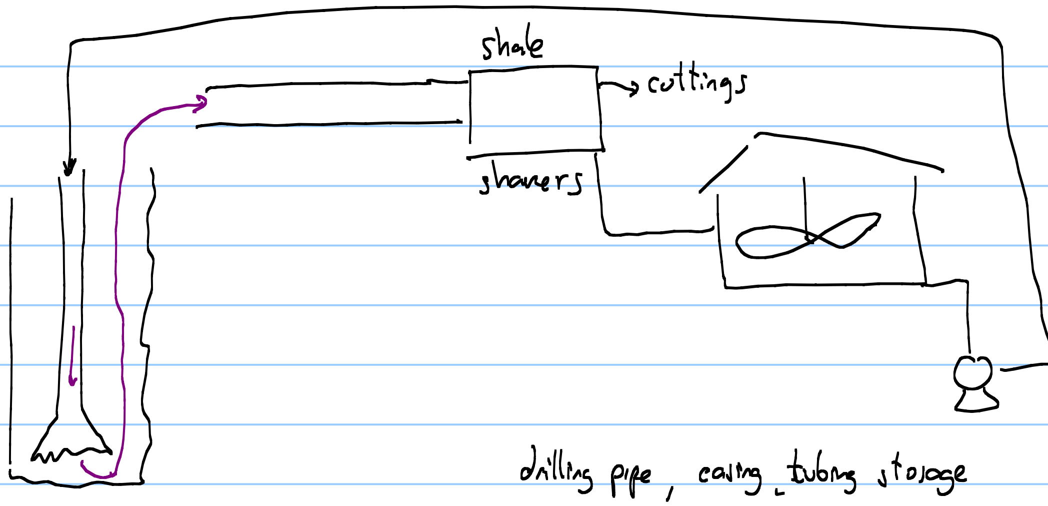
Offshore structures for oil and gas production

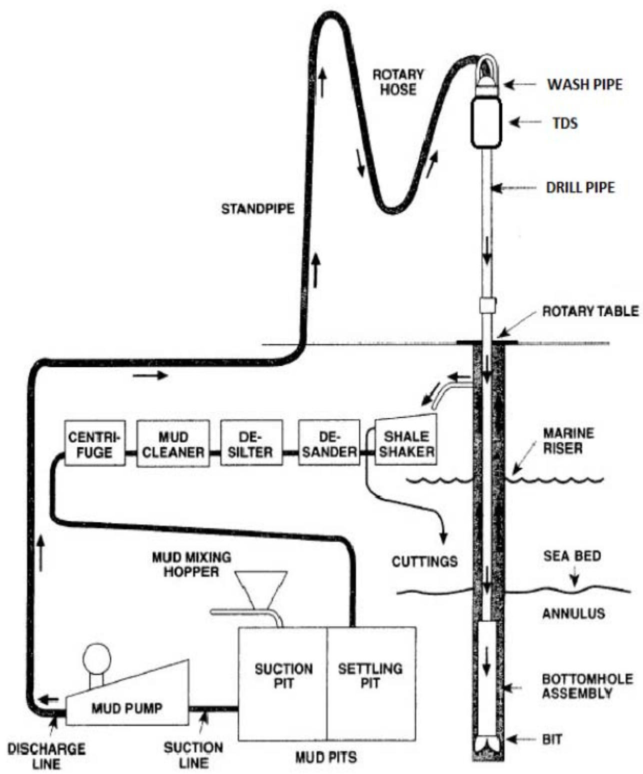
Components of offshore structure:

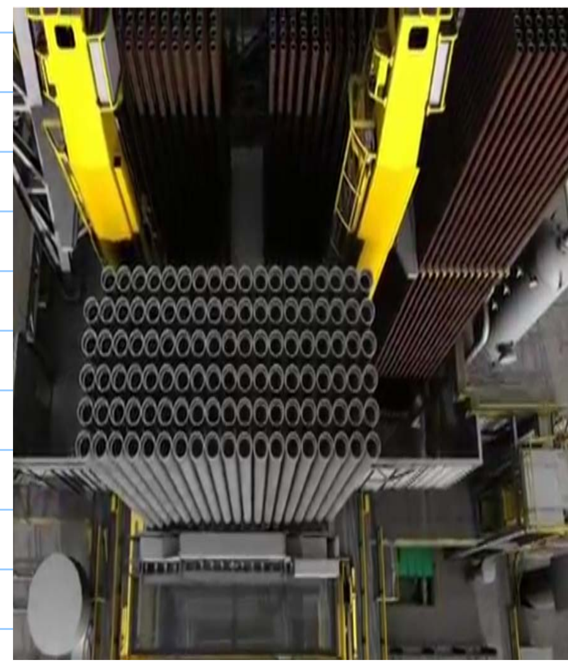
- Facilities for drilling and full intervention. This includes drilling tower, BOP, drilling floor, mud package, cementing pumps, storage deck for drill pipes and tubulars, drilling risers. (optional) [BOP: Blowout preventor]
- Facilities for light well intervention. → slickline, wireline; → coiled tubing
- Processing facilities: separator trains for primary oil, gas and water separation, gas processing train, water processing train.
- Gas injection system
- Gas compression units for pipeline transport
- Water injection system
- Living quarters
- Helideck.
- Power generation. → gas turbines
- Flare system.
- Utilities (hydraulic power fluid, compressed air, drinking water unit, air condition system, ventilation and heating system)
- Bay for wellheads and christmas trees (optional)
- Production manifolds
- Oil storage
- Facilities for oil offloading
- Control system
- Monitoring system
- System for storage, injection and recovery of production chemicals (wax, scale , hydrate or corrosion inhibitors), emulsion inhibitor, biocide
- Repair workshop,



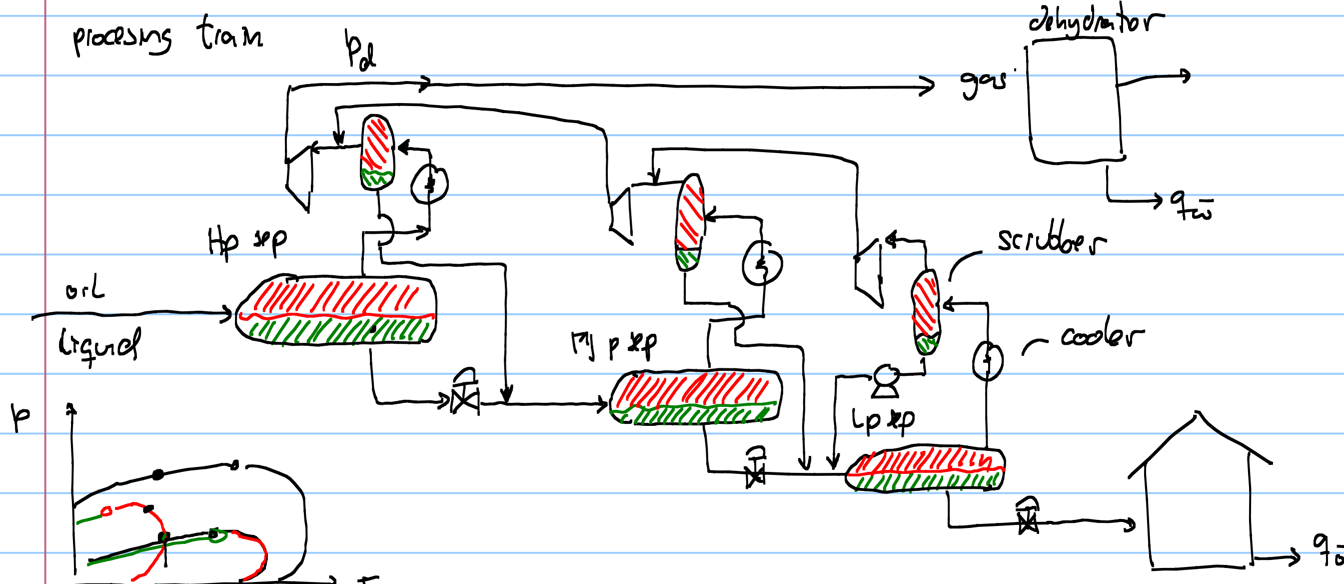


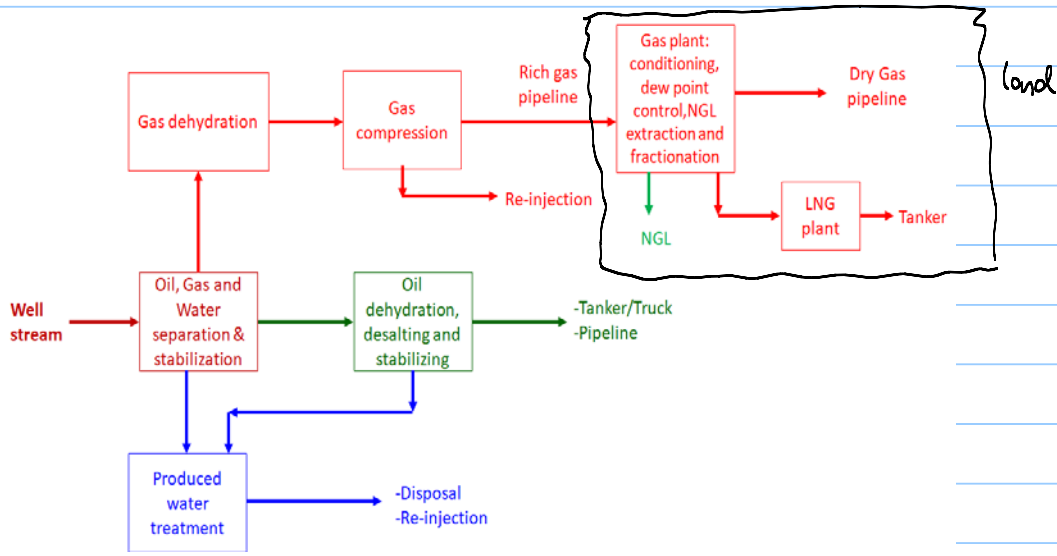




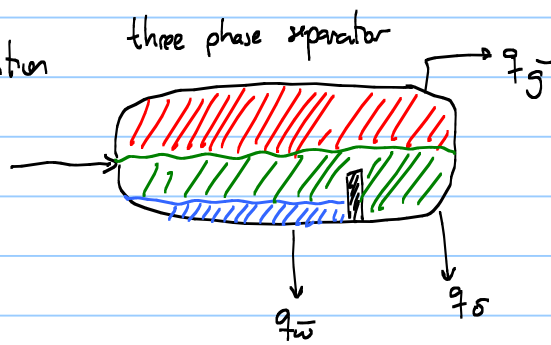


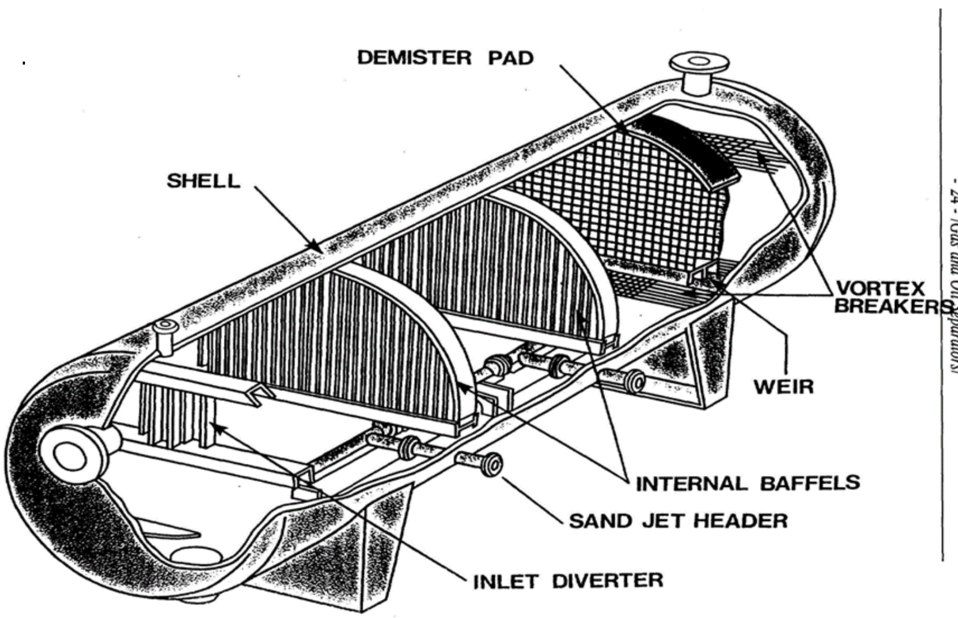
processing train



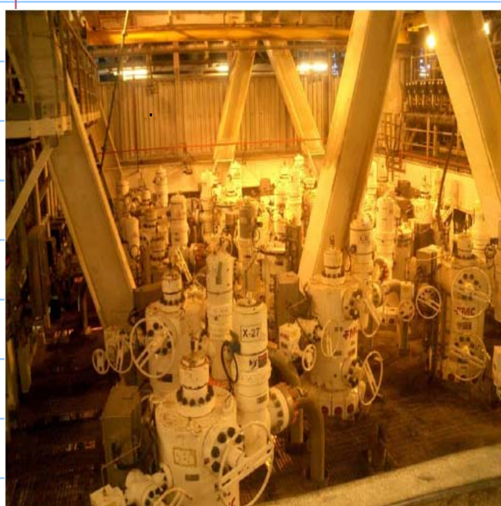


water separation



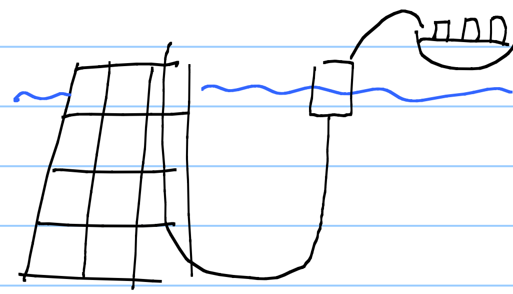


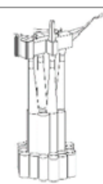
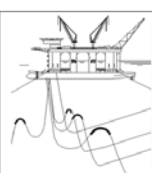
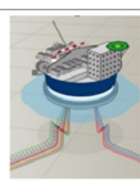
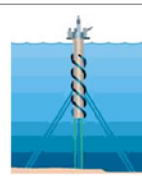
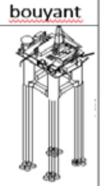
flare



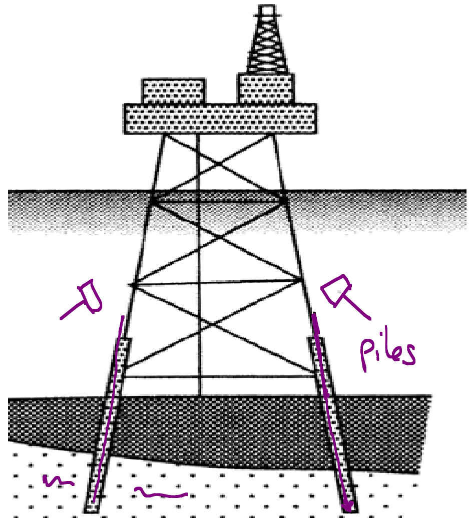
well-bay

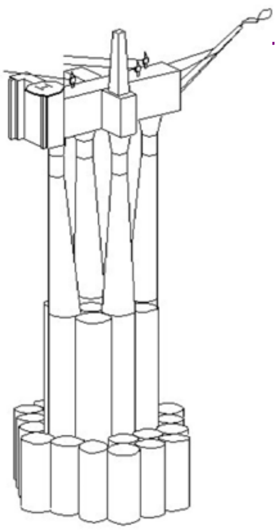
offloading facilities



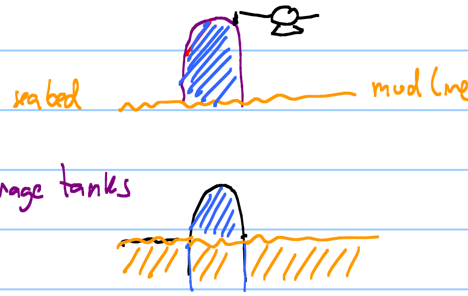
	Fixed		Compliant		
Bottom-supported					
	Jacket	Gravity-Based Structure	Compliant tower		
Floating	Neutrally bouyant				Positively bouyant
					
	Ship FPSO	Semi-Sub	Sevan FPSO	Spar	Tension Leg Platform (TLP)

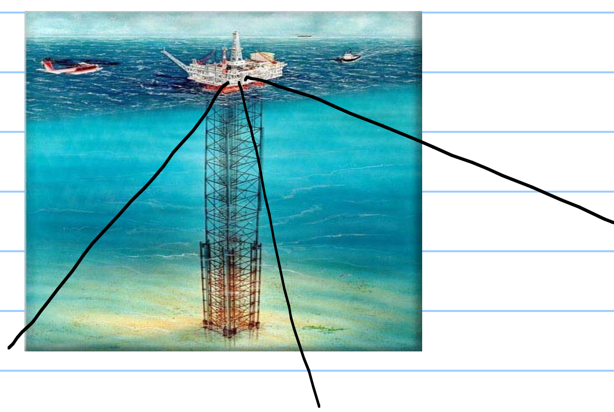
fixed structure





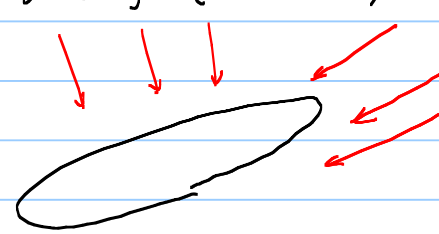
suction anchor

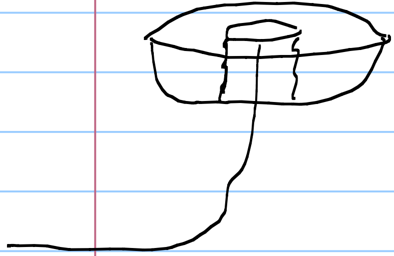


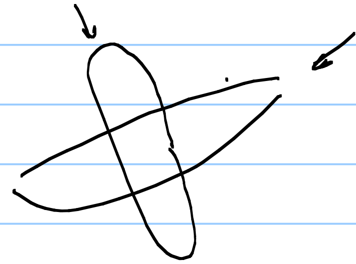


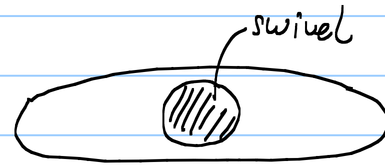
FPSO

high storage (3 E06 stb)





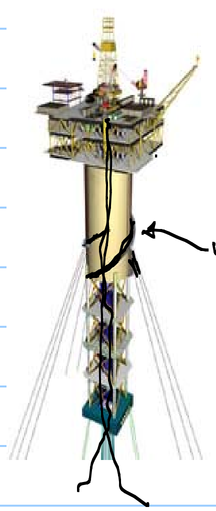


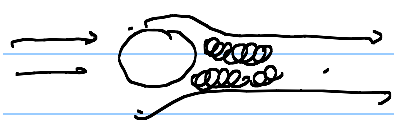


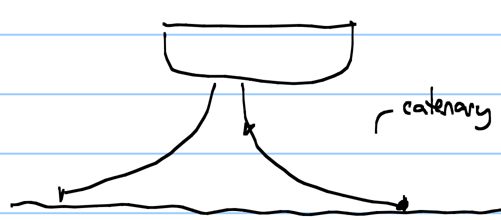
FPSO Sevan

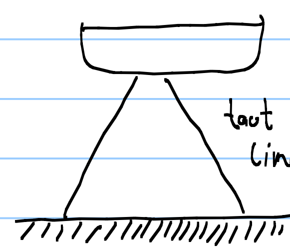
Semi submersible
(they are used for drilling subsea)

SPAR

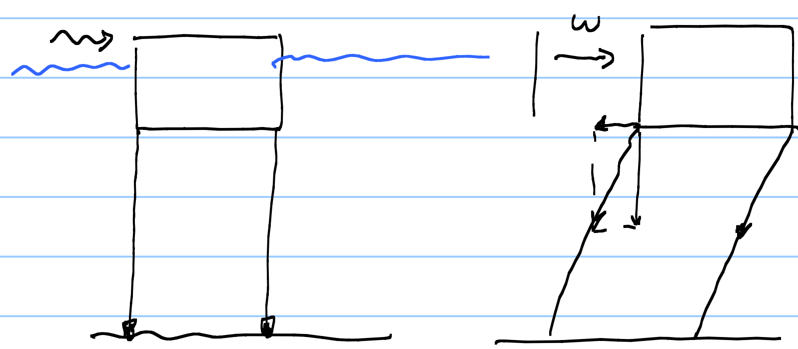


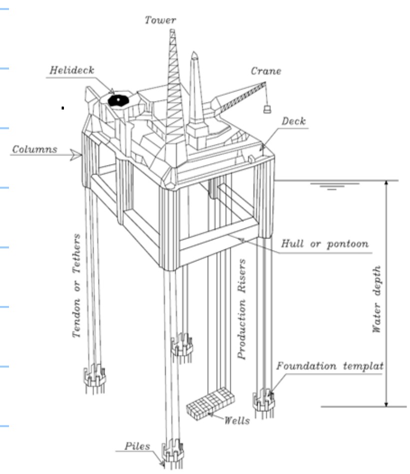






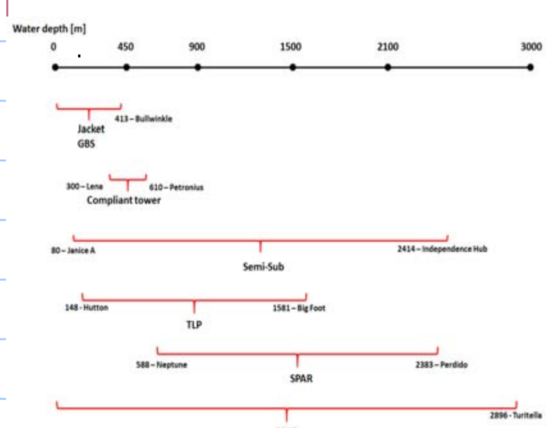
Positively bougant structure (Tension leg platform)





How do we select offshore structures?

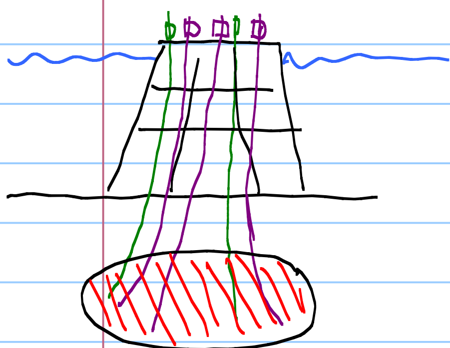
technical reasons
1. water depth — <600 m bottom supported structures; >600 m floating structure
2. location of X-mas tree
3. oil storage
4. marine loads

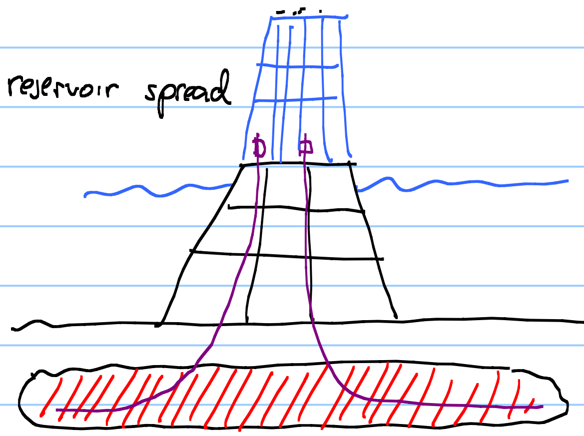


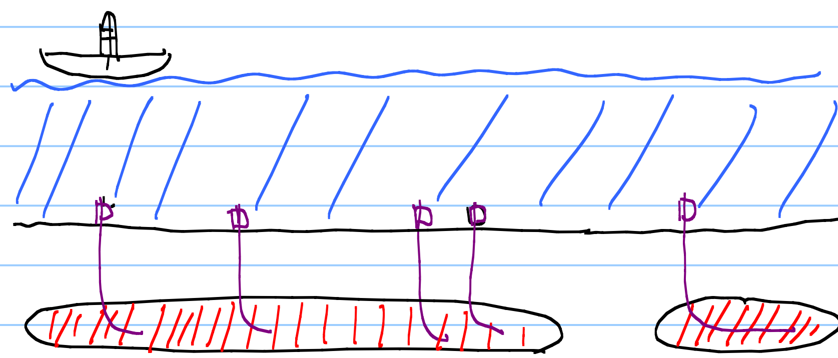
7- location of X-mas tree → under the sea
→ above the sea level

- water depth: only bottom-supported structures, TLP, SPARS allow for dry x-mas trees
the current limit is 1500 m

- reservoir spread







- well intervention needs
  → tubing replacement
  → completion modification
  → artificial lift
    ESP lifetime 6 month - 2 years
    no pump 5 years +

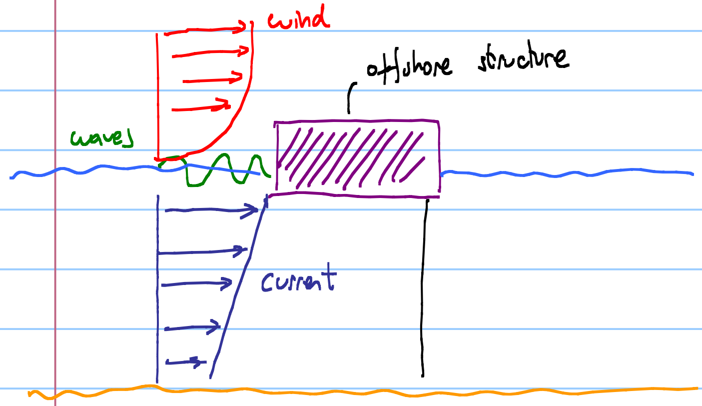
If frequent intervention is needed → dry X-mas trees
If " " is not needed → wet x-mas trees

- infill drilling? → yes subsea well might be more suitable. (limited space in platform)

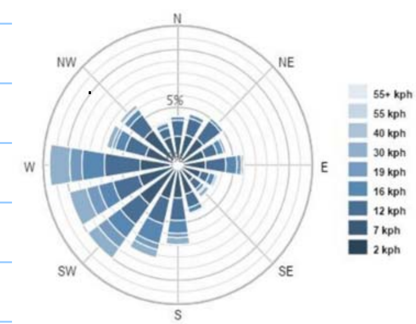
③ oil storage? → remoteness, weather conditions → yes!

Structures with storage are GBS, FPSO, SPAR ~ 150000 stb

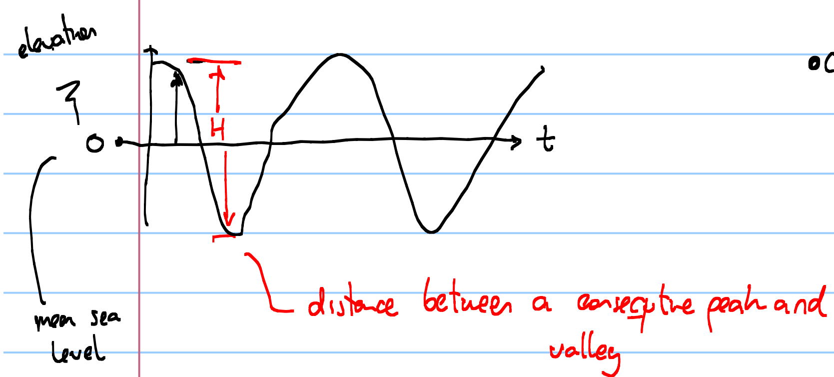
- marine loads



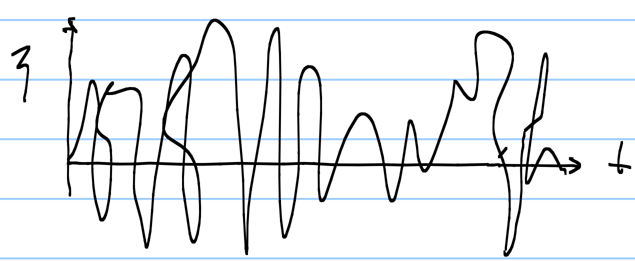
- wind: a fixed value is used for design
  it's important to look at orientation



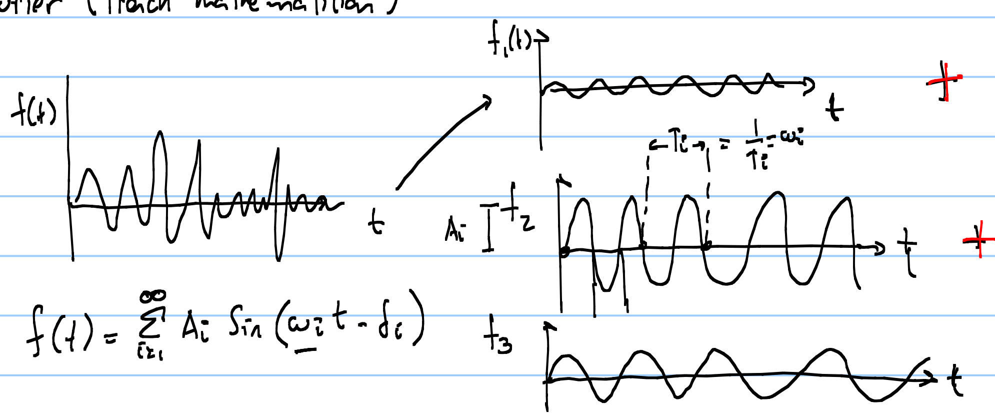
- waves



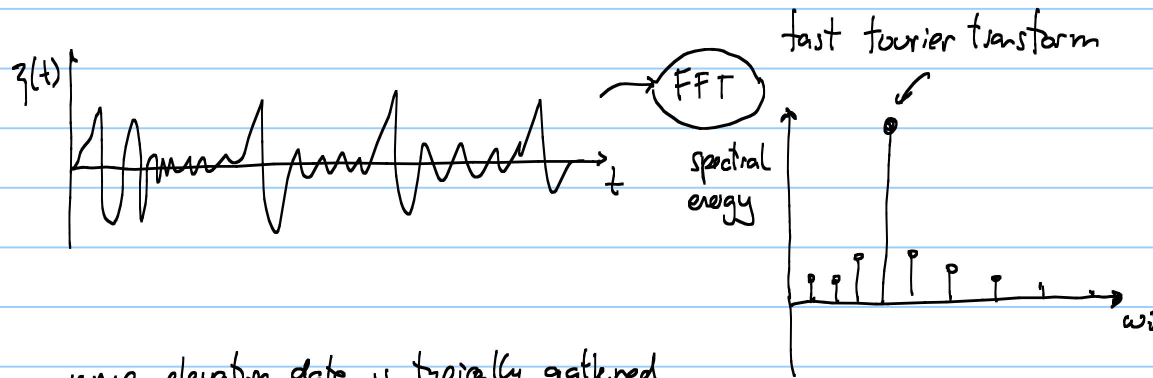
- currents: typically a constant value is used
  it is important to look at variation with depth



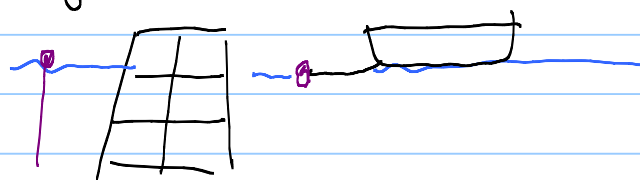
Fourier (french mathematician)

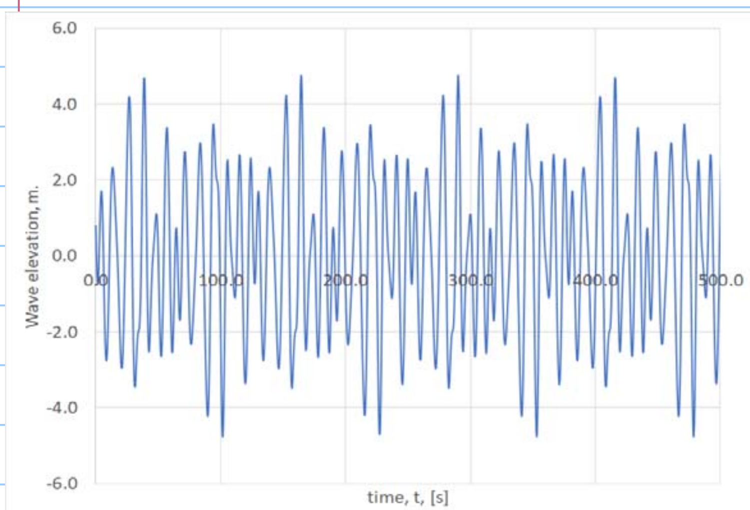


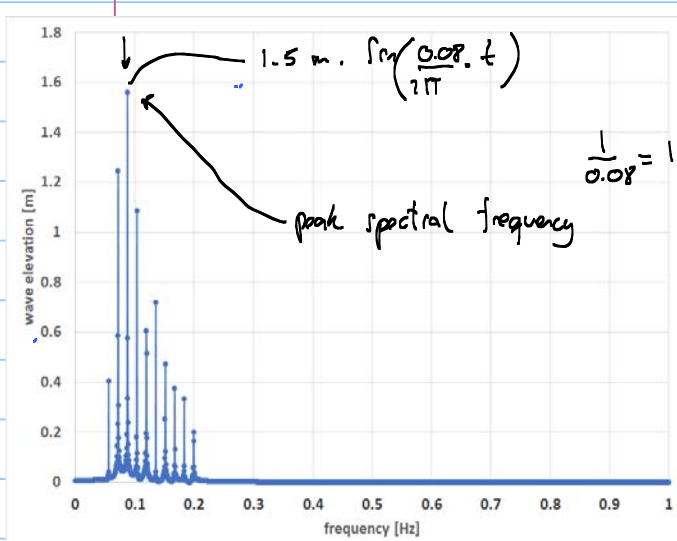
$$f(t) = \sum_{i=1}^{\infty} A_i \sin(\omega_i t - \delta_i)$$



- wave elevation data is typically gathered with bouys



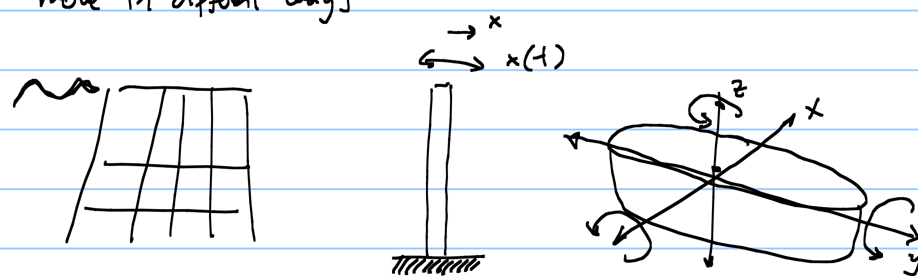




$\frac{1}{0.08} = 12.5$ s

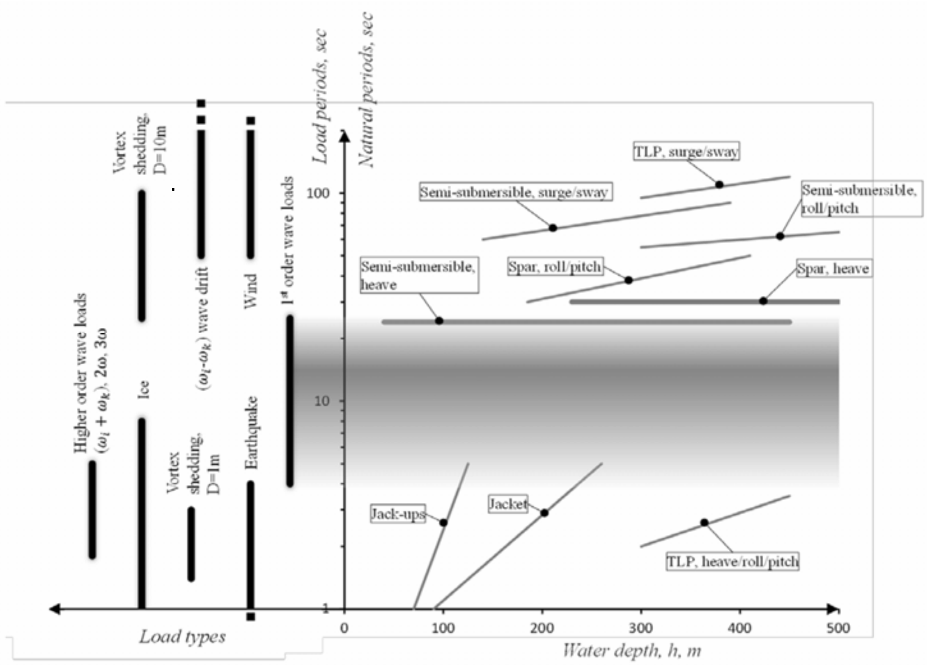
Time interval [s]	2047.5			
Number of points	4096			
sampling frequency [samples/s]	2.00			
Time	Elevation	FFT freq	FFT mag	FFT complex
[s]	[m]			
0.0	0.8	0	0.007144	-14.6310630637753
0.5	0.0	0.000	0.007144	-14.6314355376179-2.17584020171838E-002i
1.0	-0.5	0.001	0.007145	-14.6325531382138-4.35187835418294E-002i
1.5	-0.8	0.001	0.007146	-14.634416403011-6.52831256995594E-002i
2.0	-0.6	0.002	0.007147	-14.6370262285584-8.70534128729824E-002i
2.5	-0.1	0.002	0.007149	-14.6403838717195-0.108831634337723i
3.0	0.5	0.003	0.007151	-14.6444909513754-0.13061978594503i
3.5	1.1	0.003	0.007153	-14.6493494506153-0.152419871829957i
4.0	1.6	0.004	0.007156	-14.6549617194251-0.174233906173646i
4.5	1.7	0.004	0.007159	-14.6613304778867-0.196063915009091i
5.0	1.5	0.005	0.007163	-14.6684588198886-0.217911938100365i
5.5	0.9	0.005	0.007167	-14.6763502173536-0.239780030911572i
6.0	0.2	0.006	0.007172	-14.6850085250036-0.261670266637959i
6.5	-0.7	0.006	0.007176	-14.6944379856753-0.283584738366725i
7.0	-1.6	0.007	0.007182	-14.7046432361733-0.305525561331911i
7.5	-2.3	0.007	0.007187	-14.7156293137251-0.327494875310597i
8.0	-2.7	0.008	0.007193	-14.727401663005-0.349494847163372i

offshore structures move in different ways



natural frequency

if wave frequency is close to the natural frequency of structure then movement will be maximum, stress will also be maximum ~> high risk of failure

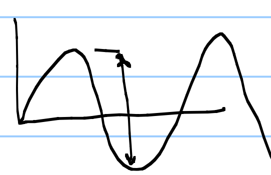


$$T = \frac{1}{\omega}$$

1 assumption to gather wave data: sea state is a period of (3hrs) time when the spectral period doesn't change much

period of time	t_p (peak spectral period)	H_s
1	12,5	( )
2	9	( )
3	2	( )
4		
5		
100.000		

H_s: significant wave height



- visualize sea-state data

	Spectral Peak period (T_p) [s]																						
Hs [m]	0-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	Sum
0-1	15	290	1367	2876	3716	3527	2734	1849	1138	656	362	192	101	52	26	13	7	3	2	1	0	0	0	18927
1-2	1	81	1153	5308	12083	17323	18143	15262	10980	7053	4169	2316	1229	631	315	155	75	36	17	8	4	5	1	96348
2-3	0	2	94	1050	4532	10304	15020	15953	13457	9752	5991	3403	1795	894	426	197	88	39	17	7	3	1	1	83026
3-4	0	0	2	72	686	2782	6171	8847	9189	7493	5082	2991	1577	762	345	148	61	24	9	4	1	0	0	46246
4-5	0	0	0	2	51	433	1645	3495	4807	4750	3638	2286	1229	584	251	100	37	13	5	1	0	0	0	23327
5-6	0	0	0	0	2	39	294	1037	2069	2664	2440	1709	968	463	193	72	25	8	2	1	0	0	0	11986
6-7	0	0	0	0	0	2	32	215	692	1264	1485	1228	767	382	159	57	18	5	1	0	0	0	0	6307
7-8	0	0	0	0	0	0	2	27	157	447	730	762	555	302	130	46	14	4	1	0	0	0	0	3177
8-9	0	0	0	0	0	0	0	2	23	112	276	392	355	223	104	38	11	3	1	0	0	0	0	1540
9-10	0	0	0	0	0	0	0	0	2	19	77	160	192	148	79	31	9	2	0	0	0	0	0	719
10-11	0	0	0	0	0	0	0	0	0	2	16	50	85	85	55	24	8	2	0	0	0	0	0	327
11-12	0	0	0	0	0	0	0	0	0	0	2	12	29	40	33	18	7	2	0	0	0	0	0	143
12-13	0	0	0	0	0	0	0	0	0	0	0	2	8	15	17	12	5	2	0	0	0	0	0	61
13-14	0	0	0	0	0	0	0	0	0	0	0	0	2	5	7	6	4	1	0	0	0	0	0	25
14-15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	2	1	0	0	0	0	0	9
15-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	4
16-17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	16	373	2616	9308	21070	34410	44041	46687	42514	34212	24268	15503	8892	4587	2143	921	372	146	55	22	8	6	2	292172

I have to select an offshore structure which natural period is NOT the most frequent spectral peak period in this chart!

Michael Golan refreshment of concepts

(1) Molecular weight of pure component, (2) mole fraction, (3) apparent molecular weight of a mixture, (4) conversions between: component moles-mole fraction-component mass-mass fraction.

H_2O (2 + 16) $Mw = 18 \frac{kg}{kmol} \; \frac{g}{mol}$

exercise: air: 18 mol O_2

78 mol N_2

4 mol CO_2

$x_{O_2} = \frac{18}{18+78+4}$

$x_{O_2} = 0.18$

$x_{N_2} = 0.78$

$x_{CO_2} = 0.04$

$O_2 \rightarrow Mw = 32$

$N_2 \rightarrow Mw = 28$

$CO_2 \rightarrow Mw = 48$

MW_{air} ? $MW_{air} = MW_{O_2} \cdot x_{O_2} + MW_{N_2} \cdot x_{N_2} + MW_{CO_2} \cdot x_{CO_2}$

$MW_{air} = 32 \cdot 0.18 + 28 \cdot 0.78 + 48 \cdot 0.04$

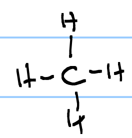
$MW_{air} = 29.52$

$MW_{air} = 28.97$ in petroleum

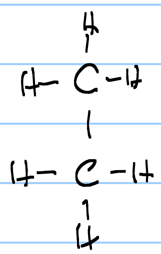
for gases $\gamma_g = \frac{MW_{gas}}{MW_{air}}$ $\gamma_g = 0.8$ $MW_{gas} = ?$

specific gas gravity $MW_{gas} = 0.8 \cdot 28.97$

$MW_{gas} = 23.176$



$MW_{methane} = 16$



$MW_{ethane} = 30$

mol $\frac{kg}{kmol}$ $\frac{g}{mol}$

mass fraction? [y]

$$y_{O_2} = \frac{m_{O_2}}{m_T} = \frac{n_{O_2} \cdot MW_{O_2}}{n_T \cdot MW_{air}} =$$

mas fraction $y_{O_2} = x_{O_2} \cdot \left(\frac{MW_{O_2}}{MW_{air}}\right)$

mole fraction

$$y_{O_2} = \frac{18 \quad 32}{100 \text{ moles} \cdot 29.52} = 0.195$$

the end