DTU

Utilizing Whole Effluent Testing in an Intelligent Testing Strategy for Offshore Produced Water Discharges

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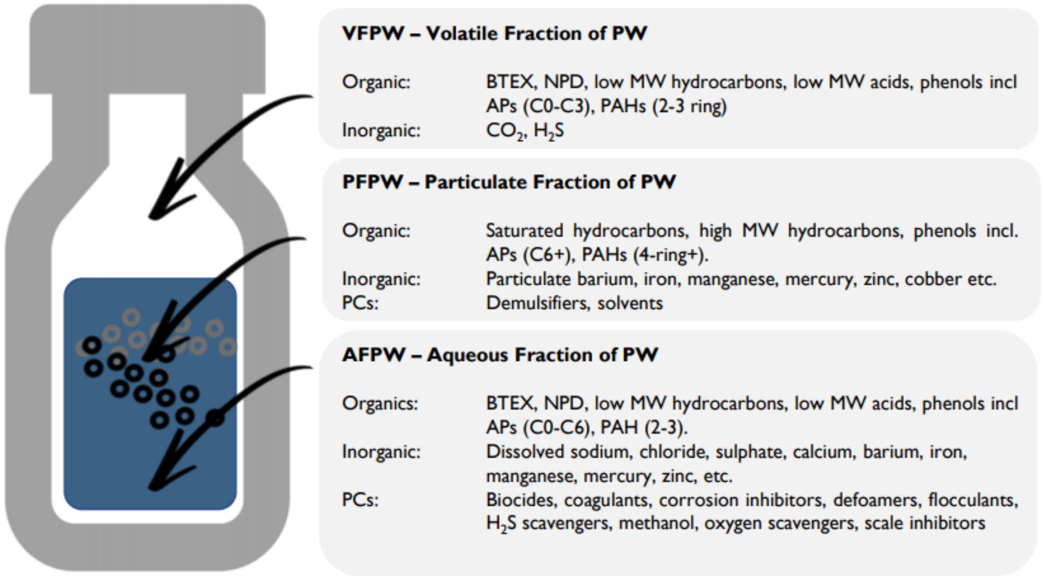
DTU Sustain

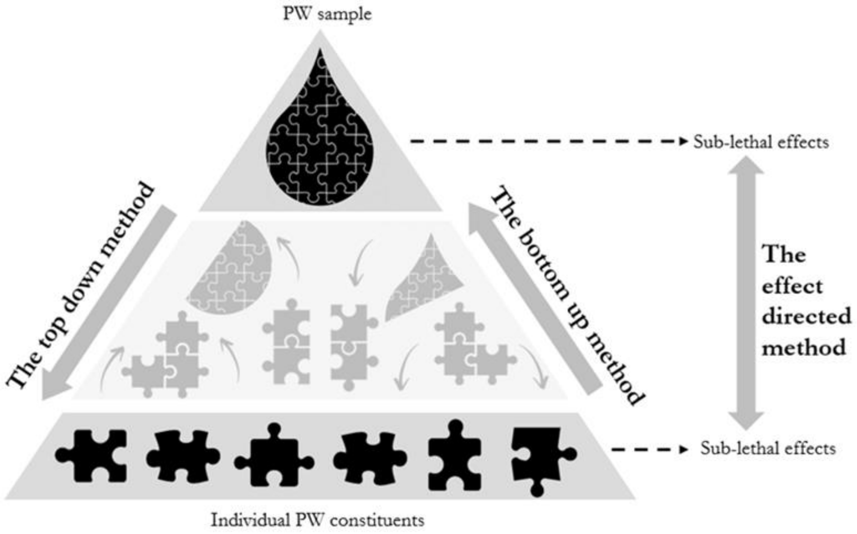
Aim: Identification of discharges and substances that represent the greatest risk to the environment… how?

Our assumptions:

- SB is hampered by W.Y.L.F.I.W.Y.G. and I.Y.D.L.F.I.Y.W.N.F.I
- VERY extensive analytical-chem characterization ≠ fully explained observed ecotoxicity
- SSD is best – but suitable data will always be a limitation

What's the link to risk management?





Aim: Identification of discharges and substances that represent the greatest risk to the environment… how?

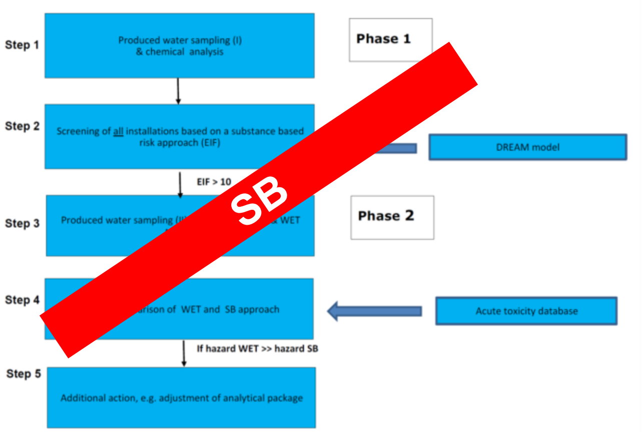
Our approach:

- Tiered approach utilizing WET hand-in-hand with TIE
  - Relative measure for id and ranking
  - Provide information on contributing fractions
  - Effects-driven chem analysis → SB

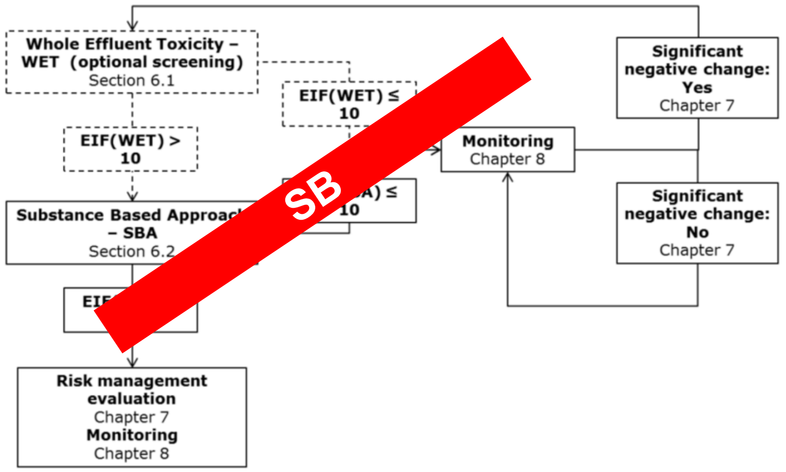
…but of course with varying tox test quality, sample variation, storage issues

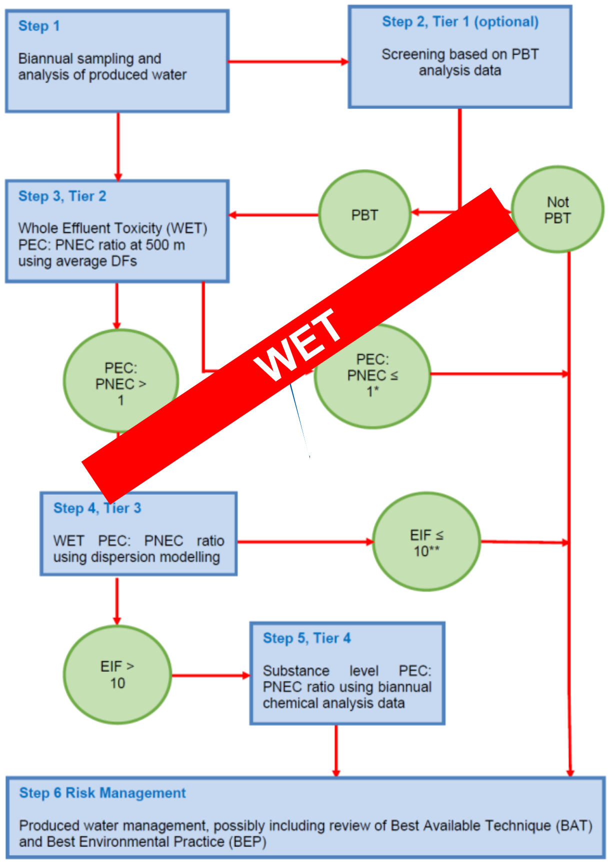
Intelligent Test Strategy utilizing a tiered approach with WET →
A procedure for hazard identification, ranking and decision-making
(not for quantifying (theoretical) risk in the environment)

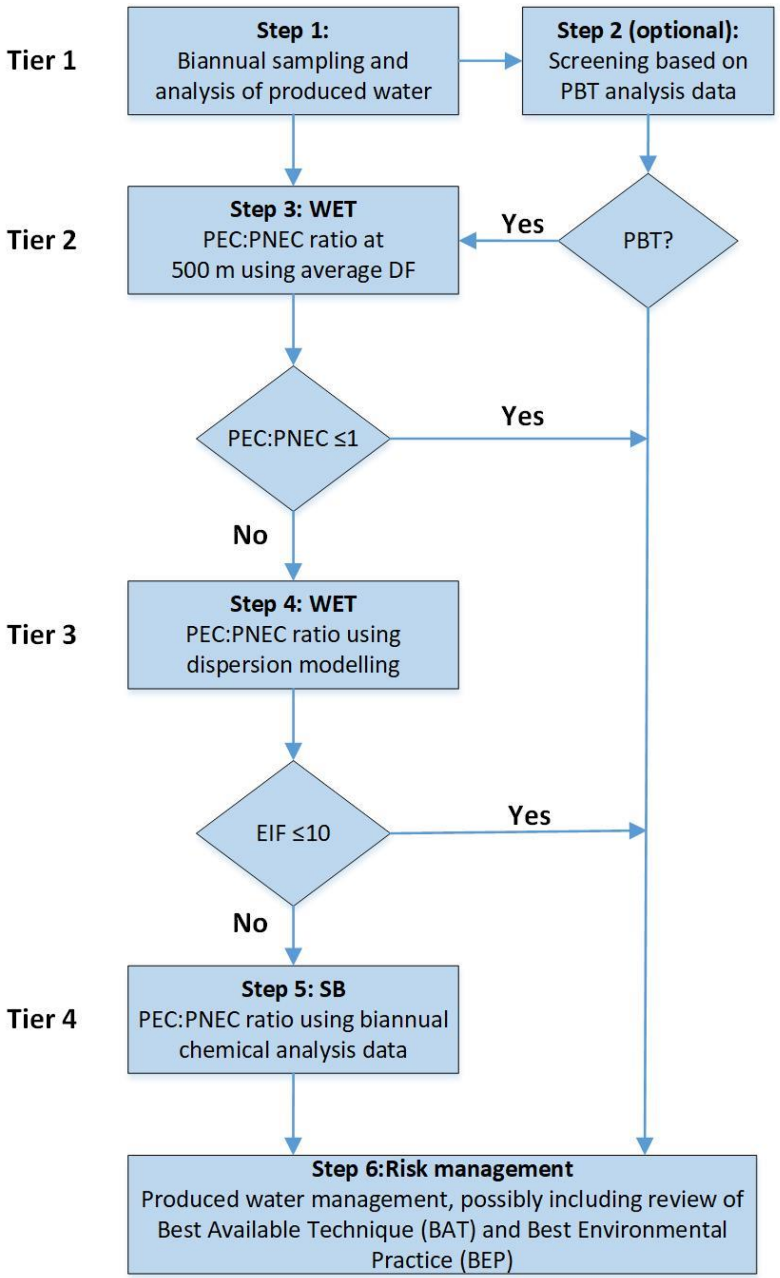
Aim: Identification of discharges and substances that represent the greatest risk to the environment… how?



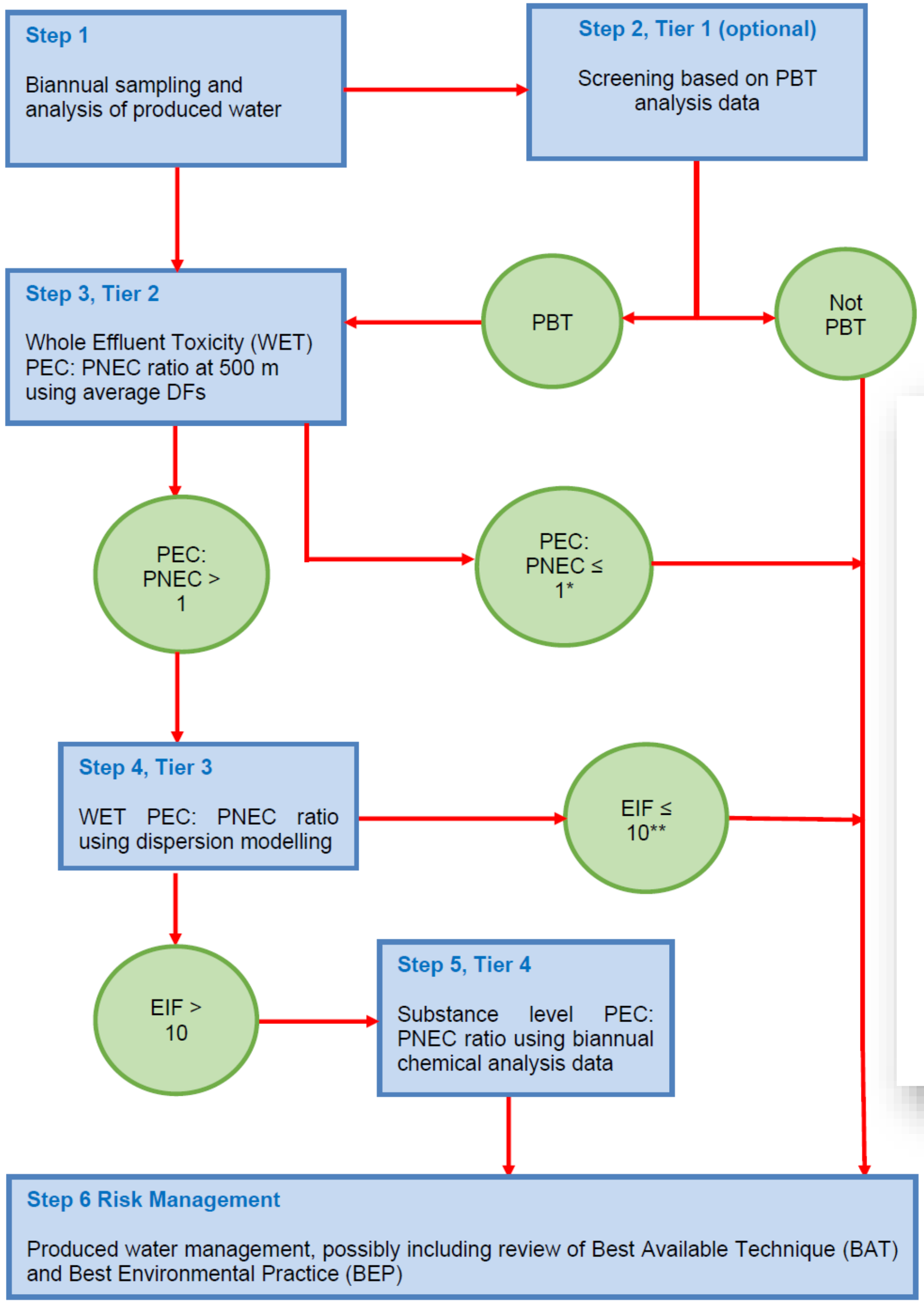
Existing frameworks
(N, DK UK)







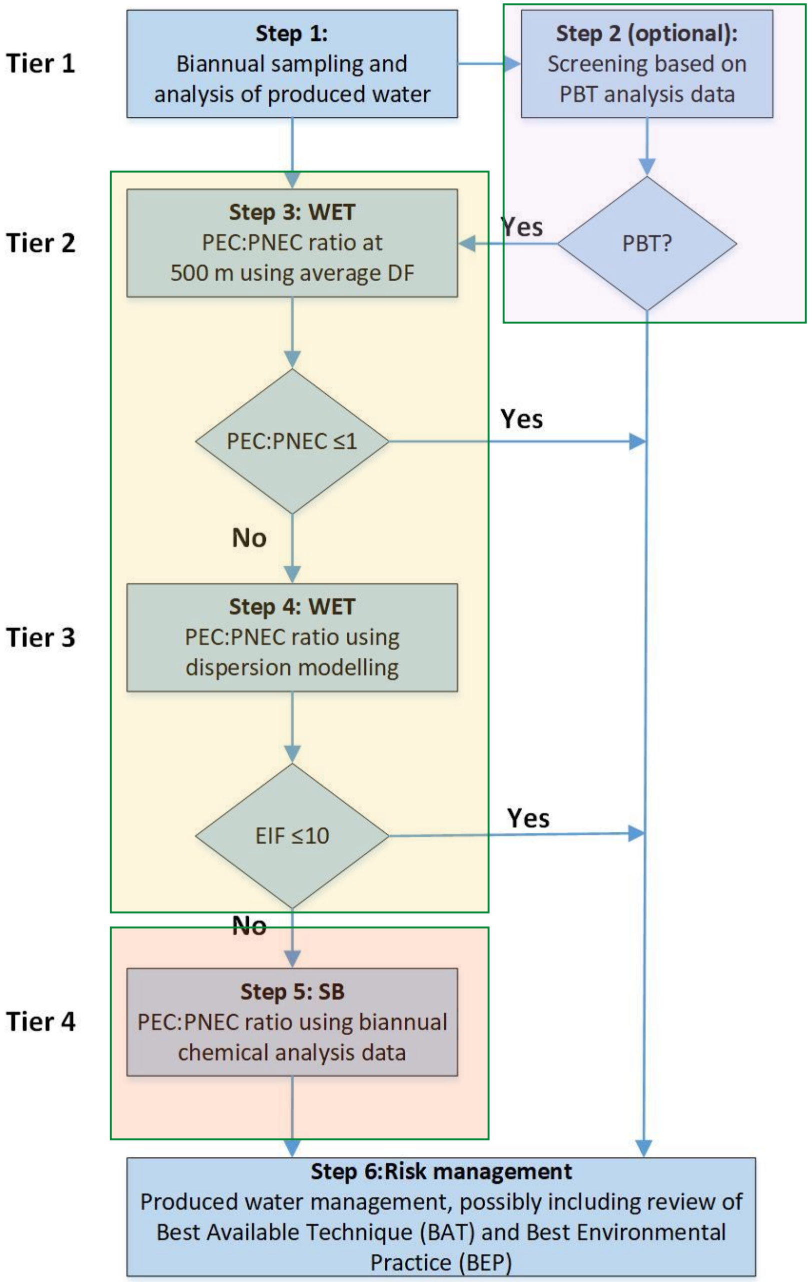
Tier 1
Step 1:
Biannual sampling and analysis of produced water
Step 2 (optional):
Screening based on PBT analysis data
Tier 2
Step 3: WET
PEC:PNEC ratio at 500 m using average DF
Yes
PBT?
PEC:PNEC ≤1
Yes
No
Tier 3
Step 4: WET
PEC:PNEC ratio using dispersion modelling
EIF ≤10
Yes
No
Tier 4
Step 5: SB
PEC:PNEC ratio using biannual chemical analysis data
Step 6:Risk management
Produced water management, possibly including review of Best Available Technique (BAT) and Best Environmental Practice (BEP)

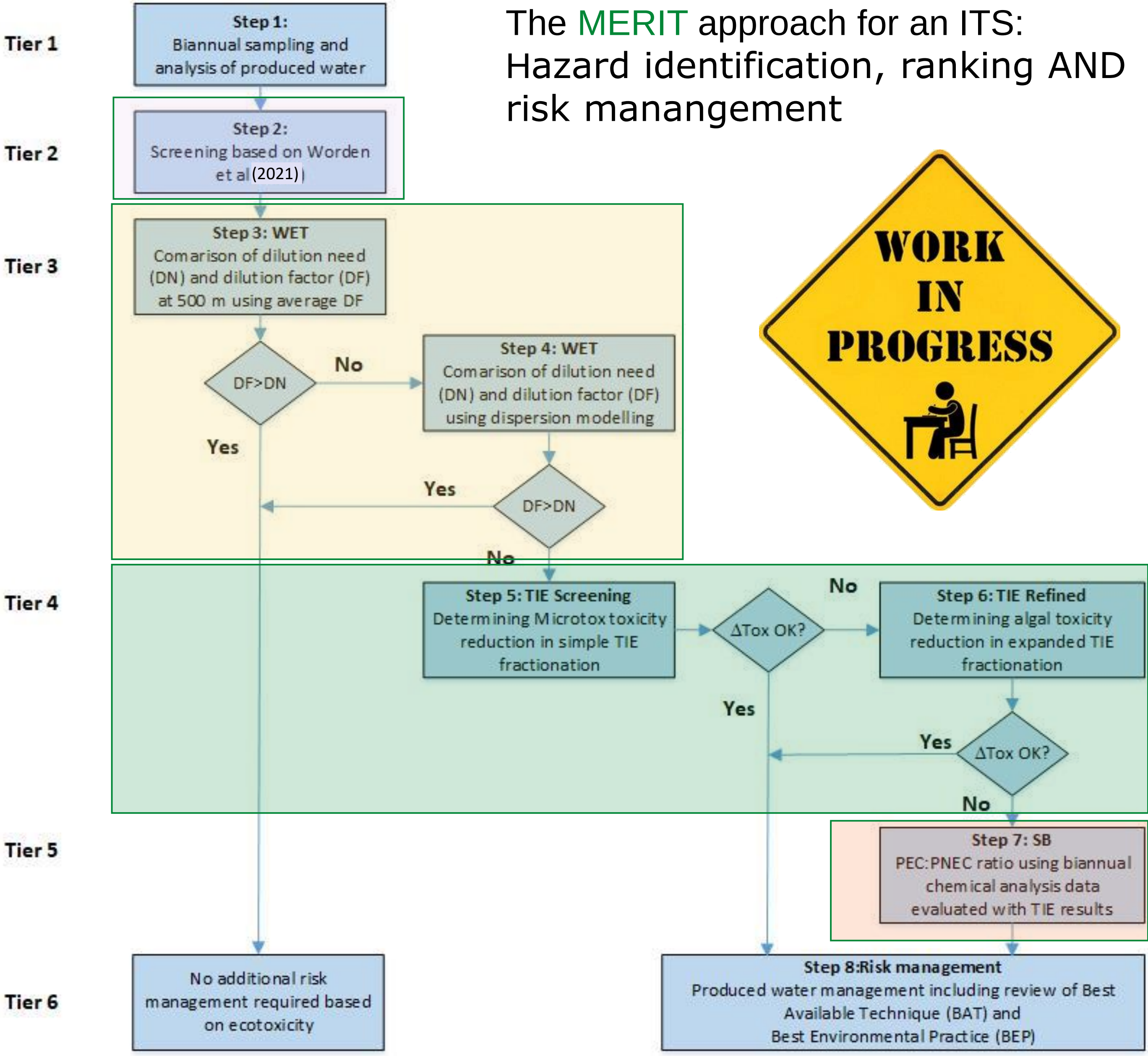


Step 1
Biannual sampling and analysis of produced water
Step 2, Tier 1 (optional)
Screening based on PBT analysis data
PBT
Not PBT
Step 3, Tier 2
Whole Effluent Toxicity (WET) PEC: PNEC ratio at 500 m using average DFs
PEC: PNEC > 1
PEC: PNEC ≤ 1*
Step 4, Tier 3
WET PEC: PNEC ratio using dispersion modelling
EIF ≤ 10**
EIF > 10
Step 5, Tier 4
Substance level PEC: PNEC ratio using biannual chemical analysis data
Step 6 Risk Management
Produced water management, possibly including review of Best Available Technique (BAT) and Best Environmental Practice (BEP)

Department for Business, Energy & Industrial Strategy
The United Kingdom Risk-Based Approach Programme
A risk-based approach to the management of produced water discharges from offshore installations.
Version 3.1
December 2020

The MERIT approach for an ITS: Hazard identification, ranking AND risk manangement





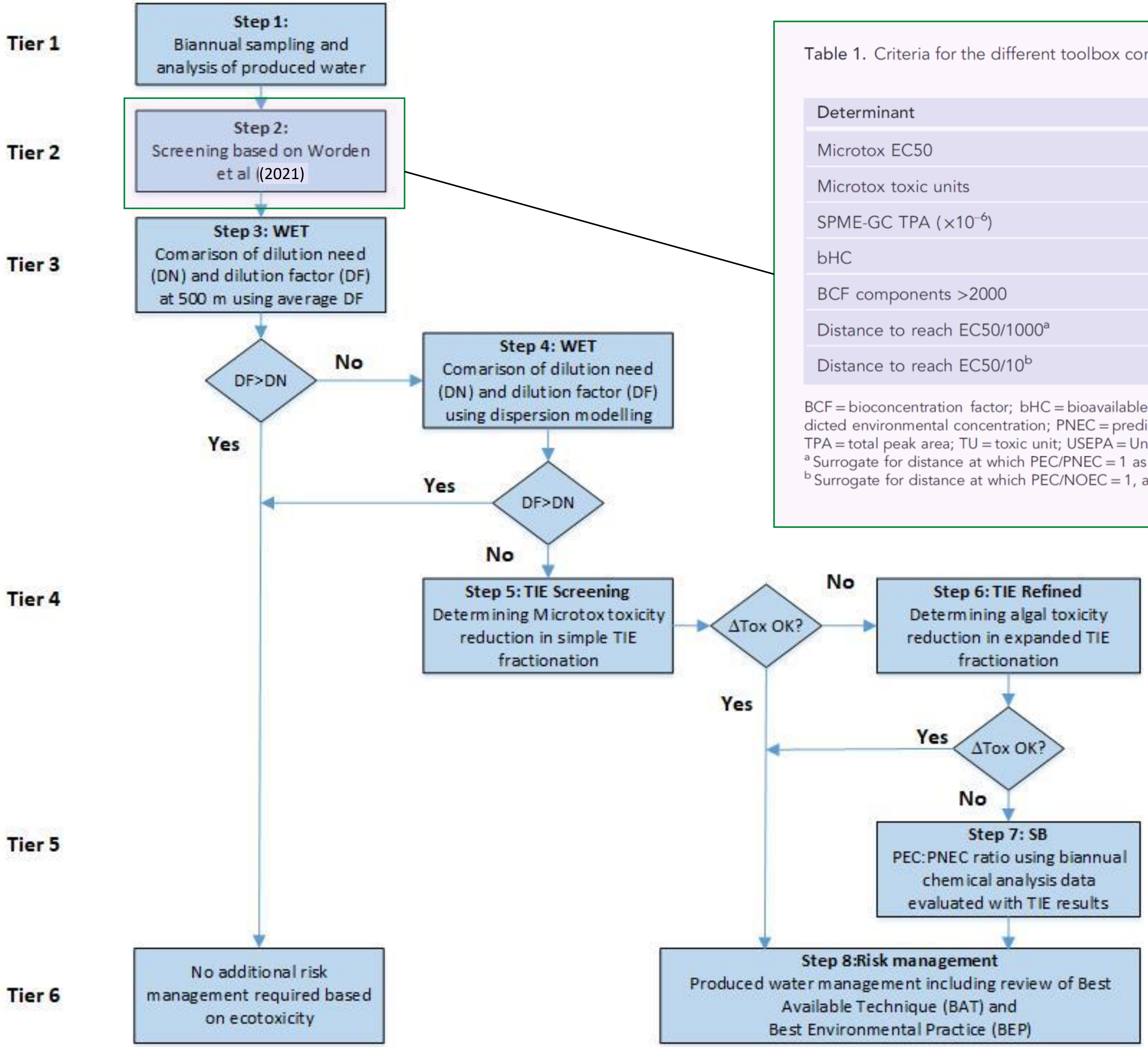
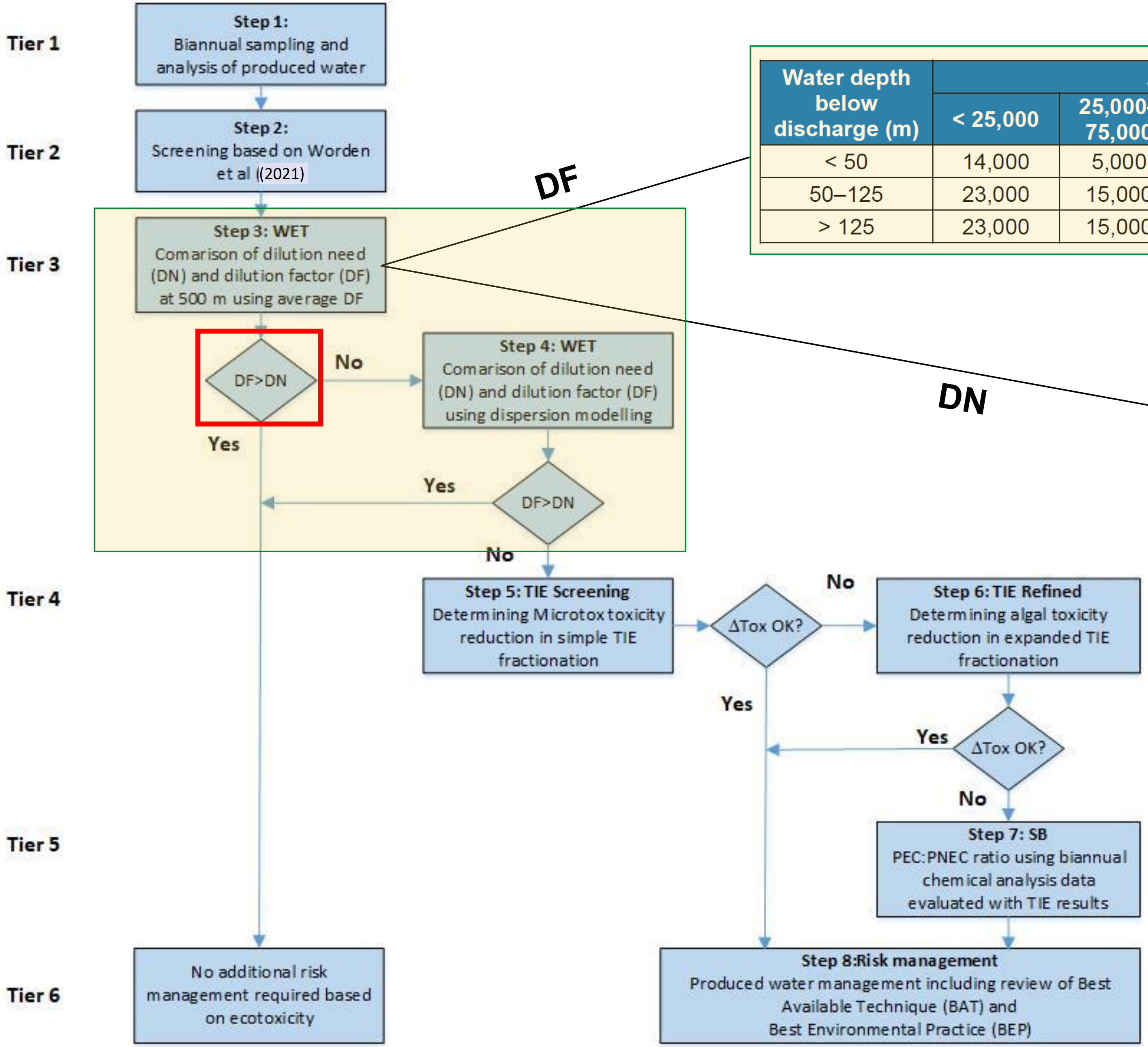


Table 1. Criteria for the different toolbox components regarding evaluation of produced waters and effluents with respect to prioritization for further assessment

Determinant	Unit	Low priority	Medium priority	High priority
Microtox EC50	(%)	>10	2–10	<2
Microtox toxic units	(–)	<10	10–50	>50
SPME-GC TPA ($\times 10^{-6}$)	(–)	<25	25–150	>150
bHC	(mg/L)	0–10	10–50	>50
BCF components >2000	(mg/L)	<0.1	0.1–1	>1.0
Distance to reach EC50/1000[a]	(m)	<500	500–2000	>2000
Distance to reach EC50/10[b]	(m)	<100	100–200	>200

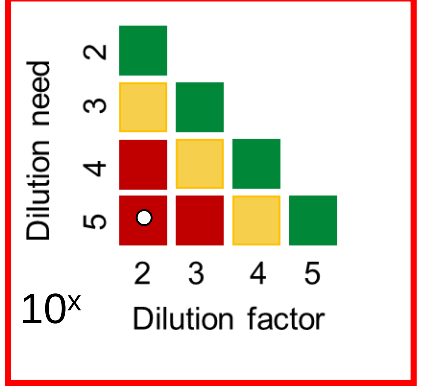
BCF = bioconcentration factor; bHC = bioavailable hydrocarbon; NOEC = no observed effect concentration; OSPAR = Oslo–Paris Commission; PEC = predicted environmental concentration; PNEC = predicted no effect concentration; SPME-GC = solid-phase microextraction with gas chromatographic analysis; TPA = total peak area; TU = toxic unit; USEPA = United States Environmental Protection Agency.
[a] Surrogate for distance at which PEC/PNEC = 1 as applied by OSPAR.
[b] Surrogate for distance at which PEC/NOEC = 1, as applied by USEPA for the Gulf of Mexico.

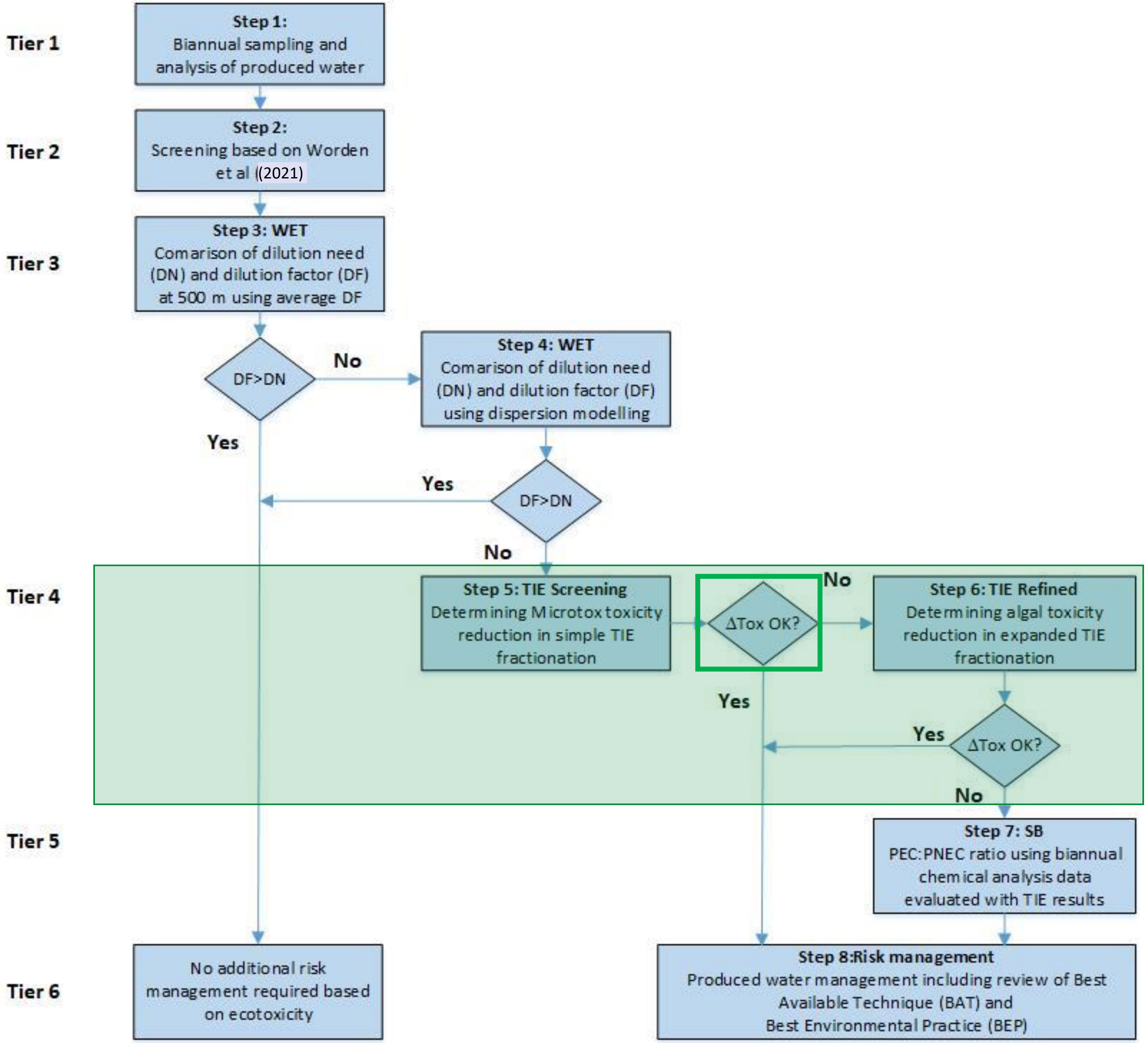


Water depth below discharge (m)	Annual PW discharge volume ($m^3\ yr^{-1}$)					
	< 25,000	25,000–75,000	75,000–125,000	125,000–1,000,000	1,000,000–8,000,000	> 8,000,000
< 50	14,000	5,000	3,000	1,000	400	100
50–125	23,000	15,000	10,000	4,000	400	100
> 125	23,000	15,000	10,000	8,000	400	100

$DN = 100/EC_{50} * MoS$

MoS: Margin of safety





Tier 1
Step 1:
Biannual sampling and analysis of produced water
Tier 2
Step 2:
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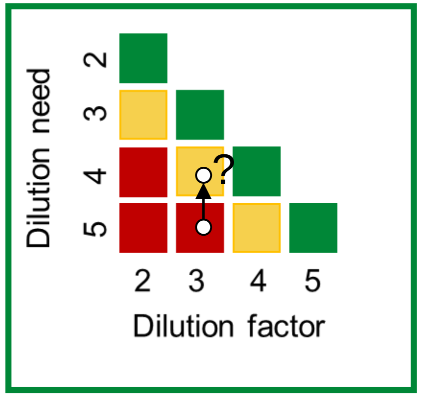
Tier 3
Step 3: WET
Comarison of dilution need (DN) and dilution factor (DF) at 500 m using average DF
DF>DN
No
Yes
Step 4: WET
Comarison of dilution need (DN) and dilution factor (DF) using dispersion modelling
Yes
DF>DN
No
Tier 4
Step 5: TIE Screening
Determining Microtox toxicity reduction in simple TIE fractionation
ΔTox OK?
No
Step 6: TIE Refined
Determining algal toxicity reduction in expanded TIE fractionation
Yes
Yes
ΔTox OK?
No
Tier 5
Step 7: SB
PEC:PNEC ratio using biannual chemical analysis data evaluated with TIE results
Tier 6
No additional risk management required based on ecotoxicity
Step 8:Risk management
Produced water management including review of Best Available Technique (BAT) and Best Environmental Practice (BEP)

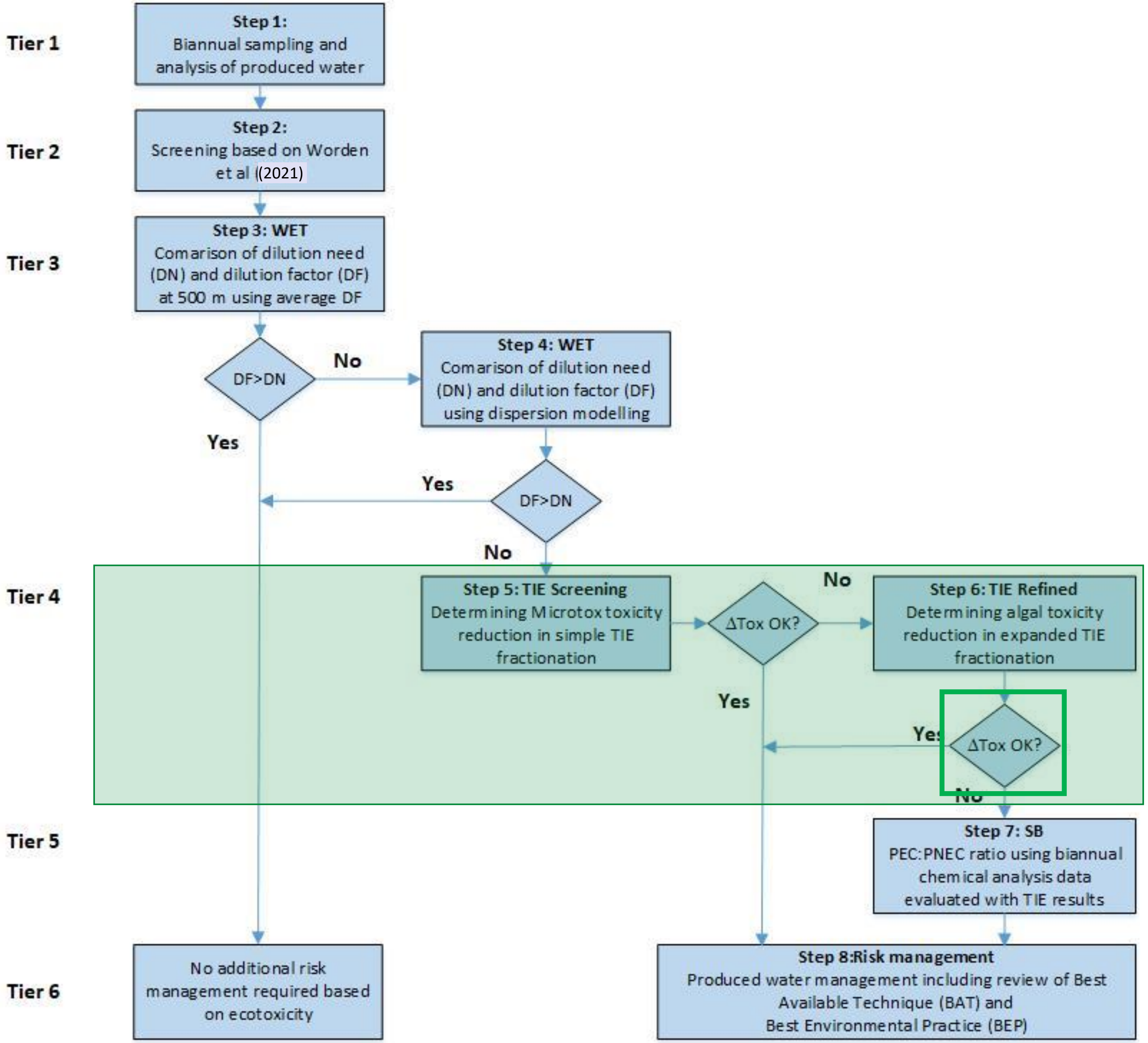


Dilution need
2
3
4
5
?
2
3
4
5
Dilution factor

TIE – using Biotox for screening

	Treatment			
Sample	Basis	Aeration	Filtration	Activated carbon
A	9 [7.8-10.2]	12 [11-13]	14 [10-18]	25 [21-29]
B	4.9 [3.9;5.9]	4.0 [3.9;4.1]	4.2 [4.0;4.4]	7.1 [6.4;7.8]
C	18 [16;20]	22 [20;24]	20 [19;21]	92 [36;147]
D	5.5 [4.6-6.4]	11 [9.1-13]	6.2 [5.3-7.1]	36 [33-39]

All values in the table are Biotox $EC_{50,\ 30\ min}$ in % sample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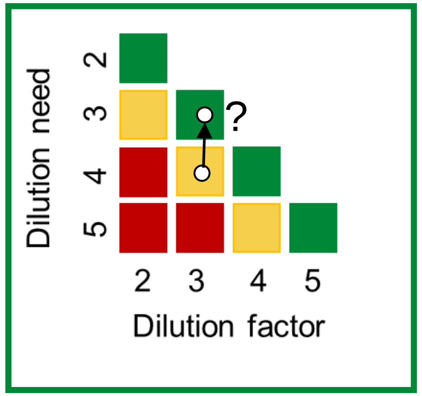
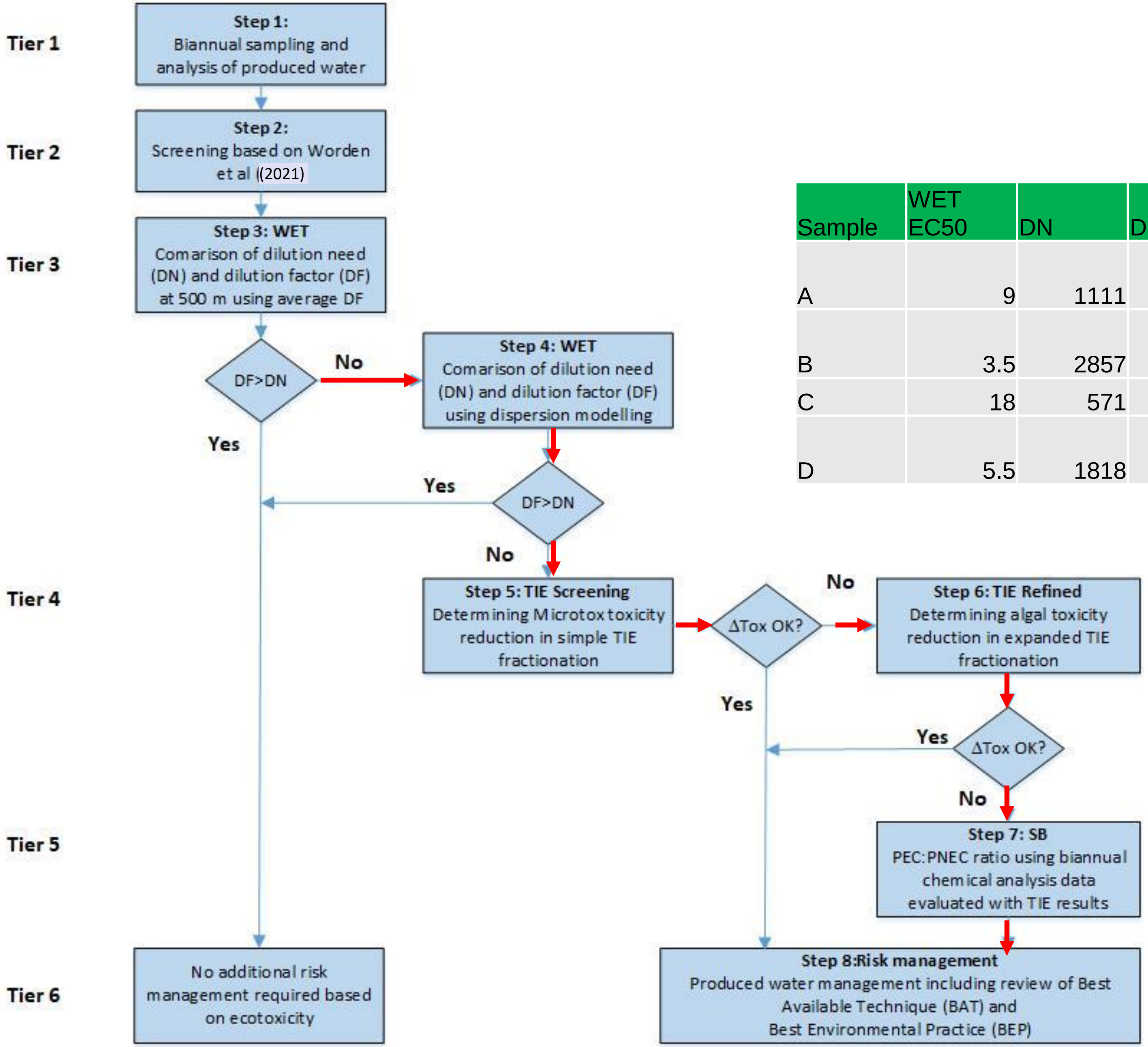
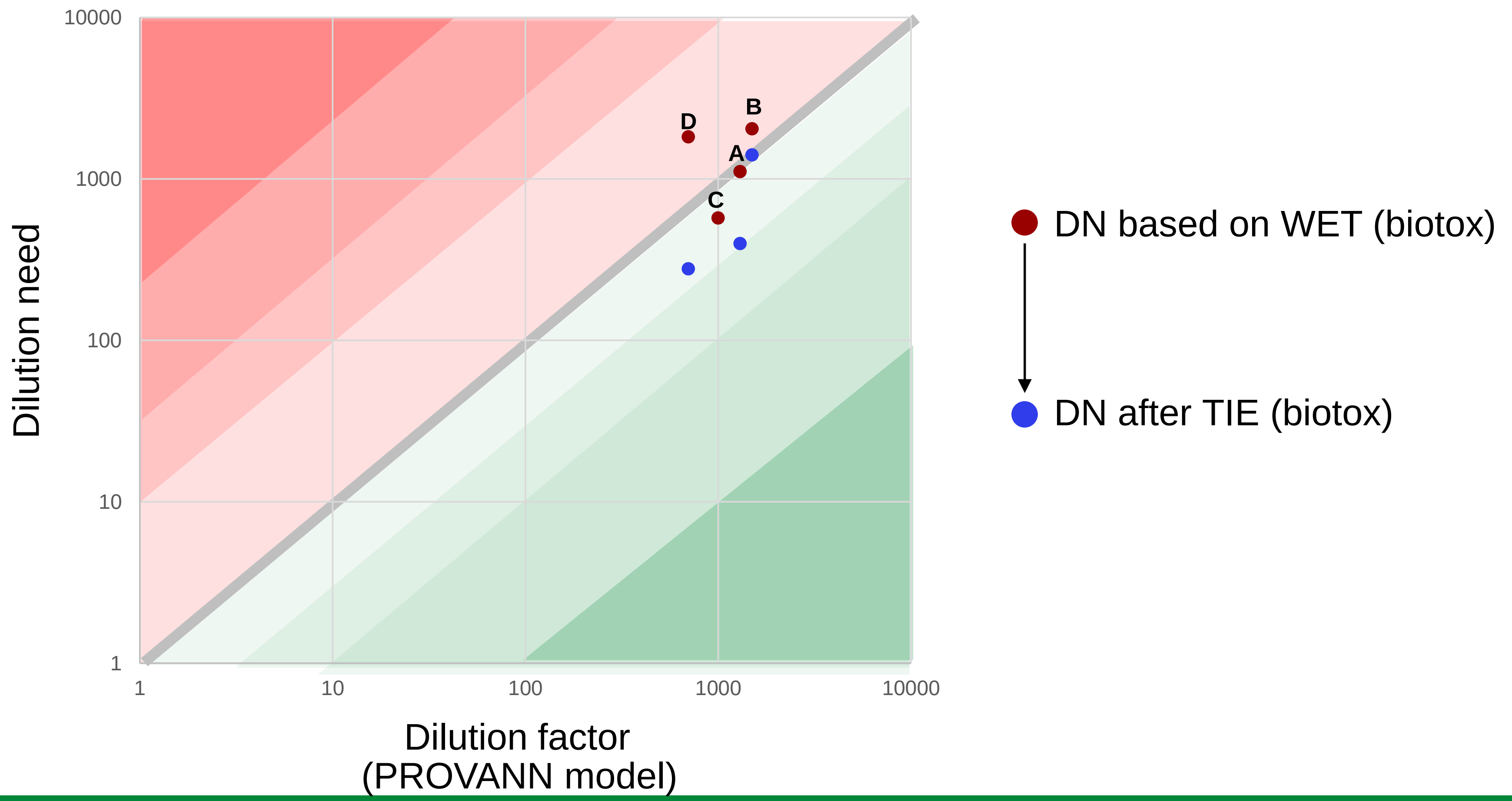

Dilution need
2
3
4
5
?
2
3
4
5
Dilution factor



Sample	WET EC50	DN	DF	DN/DF	TIE EC50	delta Tox	Actions
A	9	1111	400	2.8	25	2.8	Risk reduction possible by AC
B	3.5	2857	400	7.1	7.25	2.1	Reduction not possible - Refine
C	18	571	1000	0.57	91.7	5.2	No risk reduction required
D	5.5	1818	400	4.5	36	6.5	Risk reduction possible by AC



10000
1000
100
10
1
Dilution need
D
B
A
C
1
10
100
1000
10000
Dilution factor
(PROVANN model)
DN based on WET (biotox)
DN after TIE (biotox)

The author kindly acknowledge TotalEnergies E&P Denmark for providing produced water samples from the production sites and the Danish Offshore Technology Centre (DOTC) for providing funding under the Produced Water Management Program.