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Report

Characterization of oil properties and weathering studies on Statfjord crude oils

In relation to oil spill response

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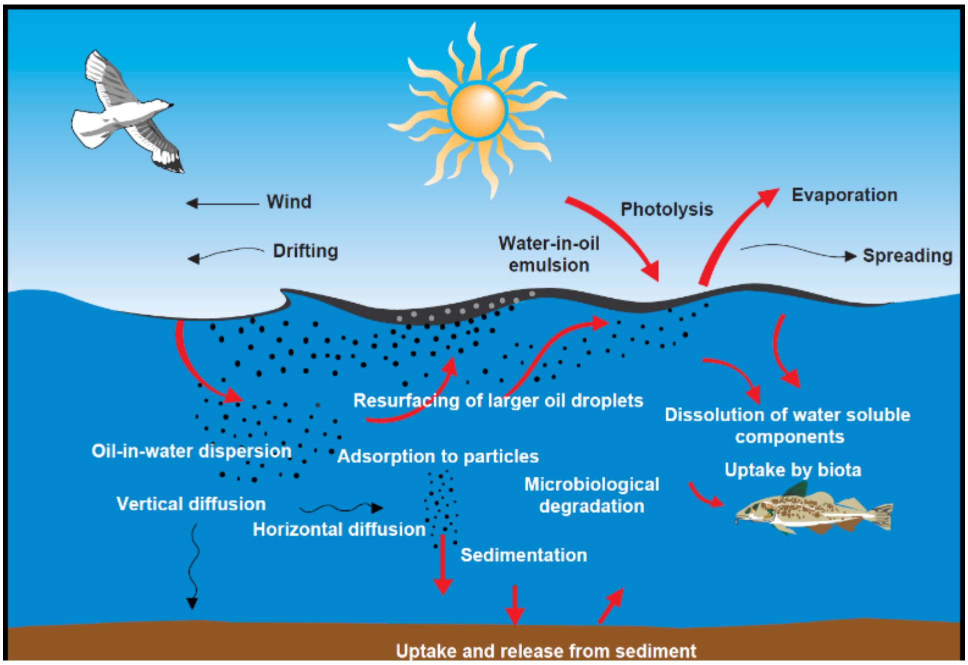

SINTEF Ocean AS

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Report

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ABSTRACT

Phase 1: The basic physio-chemical properties of eight crude oils from the Statfjord oil field have been screened. Based on an overall evaluation of the results, two of the Statfjord crude oils were further selected to extend with a bench-scale weathering study (Phase 2).

Phase2: A standardized weathering study has been conducted on SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) crude oils at 13 °C. Dispersibility testing included the dispersant Dasic Slickgone NS to estimate the viscosity limits and time window for dispersant use. The SINTEF Oil Weathering Model (OWM) was used to predict the weathering properties if the oils are spilled at sea. The weathering properties of the two oils were also discussed in relation to oil spill response.

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1 Executive summary

Spilled oils undergo changes when weathered on the sea surface. These changes affect oil behaviour and consequently oil spill preparedness. Oil weathering varies over time and with different environmental conditions. The lifetime of an oil spill at sea depends on the oil's properties, emulsification, release scenario, and environmental conditions (temperature, wind, waves). Natural dispersion and evaporation are the main weathering processes that remove an oil spill from the sea surface.

Phase 1 – Characterization of physico-chemical properties

In this project a total of eight crude oils from the Statfjord oil field has been characterized for their physico-chemical properties (Phase 1) related to oil weathering of typically crude assay parameters: density, viscosity, pour points, flash points, wax and asphaltenes, true boiling point curve (TBP). In addition to hydrocarbon profile (GC/FID) of the fresh oil and their corresponding residues (150, 200 and 250°C), reflecting approximately 0.5-1-hour, 0.5-1 day and 0.5-1 week of weathering on the sea surface. Previous studies of Statfjord C Blend (2000) and Tyrihans Sør (2003) were selected for comparison of weathering data and oil weathering predictions.

Overall, the Statfjord crude oils are typically paraffinic crude oils and exhibit several similarities, although there are some differences in their physico-chemical properties. For example, a span of the fresh oil properties of the oils with the lowest to the highest values is given below:

- Density: 0.825 g/mL (Barnacle B-29) to 0.849 g/mL (Øst Brent C-33)
- Viscosity (13 °C, 10s^{-1}): 15 mPa.s (Barnacle B-29) to 103 mPa.s (SF Nord Brent E-2&E-3)
- Pour point:-15 °C (SF Cook C-41) to + 6 °C (Munin E-1)
- Wax: 3.3 wt.% (Øst Brent C-33) to 5.3 wt.% (Sygna Brent N-1&N-2)
- Asphaltenes: 0.03 wt.% (Øst Brent) to 0.48 wt.% (Sygna Brent N-1&N-2)
- Evaporation (250°C+ residue): 33 vol. % (Tyrihans Sør) and 39 vol % (Øst Brent C-33) to 50 vol.% (Barnacle B-29)

Results from the initial studies (Phase 1) were used to assess similarities within the Statfjord crude oils and whether model oils from the SINTEF oil data base could be used to predict properties for the tested oils, or whether we had to expand with standardized weathering studies (Phase 2). SINTEF Oil Weathering Model (OWM) "find model oil & crude assay" modules were used as a part of this assessment, that was done in cooperation with Equinor and discussed in designed project meetings. Based on the overall evaluation, SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) were selected to be extended with a standardized bench-scale weathering study at 13°C (Phase 2). SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) were anticipated to represent conservative estimates of weathering properties (e.g. lifetime) and dispersibility limits among of the Statfjord oils, and are also subjected to the oil spill contingency at the Statfjord field.

Phase 2 – Standard characterization of emulsifying properties and dispersibility

Based on an overall evaluation from Phase 1, SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) were further selected to extend with weathering bench-scale studies at 13 °C (Phase 2). The weathering data were further used to predict the oils behaviour on the sea surface under different wind speeds and temperatures using the SINTEF OWM. The weathering studies of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) show the following properties relevant for the behaviour, if spilled at sea from a surface release:

- SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) are paraffinic crude oil with medium densities of 0.845 g/mL and 0.843 g/mL, respective, and volatiles of 43 vol % (250°C+) that cause a moderate degree of evaporative loss: E.g. after 12 hours the evaporative loss is in the range of 20-35 wt. %.
- The combination of wax (4.1 wt.% of SF Nord Brent and 5.3 wt.% Sygna Brent), and relatively high asphaltenes of 0.28 wt.% (SF Nord Brent), and 0.48 wt.% Sygna Brent, and the density, both oils form stable water-in-oil emulsions with high water uptake of 78-79 vol .%

- The properties of the emulsions formed for both oils are expected to be relatively persistent (i.e. high lifetime) on the sea surface. E.g. the OWM predictions indicate a lifetime at 15 m/s wind speed of 2-3 days. In calmer weather conditions the lifetime is predicted to be >5 days.
- As much as 65-68 % (5 and 15 °C) of the oil can still remain on the sea surface in very calm weather conditions (2 m/s wind speed) after 5 days for SF Nord Brent (E-2&E-3) and similar 64-67 % for Sygna Brent (N-1&N-2). Due to the emulsification the overall volumes of the oils may increase with a factor of about 3 times relative to the volume of oil released.
- In winter conditions, the residues of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-3) at sea may form semi-solid lumps/material due to the high pour points of 250°C+residues (+ 27 °C) representing some days weathering at sea. In summer conditions, a remaining residue may solidify but expect to be less pronounced than in winter conditions.

Risk of fire /explosion hazard in oil spill response:

If free gas is not associated with an oil release (e.g. surface release of stabilized oil at 1 atm.), the flash point of the oil is the most important parameter when evaluating the potential for fire /explosion hazard. In such cases when the oil is spilled on the sea surface it assumes to reach the ambient water temperature within a short period. The fire hazard, based on the volatile components from the oil, may be high if the flash point of the oil is below the sea temperature.

For SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2), the flash points are predicted to exceed the sea temperature within the first 15 minutes at wind speeds (5-15 m/s), and within 0.5 hours at lower winds speed (2 m/s) assumed an oil film thickness of 1 mm. However, for larger surface release rates, the time for the flash point to exceed the sea temperature can be extended. Moreover, some storage tanks in vessels engaged in oil recovery operations may not be classified to carry liquids with flash points lower than 60 °C. SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) reach this limit (60 °C) in 3 hours after a spill at calm wind speed (2 m/s) at summer and 6 hours in winter conditions respective, and more rapidly at higher wind speeds. However, this limit is not considered as relevant for oil recovery vessels with A class certification for transport of liquids (Class I/II, flash point < 60 °C).

A "safety" zone should be established early and downwind from the spill site before any response actions in case of an acute oil spill involving free gas. In a response operation, explosimeters should anyway be utilized to measure concentrations of free gas to minimize the risk for fire and explosion hazard at the spill site.

Effect of adding emulsion breaker:

SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) formed stable water-in-oil (w/o) emulsions but easily released water when adding concentrations (500 and 2000 ppm by weight) of the emulsion breaker (Aerosol OT-SE surfactant). The highest concentration (2000 ppm) was shown to be more effective than 500 ppm, particularly on the emulsified 250°C+ residue on both oils (24-26 % vs. 88 % efficiency). Use of emulsion breaker may effectively be used during an oil spill operation to remove or reduce water from the recovered oil/emulsion which minimizes the storage volume. Emulsion breakers are normally injected at the skimmer head prior to transferring the collected oil/water to storage tanks,

Mechanical recovery :

The risk for boom leakage in a mechanical recovery operation is more of a concern for low viscous emulsions (lower than 1000 mPa.s) compared to emulsions that are more viscous. Boom leakage is also influenced by other factors such as operational speed and weather conditions. This study shows that the emulsion viscosities of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) surpassed 1000 mPa.s about 6-9 hours at 5 m/s wind speed (5 and 15 °C), and about 2 hours at 10 m/s wind speed at 5 and 15 °C. Moreover, viscosities larger than 15-20 000 mPa.s are known to reduce the flowability of the oil/emulsion when using traditional weir skimmers. However, both oils have predicted emulsion viscosities lower than this limit within 5 days weathering for wind speeds 2-15 m/s, except from 5 °C and 15 m/s the viscosities may reach > 20 000 mPa.s after 2 days for both oils.

Chemical dispersion:
SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) are expected to have potential for chemical dispersion in both winter and summer conditions.

- SF Nord Brent (E-2&E-3) was found to be good dispersible with the dispersant Dasic Slickgone NS (DOR; dispersant-to-oil ratio 1:25) for viscosities <2500 mPa.s, and not (poor) dispersible >7000 mPa.s.
- Sygna Brent (N-1&N-2) was found to be good dispersible with the dispersant Dasic Slickgone NS (DOR; dispersant-to-oil ratio 1:25) for viscosities <1700 mPa.s, and not (poor) dispersible >8000 mPa.s.

In the field, if the viscosity of the oils indicates reduced dispersibility i.e. 2500-7000 mPa.s for SF Nord Brent (E-2&E-3) and 1700-8000 mPa.s for Sygna Brent (N-1&N-2), respective, additional energy (e.g. thrusters, Fire Fighting (Fi-Fi) systems or MOB (Man overboard boats) or higher DOR and/or repeated dispersant application may increase the dispersant effectiveness.

Solidification of residue at sea:
Increased weathering potentially increases (high) pour points to the point of solidification (i.e. elastic properties) at the sea surface. Solidification typically arises when the pour point of the oil is 5-15 °C above the seawater temperature. In such cases, if solidified (low emulsified /water free) lumps are observed on the sea surface, a lower dispersant effectiveness is likely. SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) have high pour points of their residues, and a remaining residues at sea may therefore have a potential to solidify, particularly in winter conditions.

High-capacity water flushing (mechanical dispersion) using e.g Fi-Fi monitors:
The emulsification is the limiting factor for this strategy. The predicted film thicknesses for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) are >0.2-0.3 mm which is the estimated upper limit for effective use of water flushing. Water flushing is therefore not a main response option for these oils but could be a supplementary method in areas with thin oil films e.g., metallic /rainbow appearance in very calm weather conditions.

In-Situ burning (ISB):
SINTEF OWM Response guide summary shows estimated time-windows for ISB for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2), as requested by Equinor (Appendix F).

Monitoring and remote sensing: Monitoring and remote sensing should always be used a support in a response operations for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2).

2 Introduction

New oil types, from heavy crude oil to light crude oils and condensates, are continuously coming into production worldwide, as well as the Norwegian continental shelf. Due to large variations in different crude oils' physical and chemical properties, their behaviour and fate may vary greatly if spilled at sea. For example, the "Braer" accident at the Shetlands (1993) and the "Sea Empress" accident in Wales (1996) have demonstrated how different the fate and behaviour of the crude oils can be when spilled on the sea surface. For that reason, obtaining comprehensive knowledge about the expected behaviour of spilled oil at sea is of great importance. Moreover, the "Deepwater Horizon" incident in the Gulf of Mexico (2010) clearly showed how the efficacy of the different response techniques changed as the oil weathered and emulsified on the sea surface over a time after the release. These past experiences and other incidents shape the knowledge base and the subsequent refinement of future operative strategies in terms of where, when, and how the mitigation methods should operate during a response operation. Appendix A describes the general physical and chemical properties and weathering processes of oil spilled on the sea surface.

The main objective of this project has been to characterize and map the basic physico-chemical oil properties of a total of eight different crude oils from the Statfjord oil field from production platforms and satellites (Phase I). As stated by Equinor, the Statfjord license needed to perform an evaluation of the different oil types in the field with regards to weathering. Currently, Statfjord has one weathering study performed by SINTEF in 2001, which includes the three oils Statfjord A, B and C blend. There is a need for evaluation of several oils from this complex field. An evaluation of results from Phase I was performed together with Equinor to decide if there was a need to extend the analysis with weathering data to be used as input to the oil spill response contingency plans for the Statfjord field. Based on this evaluation two crude oils from the Statfjord field were further chosen for a standardized small-scale weathering study (Phase II). Moreover, the obtained weathering data of the two crudes oils from Phase II were further used to predict the oil weathering properties using the SINTEF OWM.

An overview of the Statfjord field is given, below (Figure 2-1).

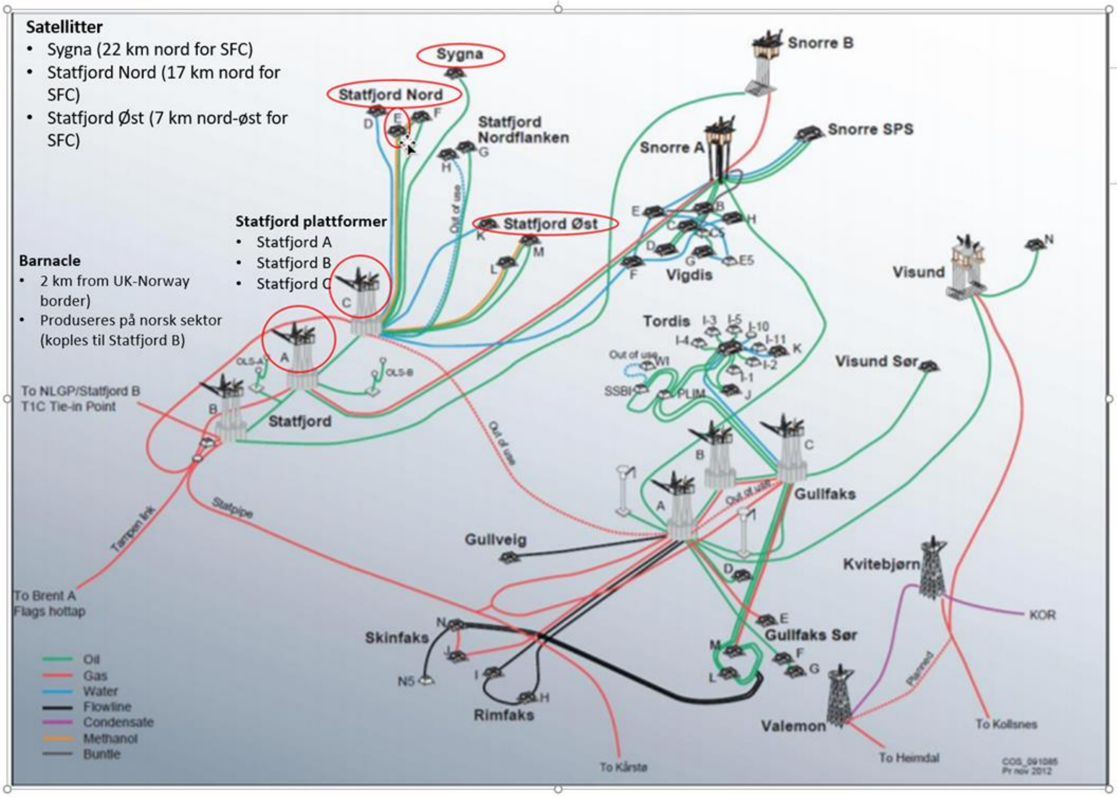


Figure 2-1 Overview of the Statfjord field, a courtesy from Equinor.

3 Crude oil samples from the Statfjord oil field

3.1 Overview of Statfjord crude oil samples

SINTEF Ocean received a total of eight crude oil samples from the Statfjord oil field. The oil samples were registered in LIMS and given unique SINTEF sample identification, as given Table 3-1. Table 3-2 shows an overview and information of the eight oils for testing when arrived SINTEF Ocean in the period of 1 October 2020 to 26 February 2021.

Table 3-1 Statfjord crude oils with respective SINTEF IDs.

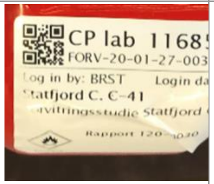
Oil name	Date of arrival	SINTEF-ID
SF Nord Brent (E-2&E-3)	01.10.2020	2020-8430
SF Cook (C-41)	01.10.2020	2020-8431
SF Brent (A-33)	01.10.2020	2020-8432
SF Statfjord (A-18)	01.10.2020	2020-8433
Sygna Brent (N-1&N-2)	14.10.2020	2020-8434
Øst Brent (C-33)	14.10.2020	2020-8435
Barnacle (B-29)	27.11.2020	2020-9872
Munin (E-1)	26.02.2021	2021-977

In this project, Statfjord C Blend (2000) (Moldestad et al., 2001) and Tyrihans Sør (2003) (Leirvik et al., 2004) were selected for comparison of weathering data with the Statfjord crude oils, as in agreement with Equinor.

3.2 Pre-handling of oils and HSE

In general, high-water content >2 vol. % is not beneficial for the topping /distillation step in the SINTEF laboratory due to a HSE (Health, Safety and Environmental) aspect. The oils samples (cans) were therefore checked for free-water and measured for water content in the oil phase by Karl-Fisher titration upon arrival. This step was needed prior to homogenization and analysis of chemical composition and physical properties related to oil weathering. Several oil samples from the Statfjord field contained free-water that was removed from the bottom of the cans to avoid free-water from being incorporated into the whole sample. In addition, some of the crude oil samples also had relatively high content of incorporated water in the oil phase, and it was therefore decided to pre-heat (50 °C) those samples to remove released water prior to homogenization. However, SF Brent (A-33), Barnacle (B-29), and Munin (E-1) had neither free-water nor incorporated water higher than 2 vol. %, and no extra precautions were needed for those crude oils prior to the distillation step.

Table 3-2 *Overview of the Statfjord crude oil samples when arrived at SINTEF Ocean laboratory.*

	SF Nord Brent	SF Cook	SF Brent	SF Statfjord	Sygna Brent	SF Øst Brent	Barnacle	Munin
Description	3 x 20L Jerry cans	3 x20L Jerry cans	2x20L Jerry cans	2x20L Jerry cans	1x20L Jerry can	1x20L Jerry can	2x20L Jerry can	3x20L Jerry cans
Sampling date	27.01.2020	22.12.2019	24.09.2020	23.09.2020	02.10.2020	03.10.2020	18.11.2020	20.02.2021
Sampling time	12:54:00	02:00:00	-	-	18:30:00	14:30:00	17:02:00	13:40:00
Customer Marking	SFC - E2 and E3	SFC C-41	Statfjord A (tatt av Vivian Marheim)	Statfjord A (tatt av Vivian Marheim)	Statfjord C (Tatt på test-SEP, kjemikaliefritt)	Statfjord C (Prøvetatt fra test-SEP, kjemikaliefri olje)	-	SFC E-1
Field/Name	SF Nord Brent (E-2 & E-3)	SF Cook (C-41)	SF Brent (A-33)	SF Statfjord (A-18)	Sygna Brent (N-1 & N-2)	Øst Brent (C-33)	Barnacle (B-29)	Munin (E-1)
Area	North Sea	North Sea	North Sea	North Sea	North Sea	North Sea	North Sea	North Sea
Matrix	Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil
Product type	Crude	Crude	Crude	Crude	Crude	Crude	Crude	Crude
Info								

4 Phase 1 – Characterization of physico-chemical properties

The eight fresh crude oil samples from the Statfjord field were characterized to map the span in physico-chemical properties among these oils. The results and findings from this screening study (Phase 1) are presented in the subchapters, below. The experimental setup is described in Appendix B.

4.1 Gas chromatographic (GC/FID) characterization

The hydrocarbon profiles of the fresh Statfjord crude oils were analysed by use of gas chromatography (GC) coupled with Flame Ionization Detector (FID). Figure 4-1 illustrates the GC-FID outputs (gas chromatograms) of the fresh oils for comparison. The gas chromatograms of the evaporated residues at three different degrees of evaporative loss of volatiles with boiling points 150, 200 and 200°C+ for each oil are given in Appendix D. The loss of low molecular weight (volatiles) compounds (shown towards the left of the chromatograms) at the three temperatures mimics that of natural weathering (evaporative loss at sea) corresponding to approximately 0.5-1-hour, 0.5-1 day and 0.5-1 week of weathering on the sea surface.

The gas chromatograms show the n-alkanes as systematic narrow peaks. The first peaks in the chromatogram represent components with the lowest boiling points. Some of the more complex components, such as resins and naphthenes, are shown as a broad and poorly defined bump below the sharp peaks and are often described as the "Unresolved Complex Mixture" (UCM). Heavier compounds such as asphaltenes (> nC40) are not possible to analyze with this technique.

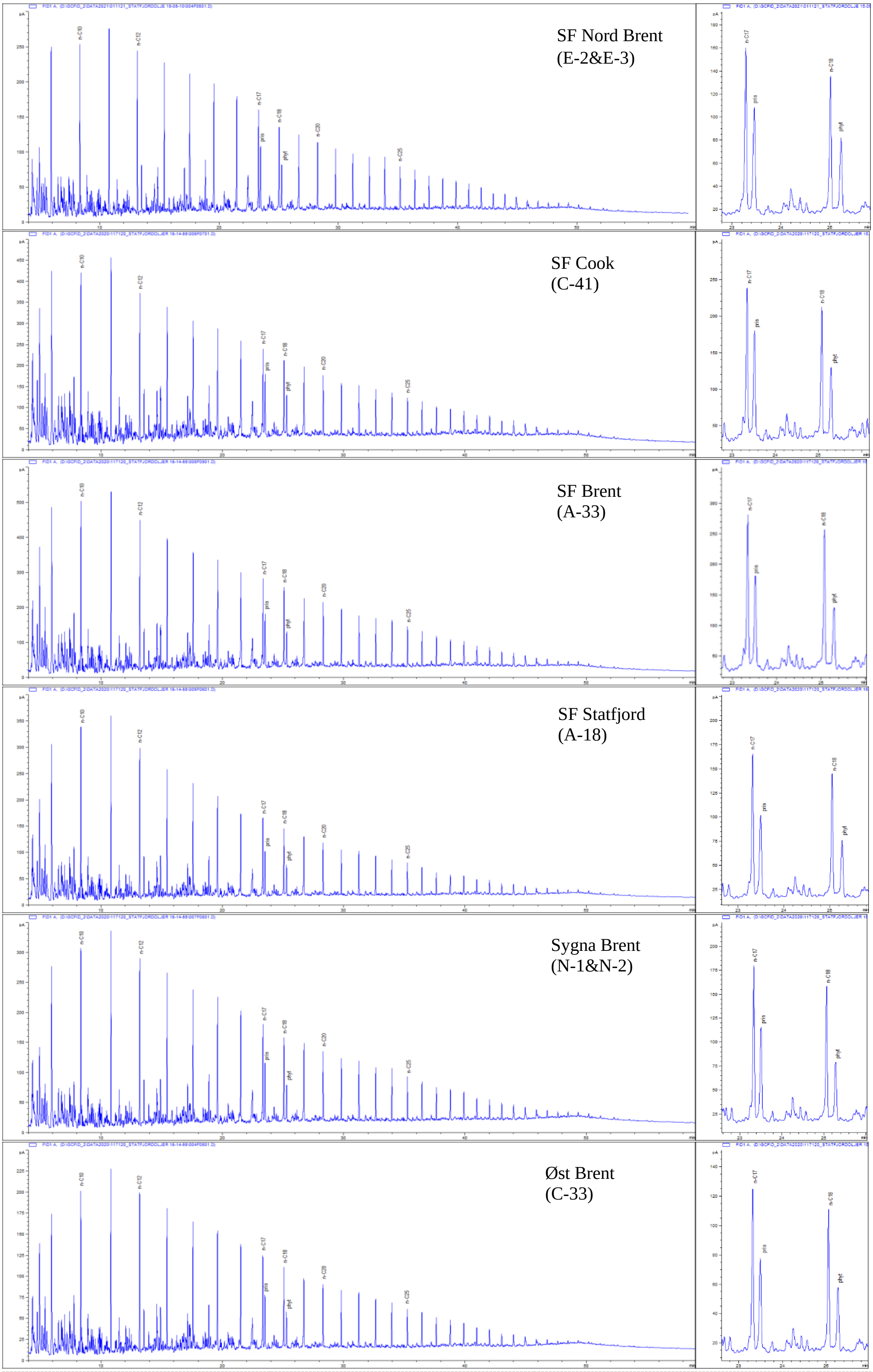
The GC/FIDs show that the eight Statfjord oils are characterized as typically paraffinic crude oils with the main range of n-alkanes from nC5 to nC30. The Statfjord crude oils exhibit great similarities in their hydrocarbon profiles, as shown in Figure 4-1.

Moreover, GC/FID is an important tool for oil characterization and for oil spill identification as an initial step. Common screening parameters used for identification, as well as for the degree of biodegradation, are the nC17/Pristane and nC18/Phytane ratios. Table 4-1 shows the ratios of the Statfjord crude oils. The ratios show small variations among the oils, except from SF Cook (C-41) which has lower ratios than the other Statfjord crude oils. This variation can be explained by a certain degree of biodegradation in the reservoir.

Table 4-1 nC_{17}/Pristane and nC_{18}/Phytane ratios for the Statfjord oils*

Oil name	nC_{17}/Pristane	nC_{18}/Phytane
SF Nord Brent (E-2 & E-3)	1.30	1.57
SF Cook (C-41)	1.18	1.50
SF Brent (A-33)	1.41	1.78
SF Statfjord (A-18)	1.38	1.78
Sygna Brent (N-1&N-2)	1.40	1.86
Øst Brent (C-33)	1.40	1.78
Barnacle (B-29)	1.41	1.82
Munin (E-1)	1.38	1.73

**Ratios > 1 typical for paraffinic oils, ratios < 1 typical for very biodegraded /naphthenic oil.*


SF Nord Brent
(E-2&E-3)
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(C-41)
SF Brent
(A-33)
SF Statfjord
(A-18)
Sygna Brent
(N-1&N-2)
Øst Brent
(C-33)

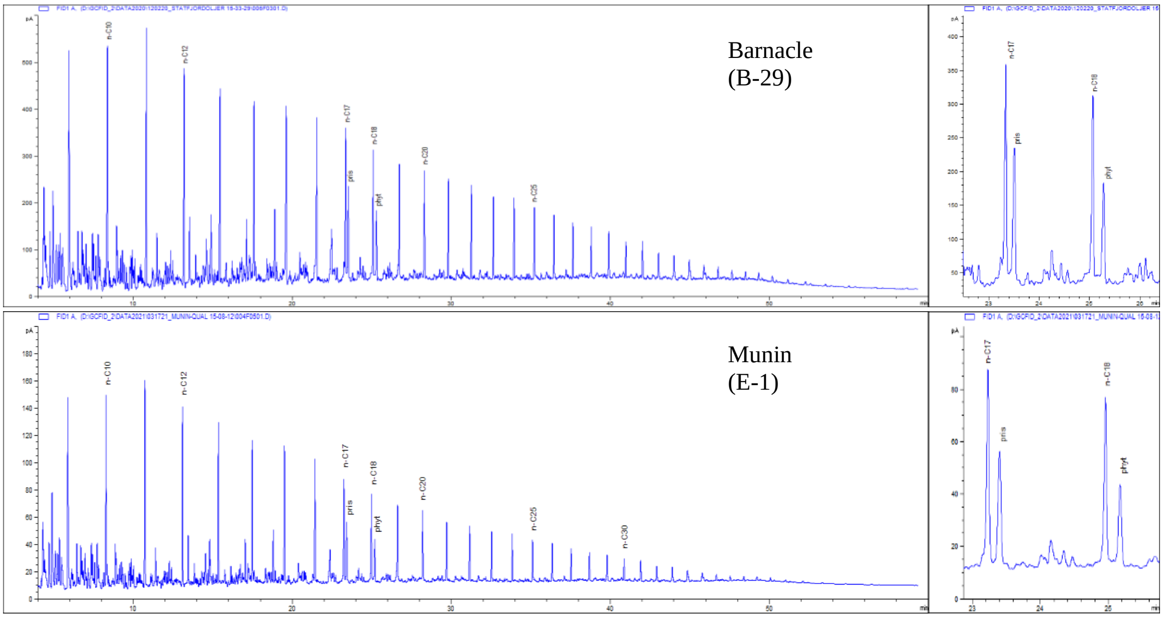

Figure 4-1 GC/FID chromatograms of fresh oil samples from the Statfjord field.

4.2 Asphaltene and wax content

The contents of asphaltene and wax of the eight Statfjord crude oils are given in Table 4-2. In addition, wax and asphaltenes of Statfjord C Blend and Tyrihans Sør (2003) from 2000 and 2003 respective, are given for comparison. The wax contents of the fresh oils are in the range of 3-5.3 wt.%, which are typically medium range compared to other Norwegian crude oils. The asphaltene contents of SF Cook (C-41), SF Brent (A-33), SF Statfjord (A-18), Øst Brent (C-33), Barnacle (B-29), Statfjord C Blend and Tyrihans Sør are low (0.03-0.11 wt.%). Whilst SF Nord Brent (E-2&E-3), Sygna Brent (N-1&N-2), and Munin (E-1) exhibit higher asphaltene contents in the range of 0.28-0.48 wt.%.

Table 4-2 Asphaltene ("hard") and wax content of Statfjord crude oils.

Oil name	Residue	Asph. "hard" (wt. %)	Wax (wt. %)
SF Nord Brent (E-2&E-3)	Fresh	0.28	4.1
	150°C+	0.33	4.9
	200°C+	0.39	5.8
	250°C+	0.45	6.7
SF Cook (C-41)	Fresh	0.07	3.0
	150°C+	0.09	3.8
	200°C+	0.11	4.4
	250°C+	0.12	5.0
SF Brent (A-33)	Fresh	0.04	3.2
	150°C+	0.04	3.9
	200°C+	0.05	4.4
	250°C+	0.06	5.2
SF Statfjord (A-18)	Fresh	0.11	3.4
	150°C+	0.13	4.1
	200°C+	0.16	4.9
	250°C+	0.19	5.7
Sygna Brent (N-1&N-2)	Fresh	0.48	5.3
	150°C+	0.58	6.4
	200°C+	0.65	7.2
	250°C+	0.78	8.6
Øst Brent (C-33)	Fresh	0.03	4.6
	150°C+	0.04	5.4
	200°C+	0.04	6.3
	250°C+	0.05	7.2
Barnacle (B-29)	Fresh	0.04	3.3
	150°C+	0.06	4.2
	200°C+	0.07	5.1
	250°C+	0.08	6.1
Munin (E-1)	Fresh	0.39	4.0
	150°C+	0.47	4.8
	200°C+	0.54	5.6
	250°C+	0.64	6.6
Statfjord C Blend (2000)	Fresh	0.09	4.2
	150°C+	0.1	5.2
	200°C+	0.1	5.9
	250°C+	0.15	6.9
Tyrihans Sør (2003)	Fresh	0.06	3.8
	150°C+	-	-
	200°C+	0.07	4.6
	250°C+	0.08	5.1

4.3 Physical properties of fresh and weathered residues

Physical properties of the eight Statfjord crude oils are listed in Table 4-3, in comparison with previous tested Statfjord C Blend (2000) and Tyrihans Sør (2003).

Table 4-3 Physical properties of Statfjord crude oils in comparison with Statfjord C Blend (2000) and Tyrihans Sør (2003)

Oil name	Residue	Evap. (vol. %)	Residue (wt. %)	Density (g/mL)	Flash point (°C)	Pour point (°C)	Visc. (mPa.s) 5˚C ($10\ s^{-1}$)	Visc. (mPa.s) 13˚C ($10\ s^{-1}$)
SF Nord Brent (E-2&E-3)	Fresh	0	100	0.845	-	3	248	103
	150°C+	19	84	0.875	41	18	742	212
	200°C+	33	71	0.893	94	27	6882	2584
	250°C+	43	61	0.907	127	27	14483	6348
SF Cook (C-41)	Fresh	0	100	0.833	0	-15	33	20
	150°C+	25	79	0.878	42	9	282	83
	200°C+	37	68	0.894	89	18	1748	379
	250°C+	45	60	0.905	121	21	5562	2168
SF Brent (A-33)	Fresh	0	100	0.837	0	-12	50	20
	150°C+	22	81	0.868	42	9	405	114
	200°C+	32	72	0.881	76	12	1118	357
	250°C+	43	61	0.894	114	27	7333	1788
SF Statfjord (A-18)	Fresh	0	100	0.836	0	-6	53	18
	150°C+	20	83	0.865	39	12	444	116
	200°C+	35	69	0.883	85	18	1927	555
	250°C+	45	59	0.897	122	27	9360	2317
Sygna Brent (N-1&N-2)	Fresh	0	100	0.843	0	3	215	45
	150°C+	20	83	0.873	43	21	1809	518
	200°C+	30	74	0.887	79	24	3756	1409
	250°C+	43	62	0.903	123	27	15836	7115
Øst Brent (C-33)	Fresh	0	100	0.849	0	-6	105	29
	150°C+	16	86	0.870	41	9	475	132
	200°C+	29	74	0.885	85	21	2797	598
	250°C+	39	64	0.897	116	24	8723	1587
Barnacle (B-29)	Fresh	0	100	0.825	0	-9	39	15
	150°C+	25	79	0.862	41	12	472	199
	200°C+	39	65	0.879	88	24	2482	1058
	250°C+	50	54	0.894	125	27	8440	2536
Munin (E-1)	Fresh	0	100	0.842	-	6	113	34
	150°C+	20	83	0.871	41	18	333	105
	200°C+	32	72	0.887	82	21	2507	917
	250°C+	43	61	0.903	126	27	9376	3893
Statfjord C Blend (2000)	Fresh	0	100	0.834	-	-3	-	21
	150°C+	20	81	0.870	-	9	-	310
	200°C+	31	71	0.884	-	18	-	1320
	250°C+	40	62	0.896	-	24	-	4179
Tyrihans Sør (2003)	Fresh	0	100	0.848	-	-6	-	20
	150°C+	16	85	0.887	-	10	-	400
	200°C+	28	75	0.890	-	21	-	2270
	250°C+	33	67	0.899	-	21	-	3170

-: No data

Overall, the eight Statfjord crude oils from this study have similarities in their selected physical properties, although with some differences. For example, Barnacle (B-29) has the highest evaporative loss (50 vol. %) of the 250°C+ residue, and the lowest density of 0.825 g/mL, whilst Øst Brent (C-33) has the highest density of 0.849 g/mL with a low evaporative loss of 39 vol.%. SF Cook (C-41), SF Brent (A-33), SF Statfjord (A-18), Øst Brent (C-33), and Barnacle (B-29) have low pour points of the fresh oils in the range of -15 to -6 °C but reach considerable higher pour points with increasing evaporative loss (+21 to +27 °C for the 250°C+residue). The fresh oils have low viscosities at 13 °C in the range of 15-34 mPa.s ($10s^{-1}$), except from SF Nord Brent (E-2&E-3) that has a higher viscosity of 103 mPa.s. The viscosities increase with evaporative loss, where SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) exhibits the highest viscosities of 6348 and 7115 mPa.s ($10s^{-1}$), respective for the 250°C+ residue. Similar, the same trends for viscosities were also found at 5 °C.

Moreover, the previous tested Statfjord C Blend and Tyrihans Sør have similarities with the Statfjord crude oils from this study. The physico-chemical properties of Statfjord C Blend are within the range of the Statfjord crude oils, whilst Tyrihans Sør exhibits the lowest evaporative loss of 33 vol. % (250°C+) among these oils, and has a density of 0.848 g/mL, which is very similar with Øst Brent (C-33) (0.849 g/mL).

The True Boiling Point curves (TBP) of the eight Statfjord crude oils are shown Figure 4-2 including Statfjord C Blend and Tyrihans Sør for comparison. The TBPs correspond to the evaporative losses of the crude oils as shown in Table 4-3.

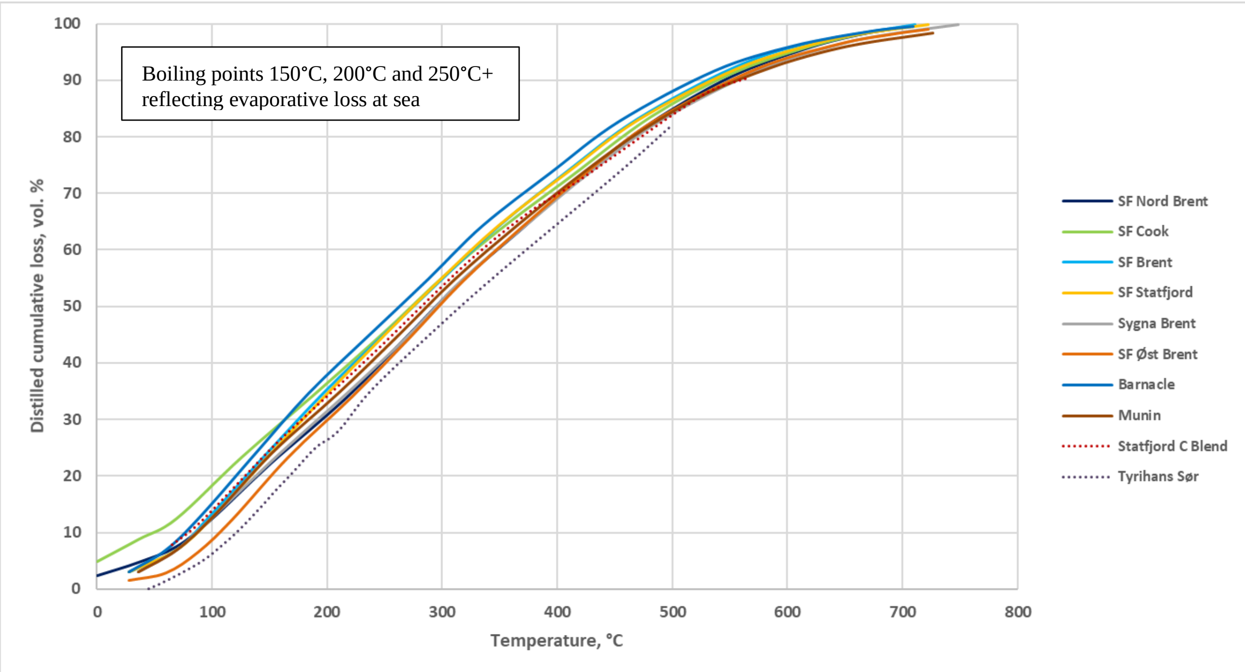

Figure 4-2 True boiling point (TBP) curves of the eight Statfjord crude oils including Statfjord C Blend (2000) and Tyrihans Sør (2003) for comparison.

4.4 Viscosity of fresh oil and water-free residues with different shear rates

The viscosity describes the oils' ability to resist gradual deformation by increasing shear, where viscosities of so-called *Newtonian* oils remain constant independent on the applied shear rate (s-1) at a given temperature. The opposite when shear is applied on so-called *non-Newtonian* oils the viscosity of such oils decreases. The dynamic viscosities (mPa.s) of the eight Statfjord fresh oils and their corresponding water-free residues are given in Table 4-4 with increasing shear rates (10 and 100 s^{-1}) at 5 and 13 °C. I addition, the previous tested Statfjord C Blend and Tyrihans Sør are included for comparison at 13°C. The fresh oils and the residues 150, 200 and 250°C+ (Table 4-4) clearly exhibit *non-Newtonian* behaviour at 5 and 13 °C, i.e., viscosities depending on the shear rates.

Table 4-4 Viscosities of fresh oils and water-free residues of the eight Statfjord crude oils (5 and 13 °C) Statfjord C Blend (2000) and Tyrihans Sør (2003) are included for comparison.

Oil name	**Residue**	**Visc. (mPa.s) 5°C ($10\ s^{-1}$)**	**Visc. (mPa.s) 5°C ($100\ s^{-1}$)**	**Visc. (mPa.s) 13°C ($10\ s^{-1}$)**	**Visc. (mPa.s) 13°C ($100\ s^{-1}$)**
SF Nord Brent (E-2&E-3)	Fresh	248	94	103	50
	150°C+	742	298	212	114
	200°C+	6882	1221	2584	568
	250°C+	14483	2644	6348	1290
SF Cook (C-41)	Fresh	33	24	20	16
	150°C+	282	165	83	60
	200°C+	1748	683	379	224
	250°C+	5562	1660	2168	817
SF Brent (A-33)	Fresh	50	30	20	15
	150°C+	405	155	114	66
	200°C+	1118	405	357	173
	250°C+	7333	1611	1788	616
SF Statfjord (A-18)	Fresh	53	32	18	13
	150°C+	444	175	116	68
	200°C+	1927	650	555	246
	250°C+	9360	1988	2317	787
Sygna Brent (N-1&N-2)	Fresh	215	90	45	31
	150°C+	1809	426	518	184
	200°C+	3756	885	1409	434
	250°C+	15836	2620	7115	1172
Øst Brent (C-33)	Fresh	105	58	29	22
	150°C+	475	188	132	70
	200°C+	2797	713	598	241
	250°C+	8723	1763	1587	622
Barnacle (B-29)	Fresh	39	23	15	11
	150°C+	472	145	199	79
	200°C+	2482	631	1058	320
	250°C+	8440	1481	2536	682
Munin (E-1)	Fresh	113	46	34	23
	150°C+	333	139	105	60
	200°C+	2507	551	917	259
	250°C+	9376	1581	3893	679
Statfjord C Blend (2000)	Fresh	-	-	21	11
	150°C+	-	-	310	123
	200°C+	-	-	1320	309
	250°C+	-	-	4179	636
Tyrihans Sør (2003)	Fresh	-	-	20	12
	150°C+	-	-	400	-
	200°C+	-	-	2270	452
	250°C+	-	-	3170	646

-: No data

5 Phase 2 – Standard characterization of emulsifying properties and dispersibility

SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) were selected in agreement with Equinor to extend the basic characterization from Phase 1 with weathering data that include emulsifying properties and dispersibility testing (Phase 2). The extended studies were conducted at 13 °C for both oils.

5.1 Emulsifying properties

In general, emulsification is the mixing of seawater droplets into spilled oil at the water's surface (water-in-oil emulsion), forming a weathered oil residue that often tends to be relatively resistant to other weathering processes such as evaporation, and increases the total volume of oil due to the uptake of water into the oil. The rotating cylinders method (Mackay and Zagroski, 1982) was used to study the emulsifying properties, and the procedure for maximum water uptake is described in Hokstad et al., 1993 (Appendix B).

5.1.1 Emulsification

Emulsification testing of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) were conducted on the residues of 150°C+, 200°C+ and 250°C+ to produce data for stability, viscosity, maximum water uptake, kinetics, and the effectiveness of the emulsion breaker application. Emulsions of maximum water content after 24 hours rotation of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) are shown in Figure 5-1 and Figure 5-2, respective.

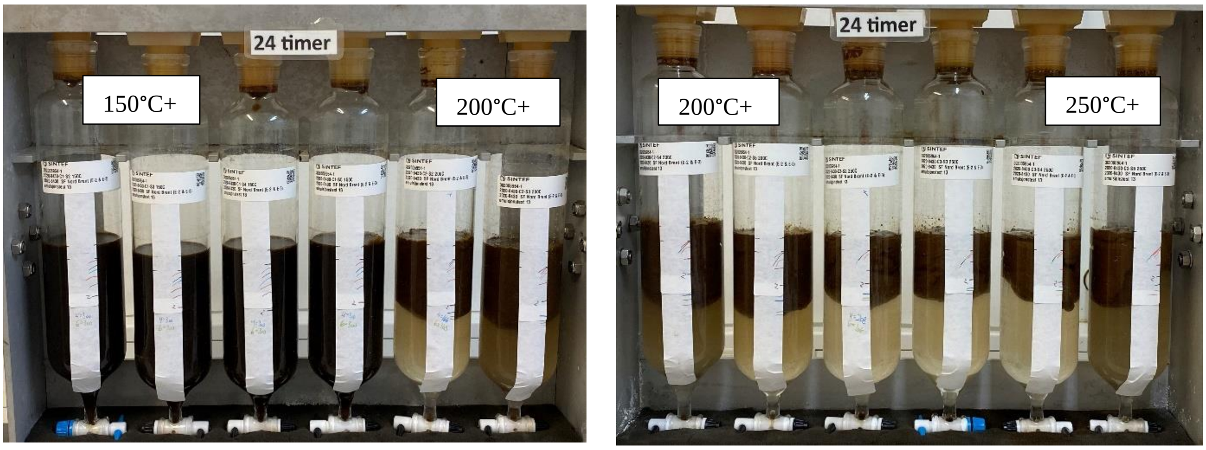

Figure 5-1 Rotating cylinders of water-in-oil (w/o) emulsions of SF Nord Brent (E-2&E-3) after 24 hours at 13 °C. The figures show from left to right emulsions prepared from the residues of 150°C+, 200°C+ and 250°C+.

Figure 5-2 Rotating cylinders of water-in-oil (w/o) emulsions of Sygna Brent (E-2&E-3) after 24 hours at 13 °C. The figures show from left to right emulsions prepared from the residues of 150°C+, 200°C+ and 250°C+.

5.1.2 Water uptake

The rate (kinetics) of water content in the water-in-oil (w/o) emulsions as a function of time is tabulated in Table 5-1 and Table 5-2 for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2), respective. The $T_{1/2}$ values are defined as the time (hours) it takes to incorporate half of the maximum water uptake (vol. %) in 24 hours (rotating time).

SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) expressed high-water uptakes for all the residues 150°C+, 200°C+ and 250°C+, which ranged from 75 to 91 vol. % (see Table 5-1 and Table 5-2).

Table 5-1 Water uptake for the evaporated residues of SF Nord Brent (E-2&E-3) at 13 °C.

Mixing time	**150°C +* (Vol. % water)**	**200°C + * (Vol. % water)**	**250°C +* (Vol. % water)**
Start	0	0	0
5 min	14	0	0
10 min	36	8	0
15 min	46	13	0
30 min	59	35	19
1 hour	67	57	56
2 hours	76	73	69
4 hours	91**	82	75
6 hours	91**	82	76
24 hours	91**	82	76
$T_{1/2}$	0.33	0.67	0.79

** Depending on weather situation and release rate, the residues are corresponding to approximately 0.5-1-hour, 0.5-1 day and 0.5-1 week of weathering on the sea surface.*
*** Supersaturation not likely to happen in a spill situation*

Table 5-2 Water uptake for the evaporated residues of Sygna Brent (N-1&N-2) at 13 °C.

Mixing time	**150°C +* (Vol. % water)**	**200°C +* (Vol. % water)**	**250°C +* (Vol. % water)**
Start	0	0	0
5 min	21	11	9
10 min	33	13	9
15 min	38	20	9
30 min	49	36	29
1 hour	59	50	59
2 hours	66	66	71
4 hours	71	81	74
6 hours	72	84	75
24 hours	91**	84	75
$T_{1/2}$	0.49	0.73	0.62

** Depending on weather situation and release rate, the residues are corresponding to approximately 0.5-1-hour, 0.5-1 day and 0.5-1 week of weathering on the sea surface.*
*** Supersaturation not likely to happen in a spill situation.*

5.1.3 Efficiency of emulsion breaker and stability of emulsions

In mechanical recovery operations, separating oil from water enables optimal use of available storage (i.e. facilities/tankers), and the efficiency of this separation can be enhanced by applying emulsion breakers. The effectiveness of the emulsion breaker Aerosol OT-SE surfactant was evaluated on different residues of emulsified SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2). The choice of emulsion breaker was selected in agreement with Equinor. The results show that the emulsified oil volume decreased significantly after treatment with the emulsion breaker in all residues for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2), as water was released from the emulsion, see Table 5-3 and Table 5-4, respective. The emulsions were almost totally broken when adding the emulsion breaker (Aerosol OT-SE). Adding 2000 ppm of the emulsion breaker, relative to the oil was shown to be slightly more efficient to break the emulsion compared with a lower concentration of 500 ppm.

The emulsion stability was studied by quantifying the amount of volume fraction of water released from the emulsion after 24 hours settling time. SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) formed stable w/o-emulsions of the 150, 200 and 250°C+ residues, as shown in the first main row of Table 5-3 and Table 5-4.

Table 5-3 Stability of emulsion and the effectiveness of emulsion breaker at 13 °C of SF Nord Brent (E-2&E-3).

Residue	Emulsion breaker	Water-in-oil emulsion (vol. %) Nord Brent, 13 °C			
		Reference	24 hours *	Stability ratio**	% Effect. (Released water)
150°C+	none	91	91	0.98	2
200°C+	none	82	81	0.98	2
250°C+	none	76	76	0.99	1
150°C+	OT-SE 500 ppm	91	32	0.05	95
200°C+	OT-SE 500 ppm	82	52	0.24	76
250°C+	OT-SE 500 ppm	76	69	0.72	26
150°C+	OT-SE 2000 ppm	91	0	0.00	100
200°C+	OT-SE 2000 ppm	82	14	0.04	96
250°C+	OT-SE 2000 ppm	76	27	0.12	88

ppm: parts per million
**: w/o emulsion after 24 hours rotation and 24 hours settling*
*** Stability ratio of 0 implies a totally unstable emulsion after 24 hours settling; all the water is settled out during 24 hours settling. Stability ratio of 1 implies a totally stable emulsion*

Table 5-4 Stability of emulsion and the effectiveness of emulsion breaker at 13 °C of Sygna Brent (N-1&N-2).

Residue	Emulsion breaker	Water-in-oil emulsion (vol. %) Sygna Brent at 13 °C			
		Reference	24 hours *	Stability ratio**	% Effect. (Released water)
150ºC+	none	91	91	0.95	5
200ºC+	none	85	85	1.00	0
250ºC+	none	75	75	1.00	0
150ºC+	OT-SE 500 ppm	91	29	0.04	96
200ºC+	OT-SE 500 ppm	85	44	0.15	85
250ºC+	OT-SE 500 ppm	75	70	0.76	24
150ºC+	OT-SE 2000 ppm	91	12	0.01	99
200ºC+	OT-SE 2000 ppm	85	17	0.04	96
250ºC+	OT-SE 2000 ppm	75	27	0.12	88

ppm: parts per million
**: w/o emulsion after 24 hours rotation and 24 hours settling*
*** Stability ratio of 0 implies a totally unstable emulsion after 24 hours settling; all the water is settled out for 24 hours settling. Stability ratio of 1 implies a totally stable emulsion*

5.1.4 Emulsion viscosities

The viscosities of emulsified residues of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) are given in Table 5-5 and Table 5-6, respective (including waterfree residues, Table 4-4). The emulsions behave as *non-Newtonian* fluids due to the increasing degree of weathering (evaporation and water uptake), with higher viscosities at a lower shear rate (10 s^{-1}) compared to the viscosities measured at higher shear rate (100 s^{-1}).

Table 5-5 Viscosity of water-free residues and emulsions of SF Nord Brent (E-2&E-3) at 13 °C.

Residue	Water content (vol. %)	Viscosity (mPa.s) 13 °C	
		10 s^{-1}	100 s^{-1}
Fresh	0	103	50
150°C+	0	212	114
200°C+	0	2584	568
250°C+	0	6348	1290
150°C+	50	580	306
200°C+	50	1922	664
250°C+	50	6386	1500
150°C+	75	1892	604
200°C+	75	5300	1548
250°C+	75	-	-
150°C+	91	1849	336
200°C+	82	7391	1718
250°C+	75	15766	829

-:No data

Table 5-6 Viscosity of water-free residues and emulsions of Sygna Brent (N-1&N-2) at 13 °C.

Residue	Water content (vol. %)	Viscosity (mPa.s) 13 °C	
		10 s^{-1}	100 s^{-1}
Fresh	0	45	31
150°C+	0	518	184
200°C+	0	1409	434
250°C+	0	7115	1172
150°C+	50	679	315
200°C+	50	1442	641
250°C+	50	6006	1412
150°C+	75	1430	464
200°C+	75	3993	1194
250°C+	75	-	-
150°C+	91	1568	274
200°C+	85	4973	1099
250°C+	76	15516	896

-:No data

5.2 Chemical dispersibility

The dispersibility testing on SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) was performed on emulsions containing different volume per cent of water, as listed in tables below. The dispersibility testing included systematic dispersant study with Dasic NS at 1:25 dosage rate (DOR - Dispersant to Oil Ratio/DER-Dispersant to Emulsion Ratio), to estimate the time window for effective dispersant use on SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) in a spill scenario. A dosage ratio of 1:25 (4 wt.%) is commonly used as the standard procedure to establish the time window for dispersant application. Dasic Slickgone NS is also the main dispersant agent in NOFO's stockpile, today. The dispersibility limits (viscosities) are further used as input to the SINTEF Oil Weathering Model (OWM) to predict the time-window for dispersant use.

5.2.1 SF Nord Brent (E-2&E-3)

Table 5-7 shows the results from the systematic dispersant testing at 13 °C for SF Nord Brent (E-2&E-3). The estimated dispersibility limits (viscosities) expressed as a function of % effectiveness is shown in Figure 5-3.

Table 5-7 Effectiveness Dasic Slickgone NS on emulsions of SF Nord Brent (E-2&E-3) at 13 °C.

Residue	Water content (vol. %)	Viscosity (mPa.s) 10 s^{-1}	Efficiency (%) IFP	Efficiency (%) MNS
150°C+	50	580	65	100
200°C+	50	1922	7	100
250°C+	50	6386	2	26
150°C+	75	1892	72	100
200°C+	75	5300	4	38
250°C+	75	-	-	-
150°C+	91	1849	46	100
200°C+	92	7391	5	0
250°C+	75	15766	0	0

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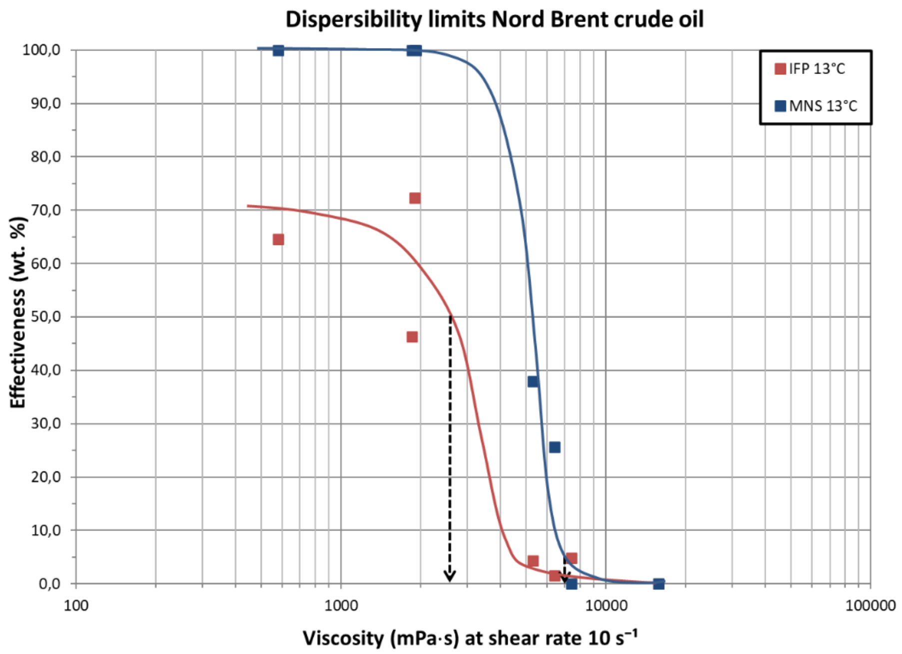

Figure 5-3 Window of opportunity for dispersion of SF Nord Brent (E-2&E-3) emulsions.

SF Nord Brent (E-2&E-3) was found to be dispersible for viscosities lower than 2500 mPa.s, reflecting >50 % effectiveness by use of the low energy IFP-test. The upper limit for then SF Nord Brent (E-2&E-3) is not or poor chemically dispersible was estimated to 7000 mPa.s expressed with effectiveness lower than 5 % using the high energy MNS-test. Reduced dispersibility is expected with viscosities between 2500 and 7000 mPa.s and means that the oil is still dispersible but may require additional energy and/or higher dispersant dosage to enhance effective dispersion. The dispersibility limits for SF Nord Brent (E-2&E-3) are also summarised in Table 5-8.

Table 5-8 Estimated viscosity limits for SF Nord Brent (E-2&E-3) and the criteria for definition of time window for dispersant use.

Dispersibility	Criteria for effectiveness (wt. %)	Dispersibility limits* based on oil viscosities (mPa.s)
Chemically dispersible	IFP efficiency > 50 %	2500
Not/poor chemically dispersible	MNS efficiency < 5 %	7000

** Estimated limits are based on the dispersibility data from both the low energy IFP-test and the high energy MNS-test.*

5.2.2 Sygna Brent (N-1&N-2)

Table 5-8 shows the results from the systematic dispersant testing at 13 °C for Sygna Brent (N-1&N-2). The estimated dispersibility limits (viscosities) expressed as a function of % effectiveness is shown in Figure 5-4.

Table 5-9 Effectiveness Dasic Slickgone NS on emulsions of SF Nord Brent (E-2&E-3) at 13 °C.

Residue	Water content (vol. %)	Viscosity (mPa·s) 10 s^{-1}	Efficiency (%) IFP	Efficiency (%) MNS
150°C+	50	679	46	100
200°C+	50	1442	20	98
250°C+	50	6006	3	100
150°C+	75	1430	67	100
200°C+	75	3993	12	27
250°C+	75	-	-	-
150°C+	91	1568	61	100
200°C+	85	4973	11	33
250°C+	76	15516	3	-

-: No data

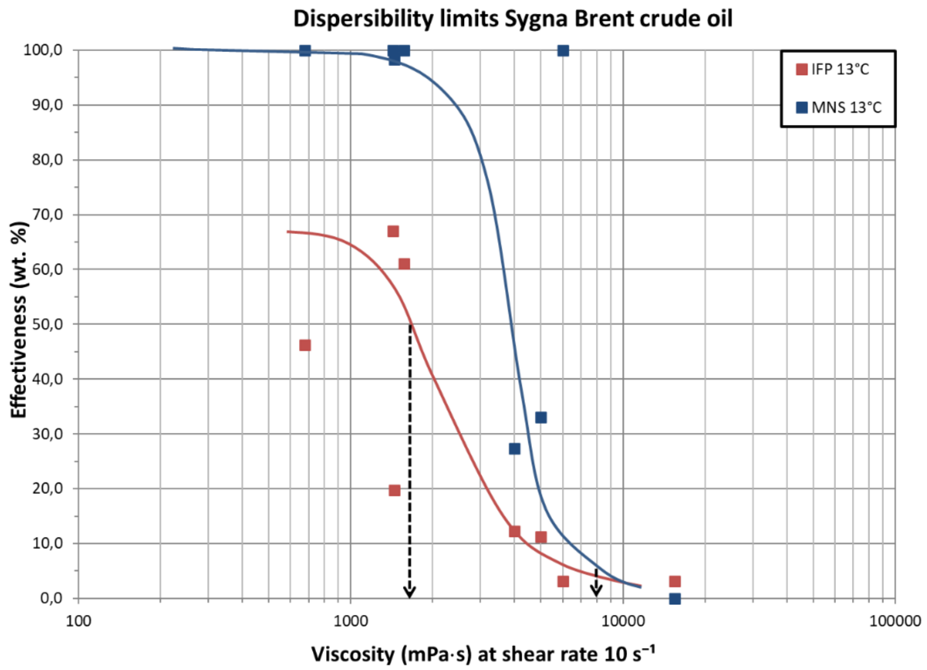

Figure 5-4 Window of opportunity for dispersion of Sygna Brent (N-1&N-2) emulsions.

Sygna Brent (N-1&N-2) was found to be dispersible for viscosities lower than 1700 mPa.s, reflecting > 50 % effectiveness by use of the low energy IFP-test. The upper limit for then Sygna Brent (N-1&N-2) is not or poor chemically dispersible was estimated to 8000 mPa.s expressed with effectiveness lower than 5 % using the high energy MNS-test. Reduced dispersibility is expected with viscosities between 1700 and 8000 mPa.s and means that the oil is still dispersible but may require additional energy and/or higher dispersant dosage to enhance effective dispersion. The dispersibility limits for Sygna Brent (N-1&N-2) are also summarised in Table 5-10.

Table 5-10 Estimated viscosity limits for Sygna Brent (N-1&N-2) and the criteria for definition of time window for dispersant use.

Dispersibility	**Criteria for effectiveness (wt. %)**	**Dispersibility limits* based on oil viscosities (mPa.s)**
Chemically dispersible	IFP efficiency > 50 %	1700
Not/poor chemically dispersible	MNS efficiency < 5 %	8000

* *Estimated limits are based on the dispersibility data from both the low energy IFP-test and the high energy MNS-test.*

6 Predictions with SINTEF Oil Weathering Model (OWM)

6.1 Description of SINTEF OWM

A systematic stepwise laboratory procedure developed at SINTEF (Daling et al., 1990) was used to isolate and map the various weathering processes that take place when oil is spilled on the sea surface. Bench-scale weathering studies of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) were conducted at 13 °C (Phase 2), and the analytical data were further used as input to the SINTEF Oil Weathering Model (OWM) for predictions of oil weathering properties at sea. In addition, predictions of Statfjord C Blend with updated viscosity input data with shear rate $100s^{-1}$ of the water-free residues are also given in the subchapter below. The experimental design for the study is described in Appendix B, and the input data to SINTEF OWM are given in Appendix C.

The SINTEF OWM relates oil properties to a chosen set of conditions (oil/emulsion film thickness, wind speeds and sea temperature) and predicts the change rate of the oil's properties on the sea surface with time. The SINTEF OWM is schematically shown in Figure 6-1. The predictions obtained from the SINTEF OWM are useful tools in the oil spill contingency planning related to the expected behaviour of oil on the sea surface, and to evaluate the time window for operational response strategies in a spill operation. In this report, the presented predictions span a period from 15 minutes to 5 days after an oil spill has occurred. The SINTEF OWM is described in more detail in Johansen (1991), and in the user's guide for the model.

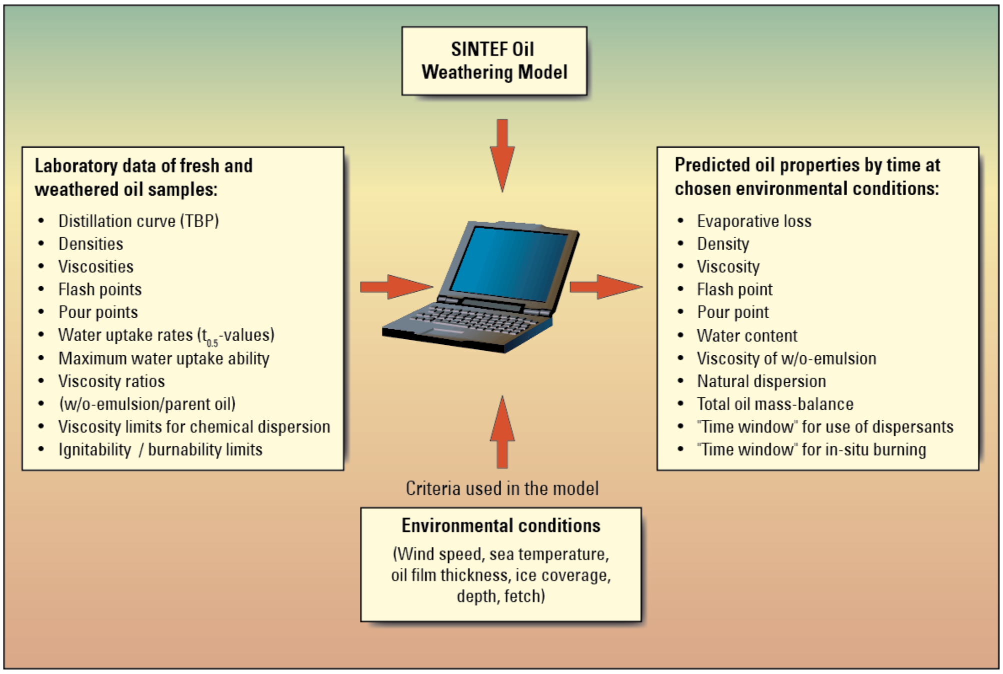

Figure 6-1 Schematic input data to the SINTEF OWM and the predicted output oil properties.

Oil film thickness

Oils in OWM are categorized as condensate (non-emulsifying oil), low emulsifying oil/condensate, emulsifying oil, heavy bunker fuel or refined distillate. The categorization is based on the experimental results obtained in the laboratory. The terminal film thicknesses vary among these categories based on experimental (field) experience. SF Nord Brent (E-2&E-3), Sygna Brent (N-1&N-2) are categorized as an emulsifying crude oils.

Seawater temperature

The prevailing weather conditions influence the weathering rate of oil on the sea surface. Due to the location of the oil field, the seawater temperatures chosen for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) were 5 and 15 °C, reflecting typically winter and summer conditions in the North Sea.

Wind speed

The relationship between the wind speed and significant wave heights used in the prediction charts obtained from the SINTEF OWM are shown in Table 6-1.

Table 6-1 Relationship between wind speed and significant wave height used in the SINTEF OWM

Wind speed [m/s]	Beaufort wind	Wind type	Wave height [m]
2	2	Light breeze	0.1 - 0.3
5	3	Gentle to moderate breeze	0.5 - 0.8
10	5	Fresh breeze	1.5 - 2.5
15	6 – 7	Strong breeze	3 - 4

6.2 Prediction of weathering properties

A standard surface release was used as a spill scenario. The scenario chosen is not oil field specific but selected to give predictions of the expected weathering properties of the oil based on the experimental data and specified terminal oil film thickness. A standardized scenario will also more easily compare results of weathering properties with other oils.

Input to the OWM

Oil type:	Crude oils
Geographical area:	Norwegian Sea
Terminal oil film thickness:	mm
Release rate:	1.33 metric tonnes/minute for 15 minutes; a total of 20 metric tonnes
Sea temperature:	5 °C and 15 °C
Wind speed:	2 m/s, 5 m/s, 10 m/s and 15 m/s

Predicted properties

- Evaporative loss
- Viscosity
- Flash point
- Pour point
- Mass balance

The predictions are based on 5 days weathering independently if there is not predicted any remining oil within shorter time. The predictions are shown to indicate the weathering properties in cases there are patches or oil left on the surface up to 5 days.

How to use the prediction charts: an example

If the oil has drifted on the sea surface, the following prediction charts could be used to determine the weathering properties of the oil/emulsion. Table 6-2 and Table 6-3 give an example of predicted weathering properties for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2), respective. Whilst Table 6-4 gives examples of predicted weathering data of Statfjord C Blend.

Table 6-2 Example of weathering properties for SF Nord Brent (E-2&E-3) obtained from the prediction charts after 12 hours of weathering at 2, 5, 10 and 15 m/s wind speed at 15 °C.

Weathering properties SF Nord Brent (E-2&E-3)	**12 hours 15 ˚C 2 m/s**	**12 hours 15 ˚C 5 m/s**	**12 hours 15 ˚C 10 m/s**	**12 hours 15 ˚C 15 m/s**
Evaporation, wt. %	26	29	34	36
Flash point, °C	78	92	107	118
Pour Point, °C	22	24	27	29
Water content, vol.%	13	40	72	78
Viscosity, mPa.s *	530	1700	6650	9850
Mass balance / Oil on surface wt.%	74	69	48	15

mPa·s = cP (mPa·s: SI-standard/cP: Industrial denotation)

Table 6-3 Example of weathering properties for Sygna Brent (N-1&N-2) obtained from the prediction charts after 12 hours of weathering at 2, 5,10 and 15 m/s wind speed at 15 °C.

Weathering properties Sygna Brent (N-1&N-2)	**12 hours 15 ˚C 2 m/s**	**12 hours 15 ˚C 5 m/s**	**12 hours 15 ˚C 10 m/s**	**12 hours 15 ˚C 15 m/s**
Evaporation, wt. %	27	31	35	37
Flash point, °C	79	93	108	118
Pour Point, °C	23	25	28	29
Water content, vol.%	12	39	72	78
Viscosity, mPa.s *	580	1780	6130	8930
Mass balance / Oil on surface wt.%	73	68	47	14

**mPa·s = cP (mPa·s: SI-standard/cP: Industrial denotation)*

*Table 6-4 Example of weathering properties for Statfjord C Blend** obtained from the prediction charts after 12 hours of weathering at 2, 5,10 and 15 m/s wind speed at 15 °C.*

Weathering properties Statfjord C Blend	**12 hours 15 ˚C 2 m/s**	**12 hours 15 ˚C 5 m/s**	**12 hours 15 ˚C 10 m/s**	**12 hours 15 ˚C 15 m/s**
Evaporation, wt. %	29	33	37	39
Flash point, °C	-	-	-	-
Pour Point, °C	17	20	23	25
Water content, vol.%	13	40	66	70
Viscosity, mPa.s *	425	1580	5670	8190
Mass balance / Oil on surface wt.%	71	65	43	11

**mPa·s = cP (mPa·s: SI-standard/cP: Industrial denotation)*
*** Updated Statfjord C Blend with shear rate 100s^{-1} for waterfree residues*

6.3 Predictions SF Nord Brent (E-2&E-3)

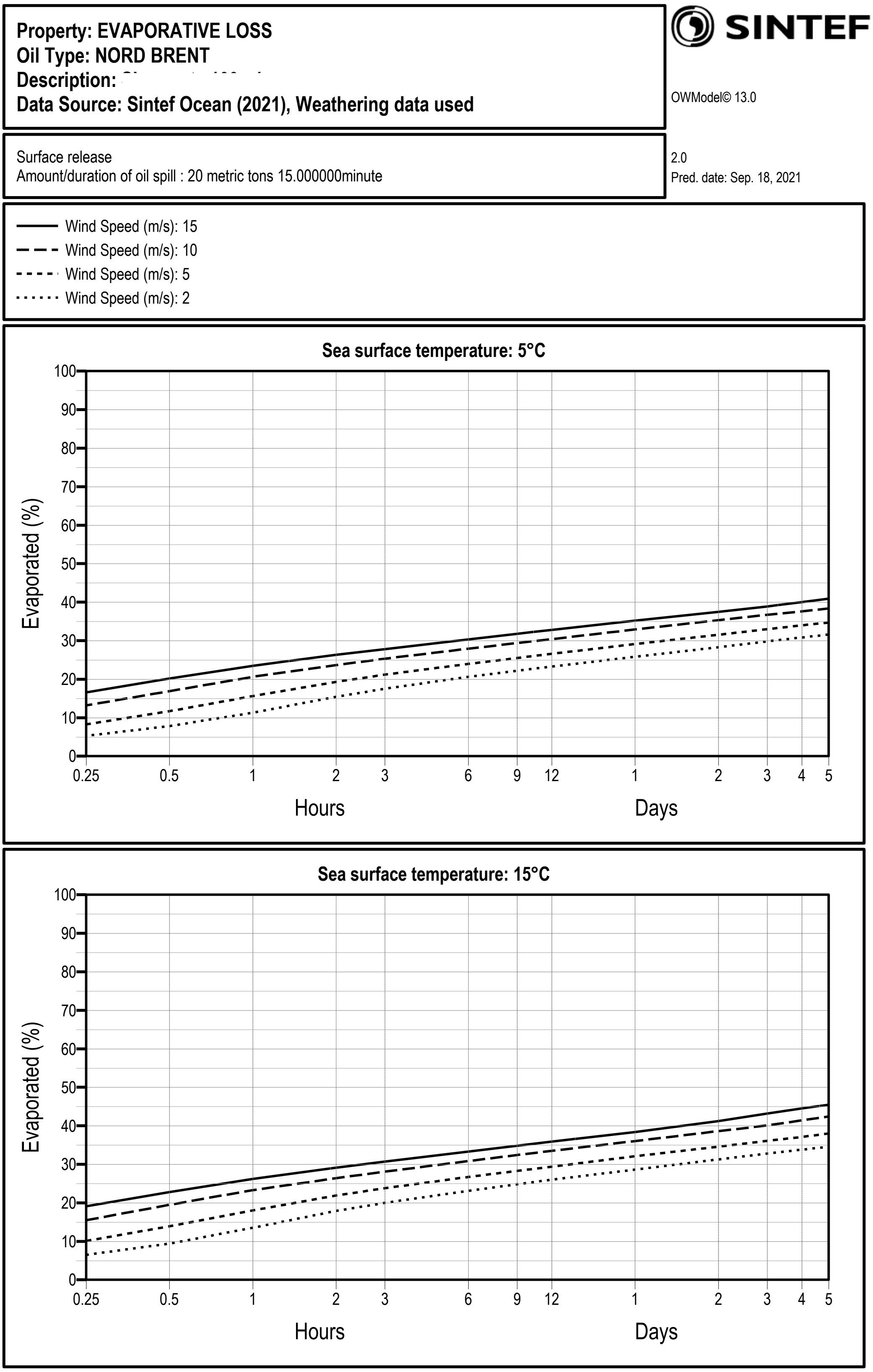

Figure 6-2 Evaporative loss of SF Nord Brent (E-2&E-3) predicted at sea temperatures of 5 and 15 °C.

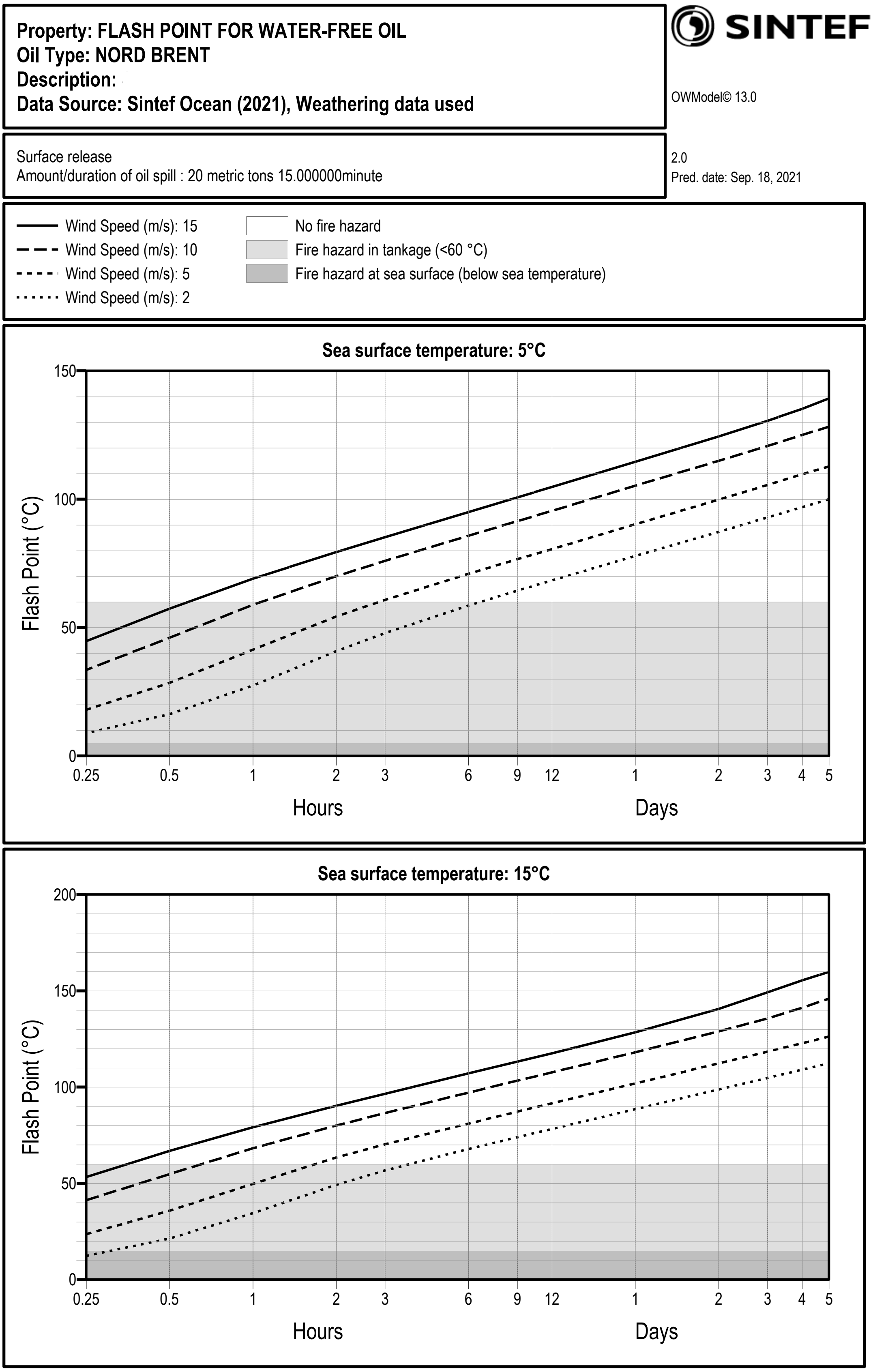

Figure 6-3 Flash point of SF Nord Brent (E-2&E-3) predicted at sea temperatures of 5 and 15 °C.

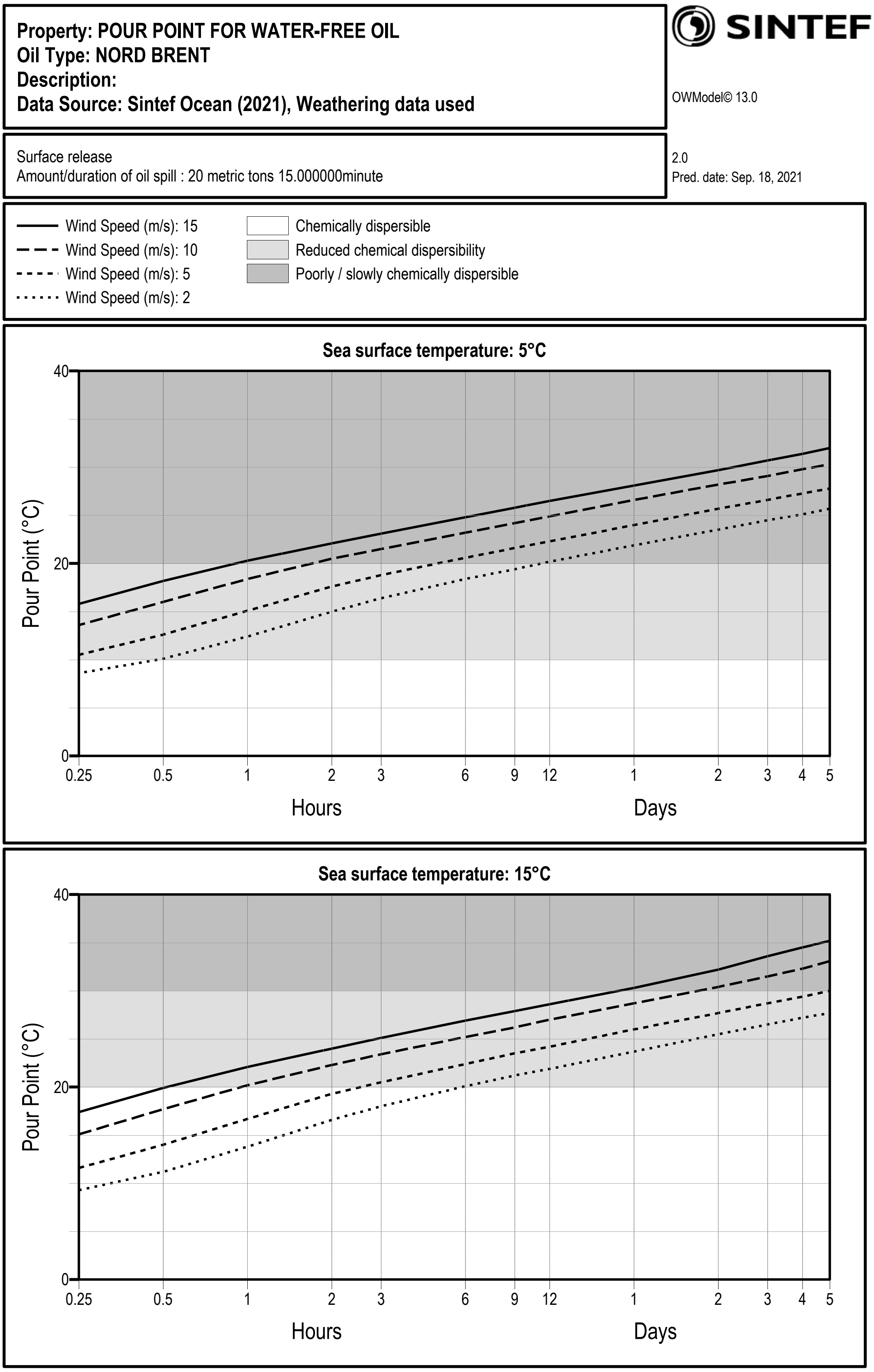

Figure 6-4 *Pour point of SF Nord Brent (E-2&E-3) predicted at sea temperatures of 5 and 15 °C.*

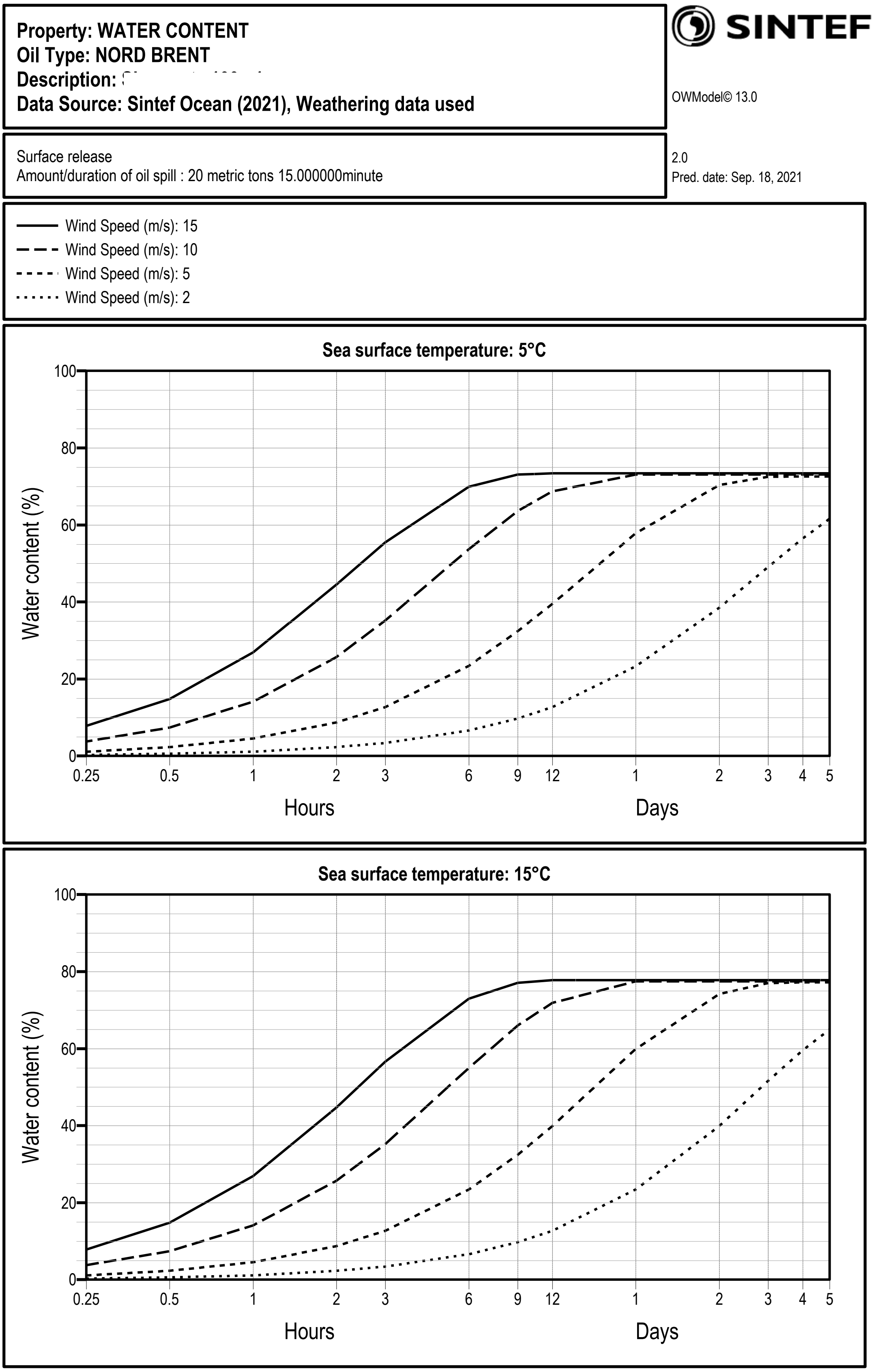

Figure 6-5 Water content of SF Nord Brent (E-2&E-3) predicted at sea temperatures of 5 and 15 °C.

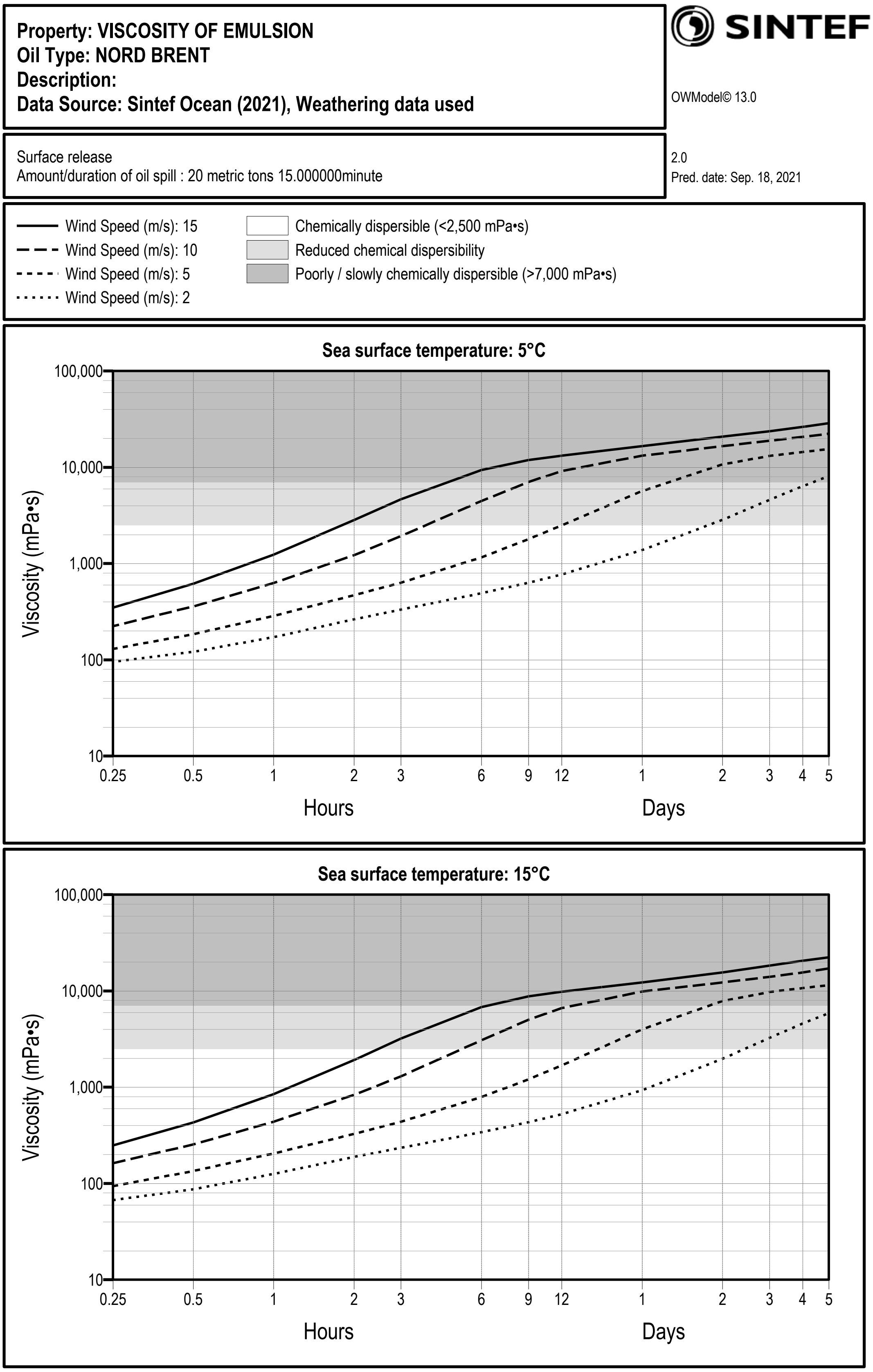

Figure 6-6 Emulsion viscosity of SF Nord Brent (E-2&E-3) predicted at sea temperatures of 5 and 15 °C.

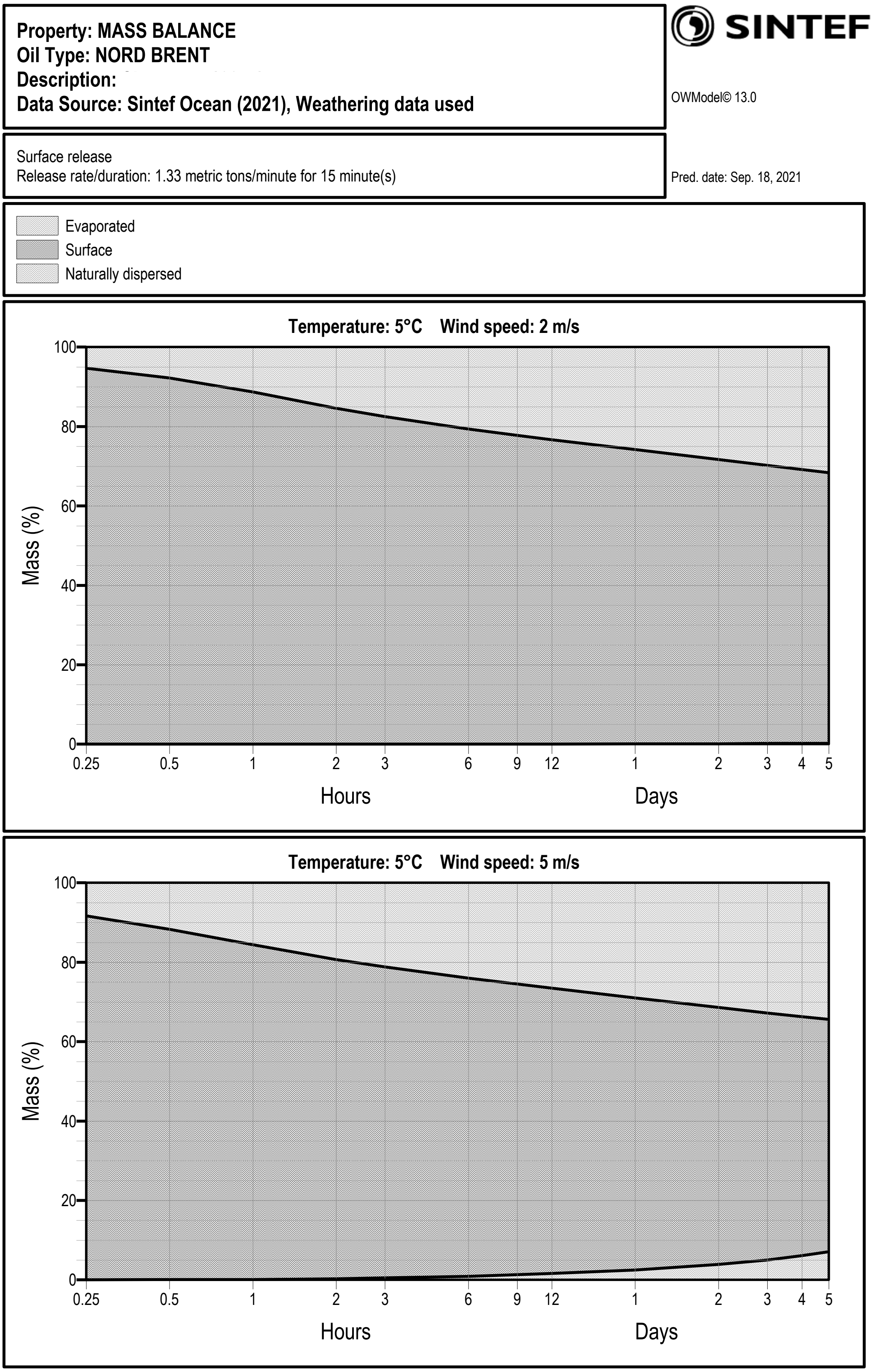

Figure 6-7 Mass balance of SF Nord Brent (E-2&E-3) predicted at sea temperature 5 °C, wind speeds 2 and 5 m/s.

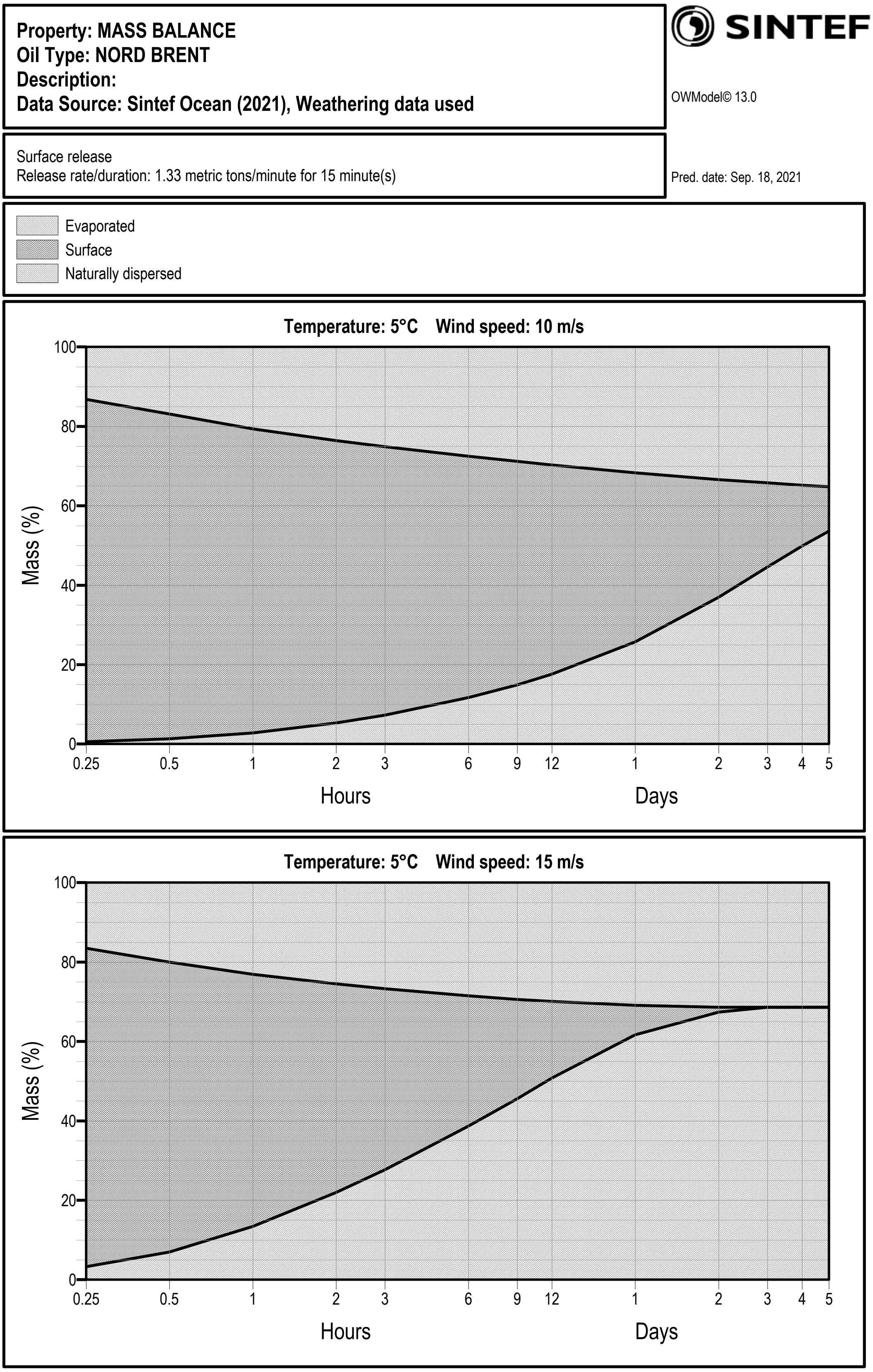

Figure 6-8 *Mass balance of SF Nord Brent (E-2&E-3) predicted at sea temperature 5 °C, wind speeds 10 and 15 m/s.*

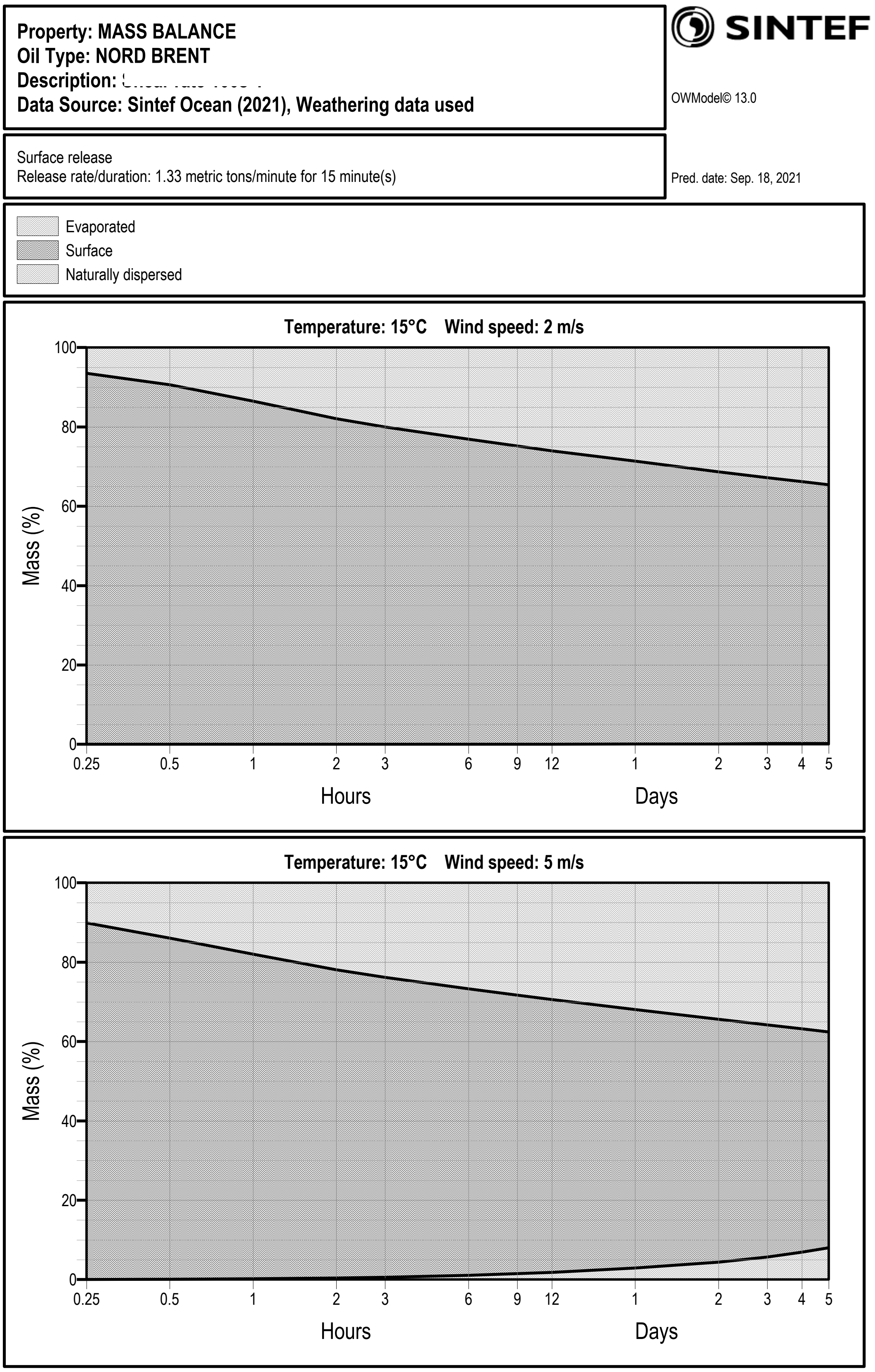

Figure 6-9 *Mass balance of SF Nord Brent (E-2&E-3) predicted at sea temperature 15 °C, wind speeds 2 and 5 m/s.*

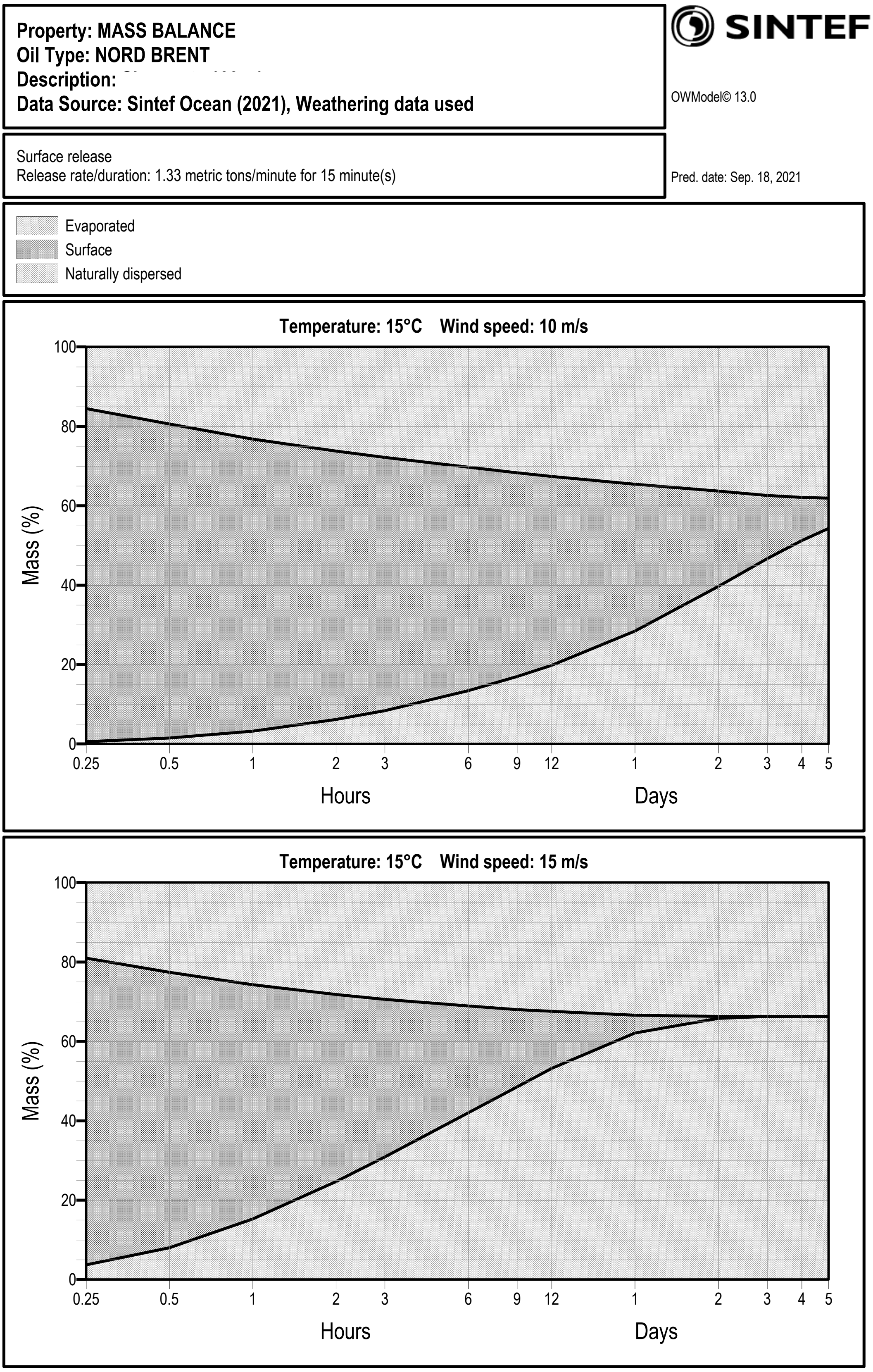

Figure 6-10 Mass balance of SF Nord Brent (E-2&E-3) predicted at sea temperatures 15 °C, wind speeds 2 and 5 m/s.

6.4 Predictions Sygna Brent (N-1&N-2)

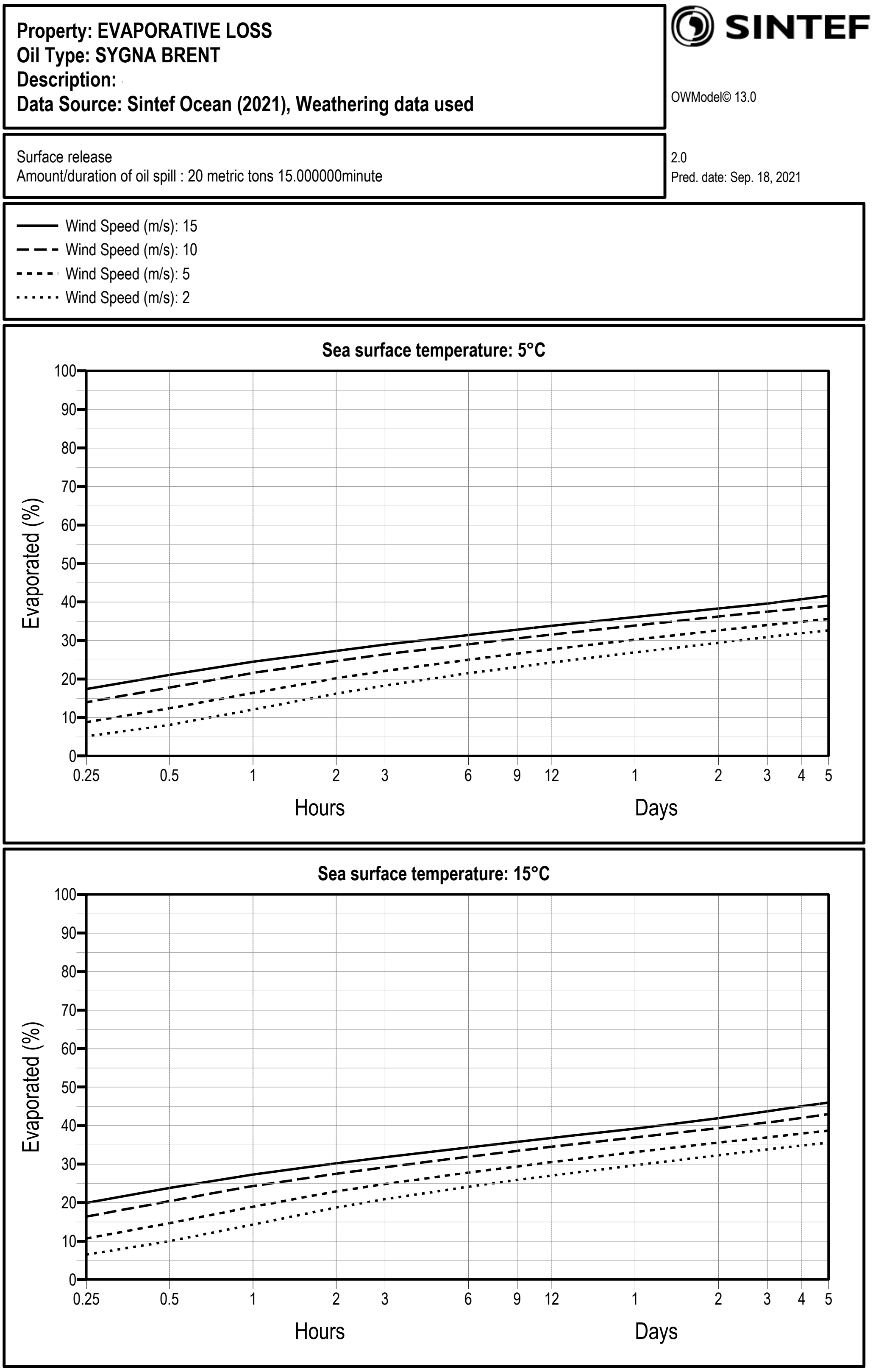

Figure 6-11 Evaporative loss of Sygna Brent (N-1&N-2) predicted at sea temperatures of 5 and 15 °C.

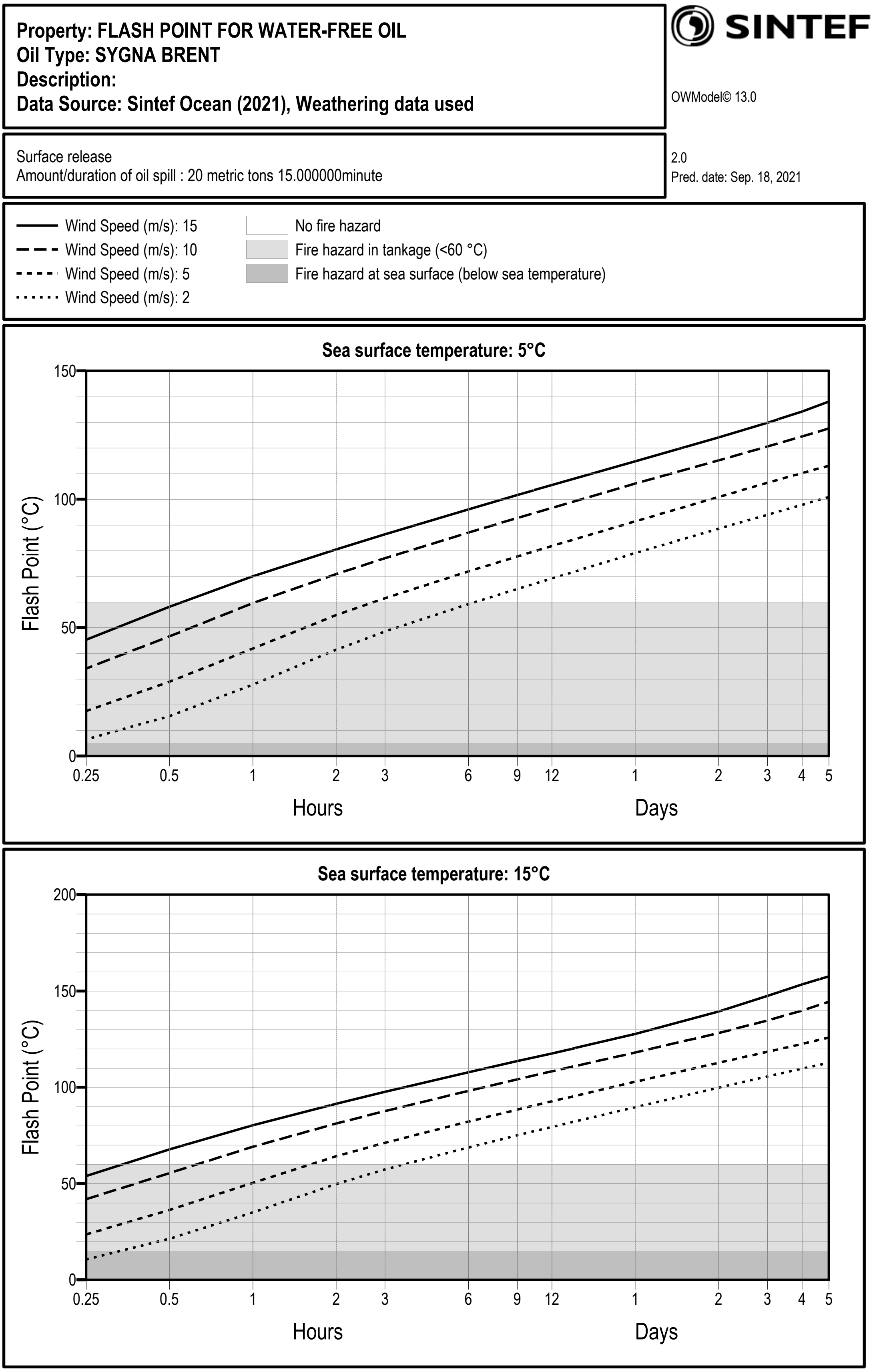

Figure 6-12 Flash point of Sygna Brent (N-1&N-2) predicted at sea temperatures of 5 and 15 °C.

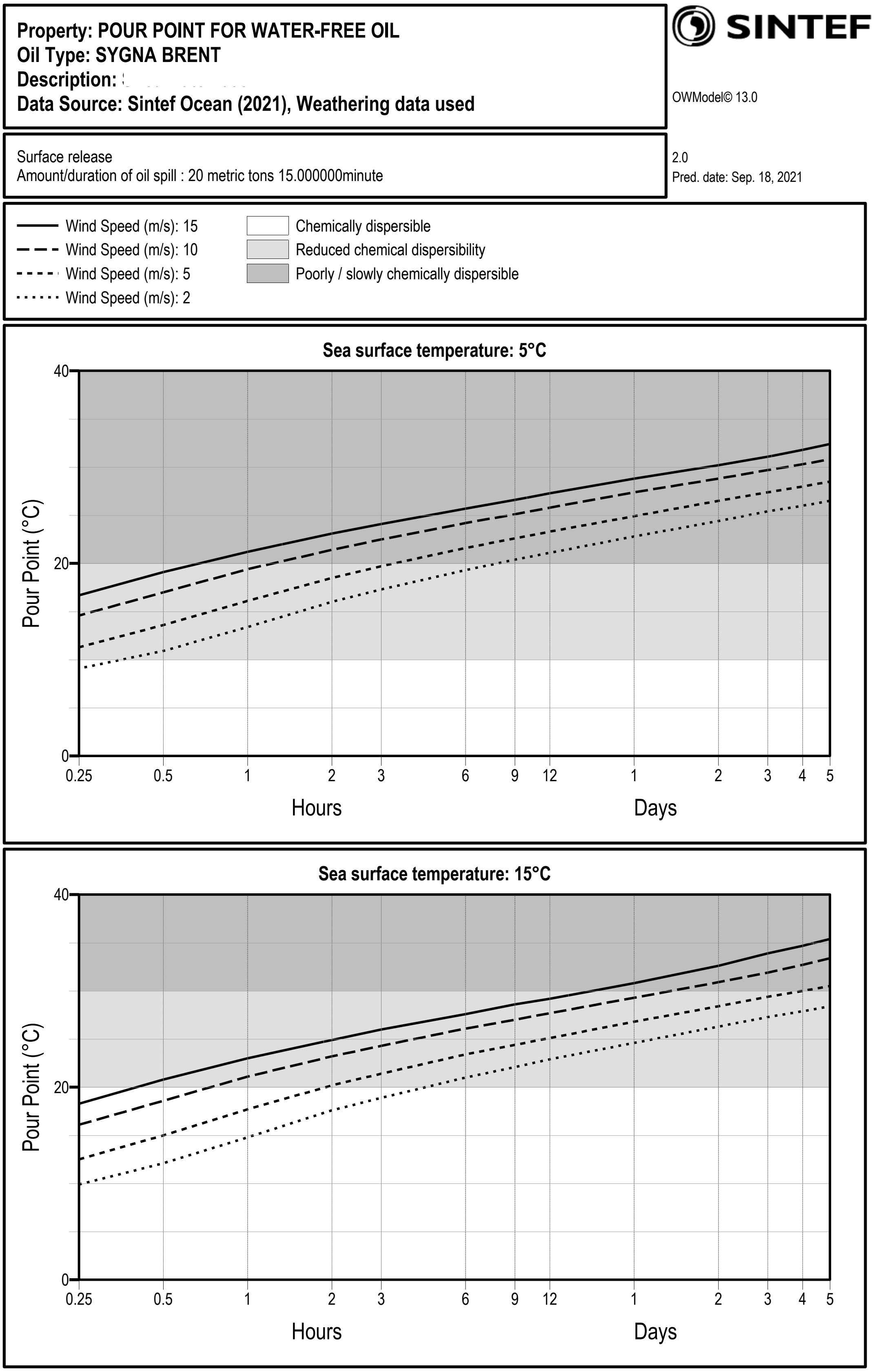

Figure 6-13 Pour point of Sygna Brent (N-1&N-2) predicted at sea temperatures of 5 and 15 °C.

Property: WATER CONTENT
Oil Type: SYGNA BRENT
Description:
Data Source: Sintef Ocean (2021), Weathering data used

SINTEF

OWModel© 13.0

Surface release
Amount/duration of oil spill : 20 metric tons 15.000000minute

2.0
Pred. date: Sep. 18, 2021

Wind Speed (m/s): 15
Wind Speed (m/s): 10
Wind Speed (m/s): 5
Wind Speed (m/s): 2

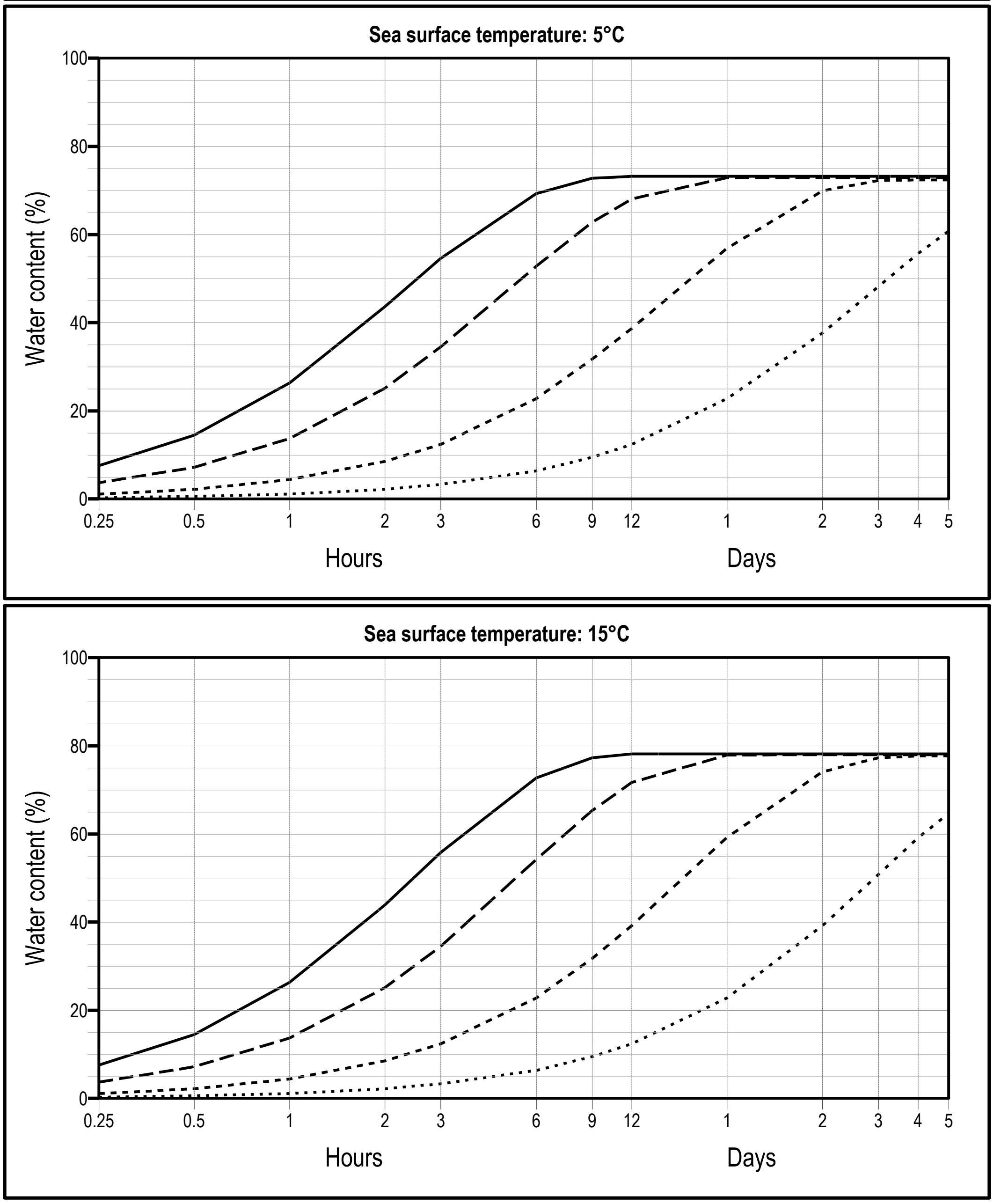

Figure 6-14 Water content of Sygna Brent (N-1&N-2) predicted at sea temperatures of 5 and 15 °C.

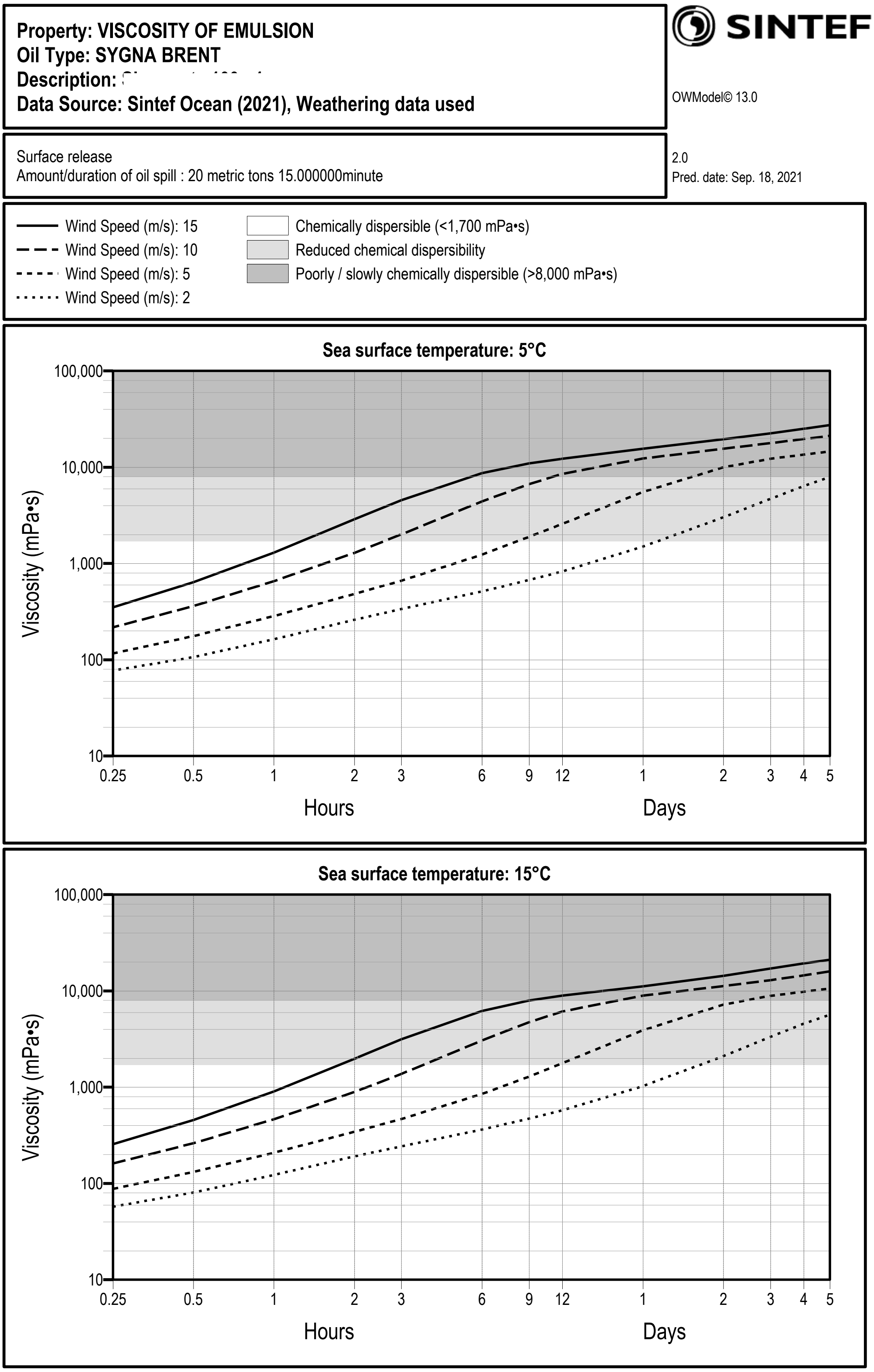

Figure 6-15 Emulsion viscosity of Sygna Brent (N-1&N-2) predicted at sea temperatures of 5 and 15 °C.

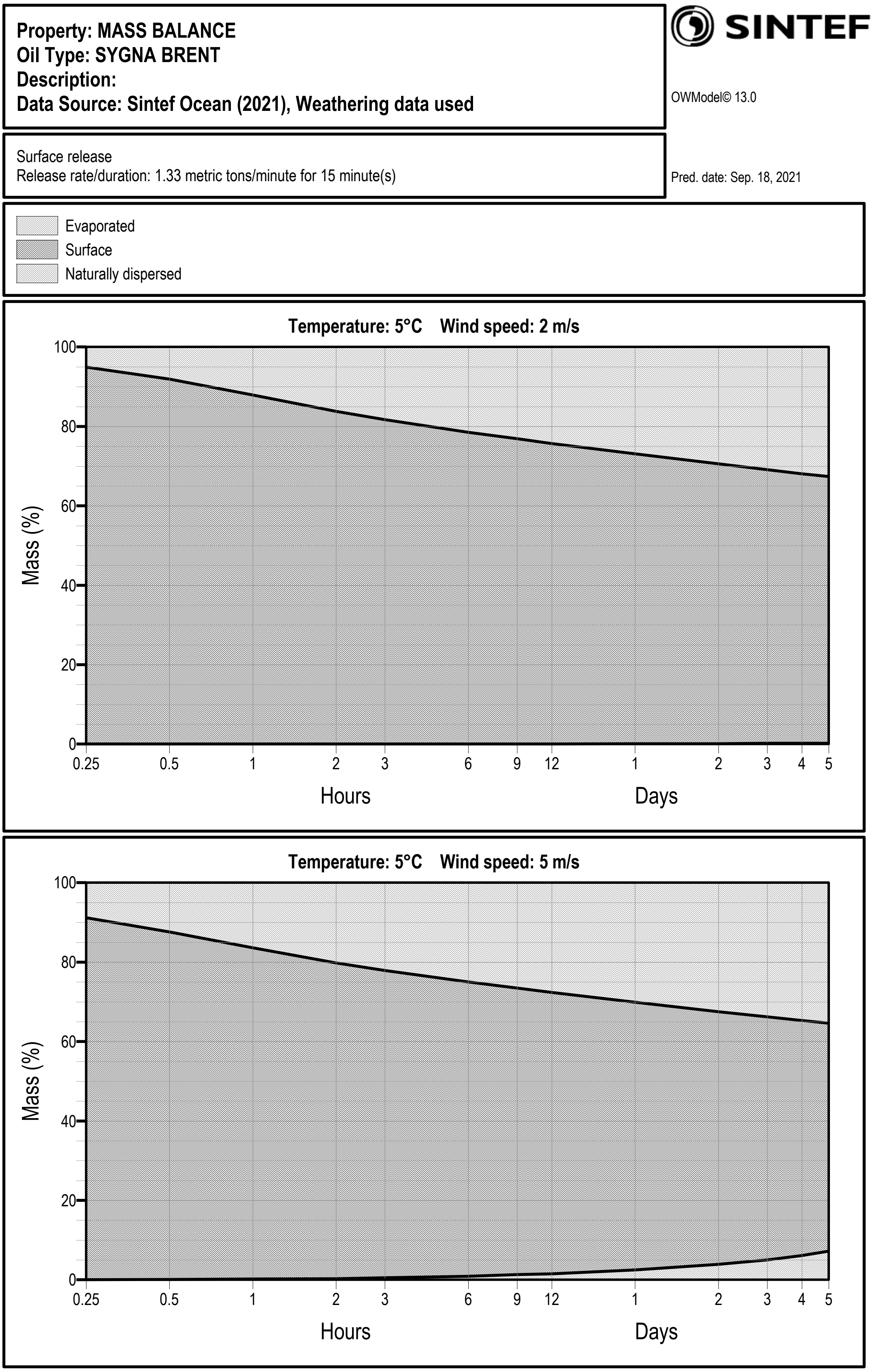

Figure 6-16 Mass balance of Sygna Brent (N-1&N-2) predicted at sea temperature 5 °C, wind speeds 2 and 5 m/s.

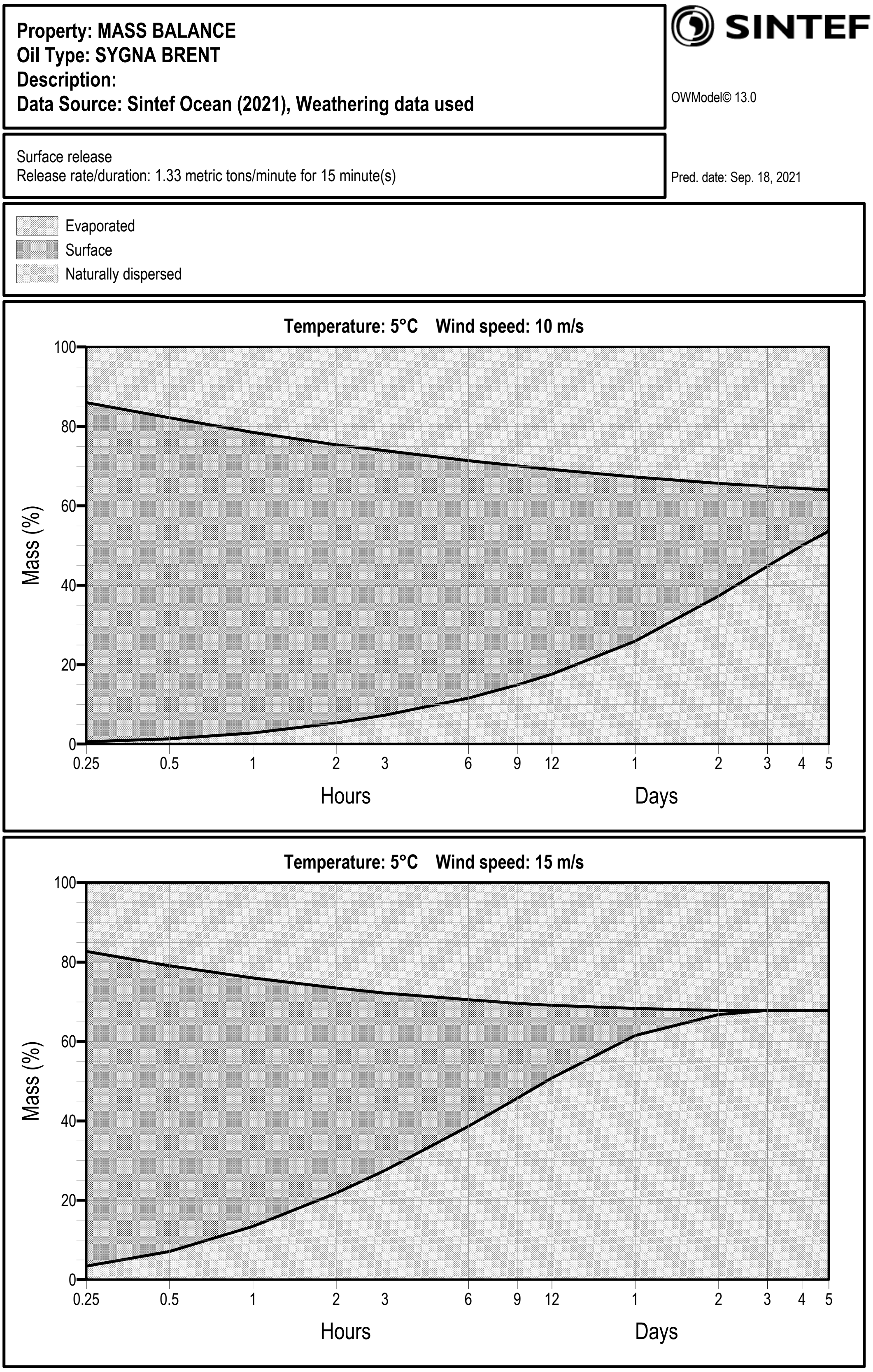

Figure 6-17 Mass balance of Sygna Brent (N-1&N-2) predicted at sea temperature 5 °C, wind speeds 10 and 15 m/s.

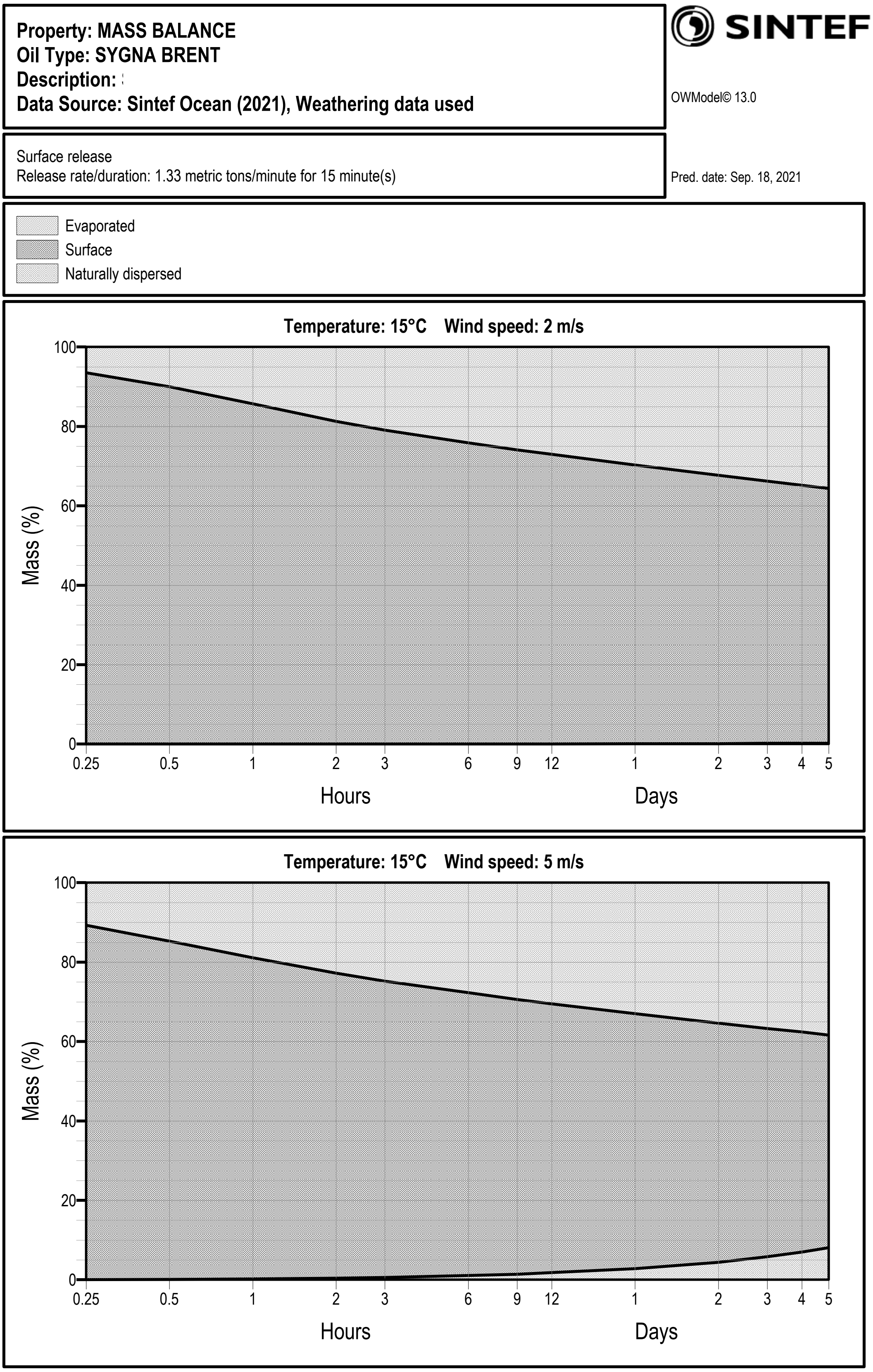

Figure 6-18 Mass balance of Sygna Brent (N-1&N-2) predicted at sea temperature 15 °C, wind speeds 2 and 5 m/s.

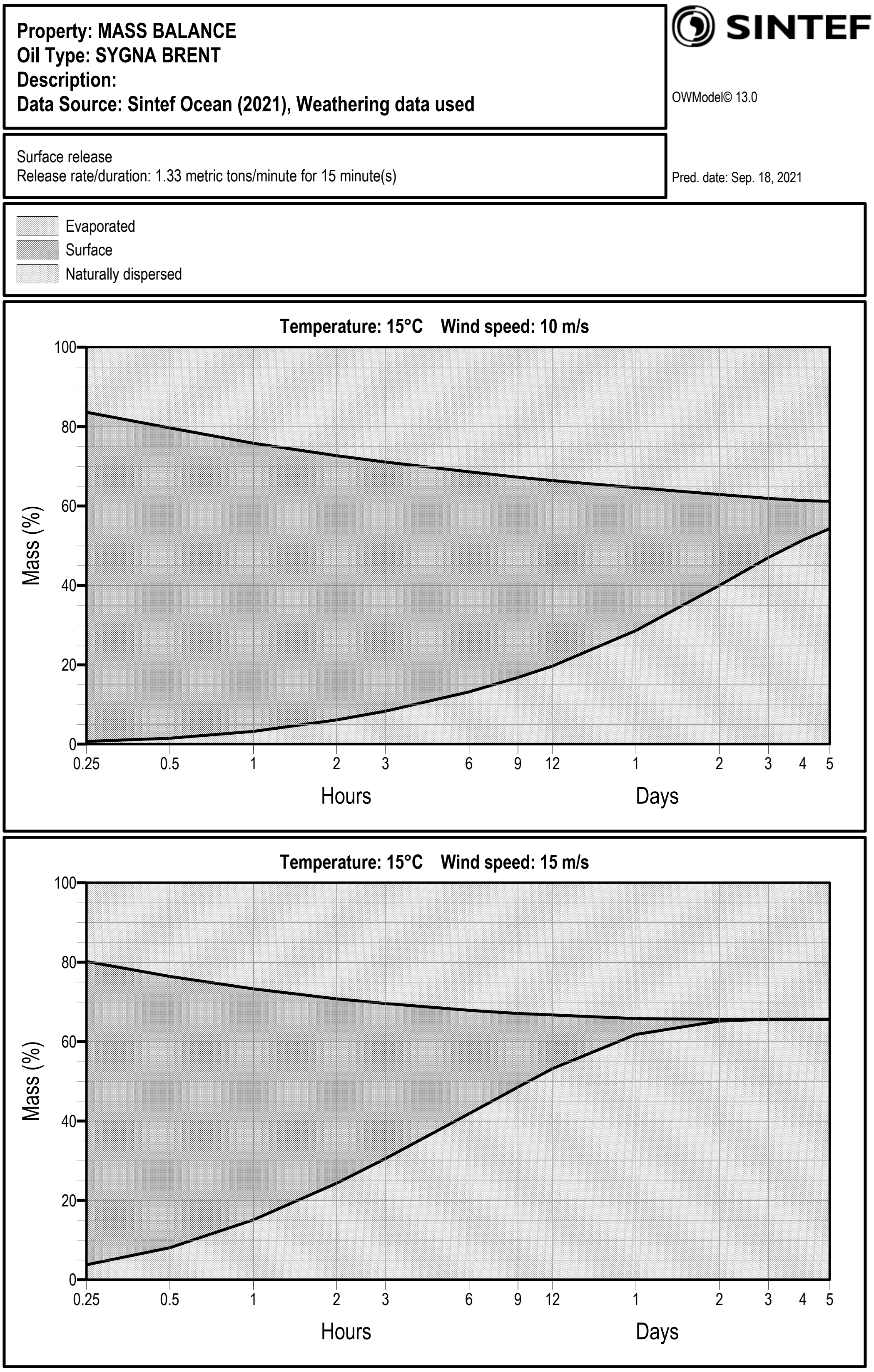

Figure 6-19 *Mass balance of Sygna Brent (N-1&N-2) predicted at sea temperature 15 °C, wind speeds 2 and 5 m/s.*

6.5 Predictions Statfjord C Blend (updated)

Updated Statfjord C Blend from 2000 with shear rate 100s^{-1} for waterfree residues.

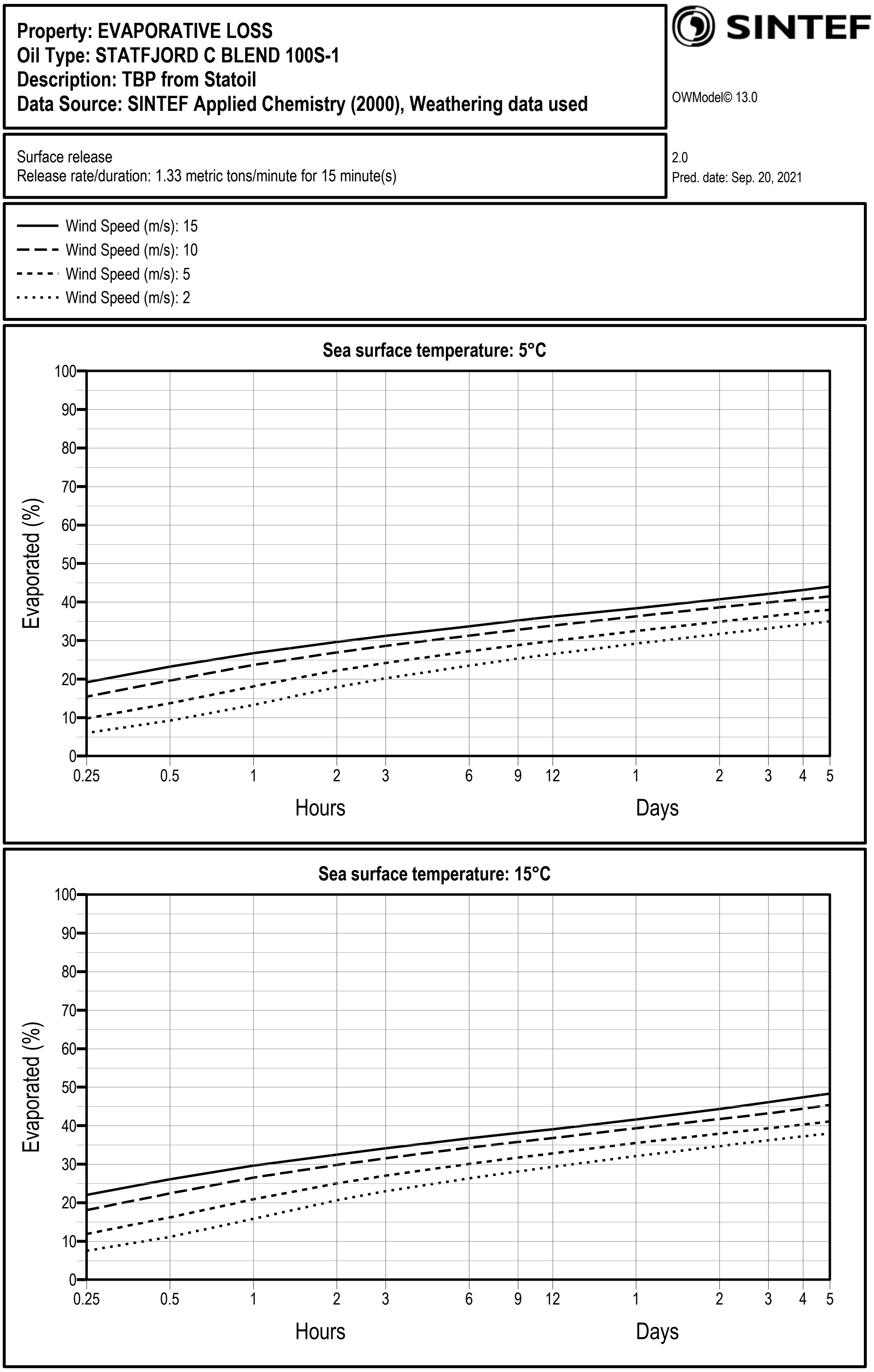

Figure 6-20 Evaporative loss of Statfjord C Blend predicted at sea temperatures of 5 and 15 °C.

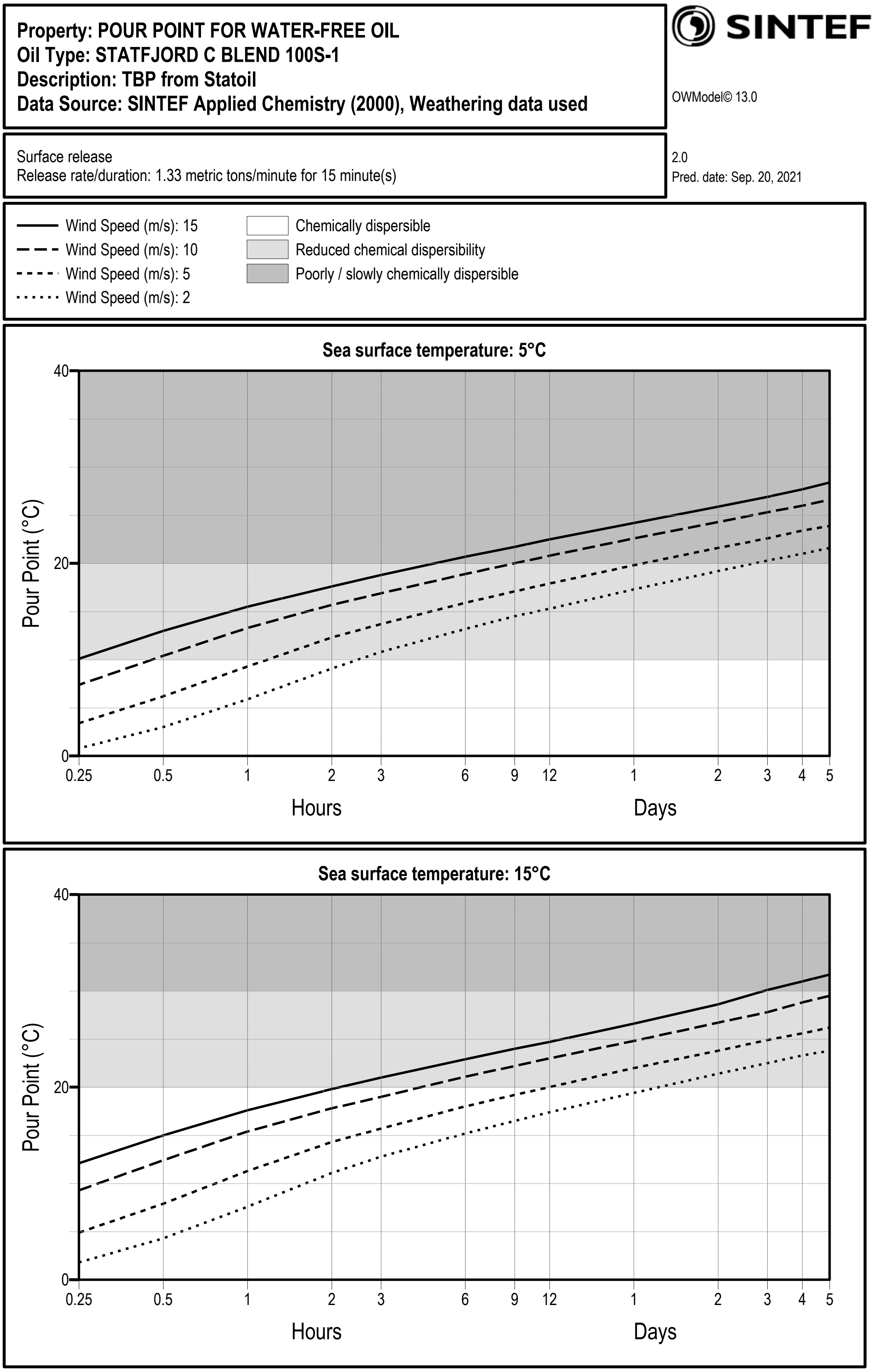

Figure 6-21 Pour point of Statfjord C Blend predicted at sea temperatures of 5 and 15 °C.

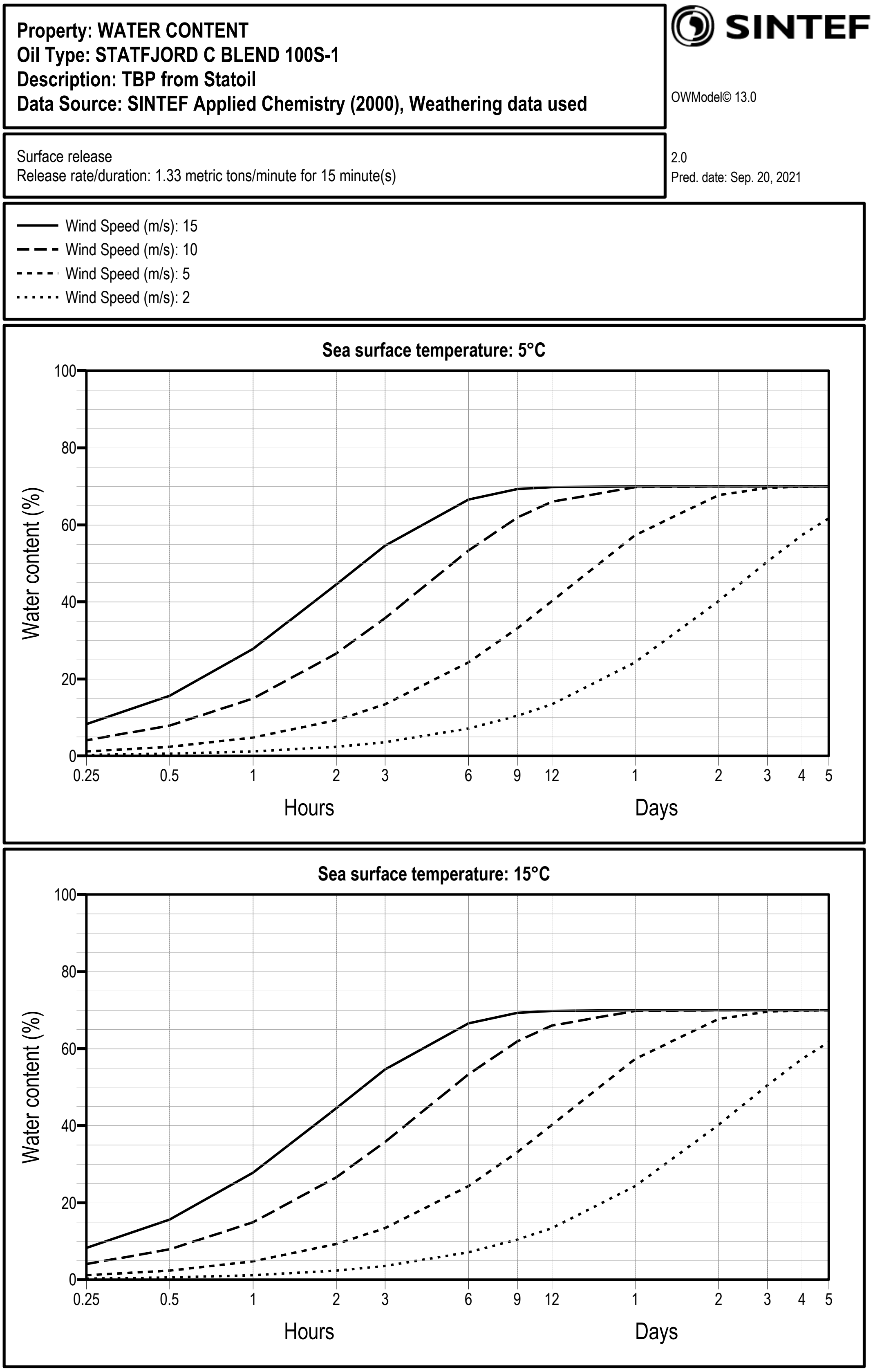

Figure 6-22 Water content of Statfjord C Blend predicted at sea temperatures of 5 and 15 °C.

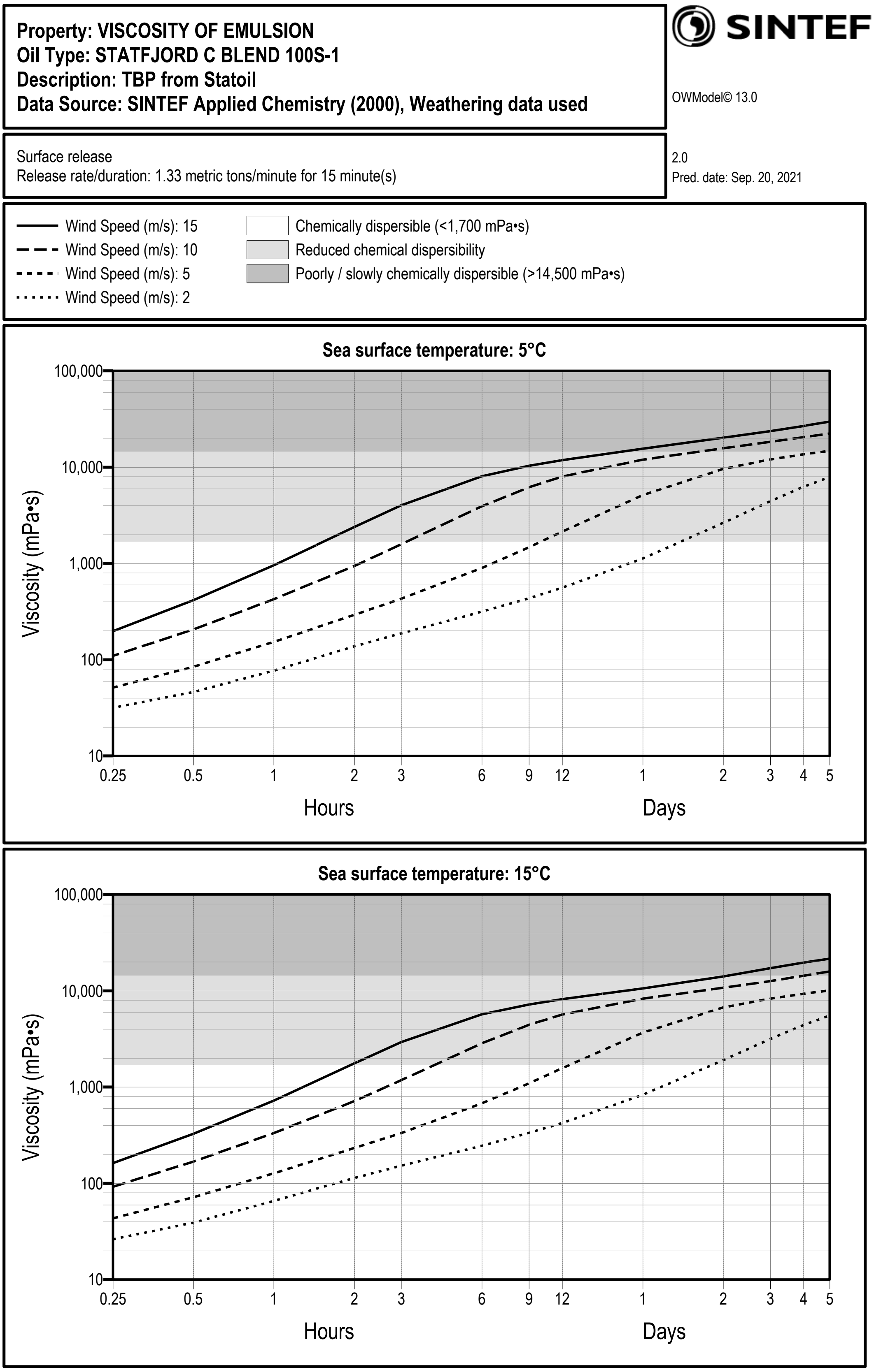

Figure 6-23 Emulsion viscosity of Statfjord C Blend predicted at sea temperatures of 5 and 15 °C.

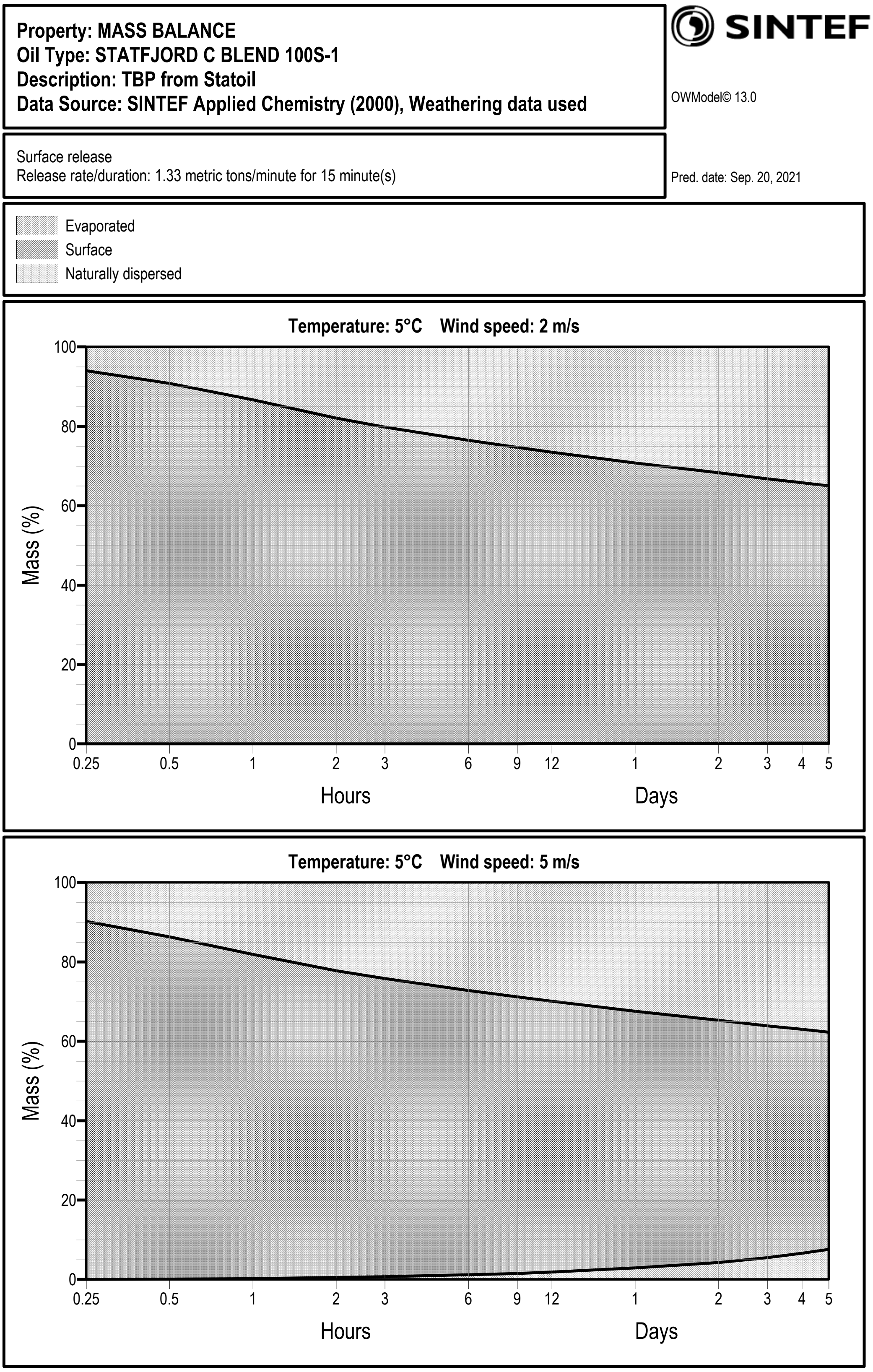

Figure 6-24 Mass balance of Statfjord C Blend predicted at sea temperatures of 5 °C, wind speeds 2 and 5 m/s.

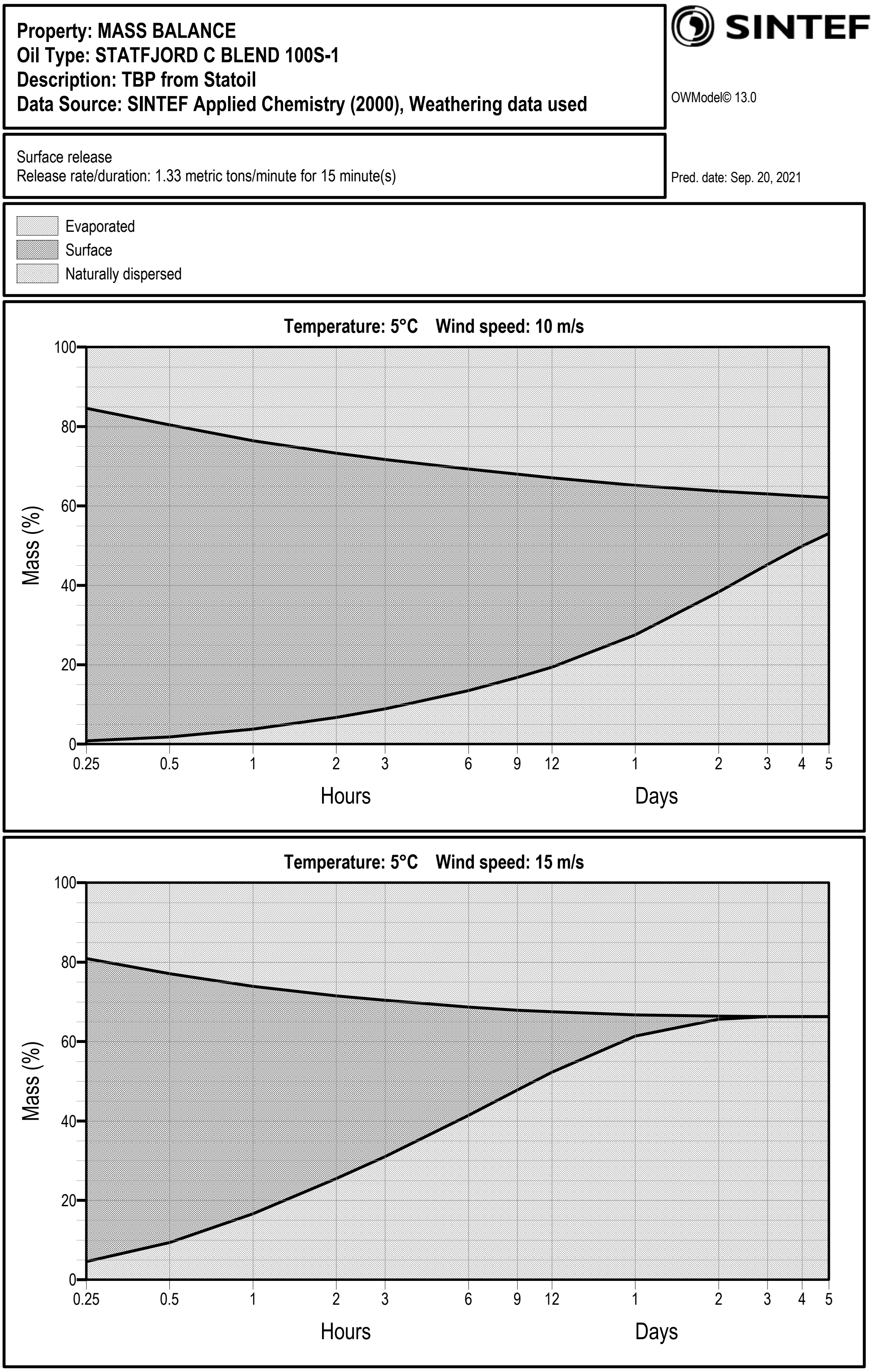

Figure 6-25 Mass balance of Statfjord C Blend predicted at sea temperatures of 5 °C, wind speeds 10 and 15 m/s.

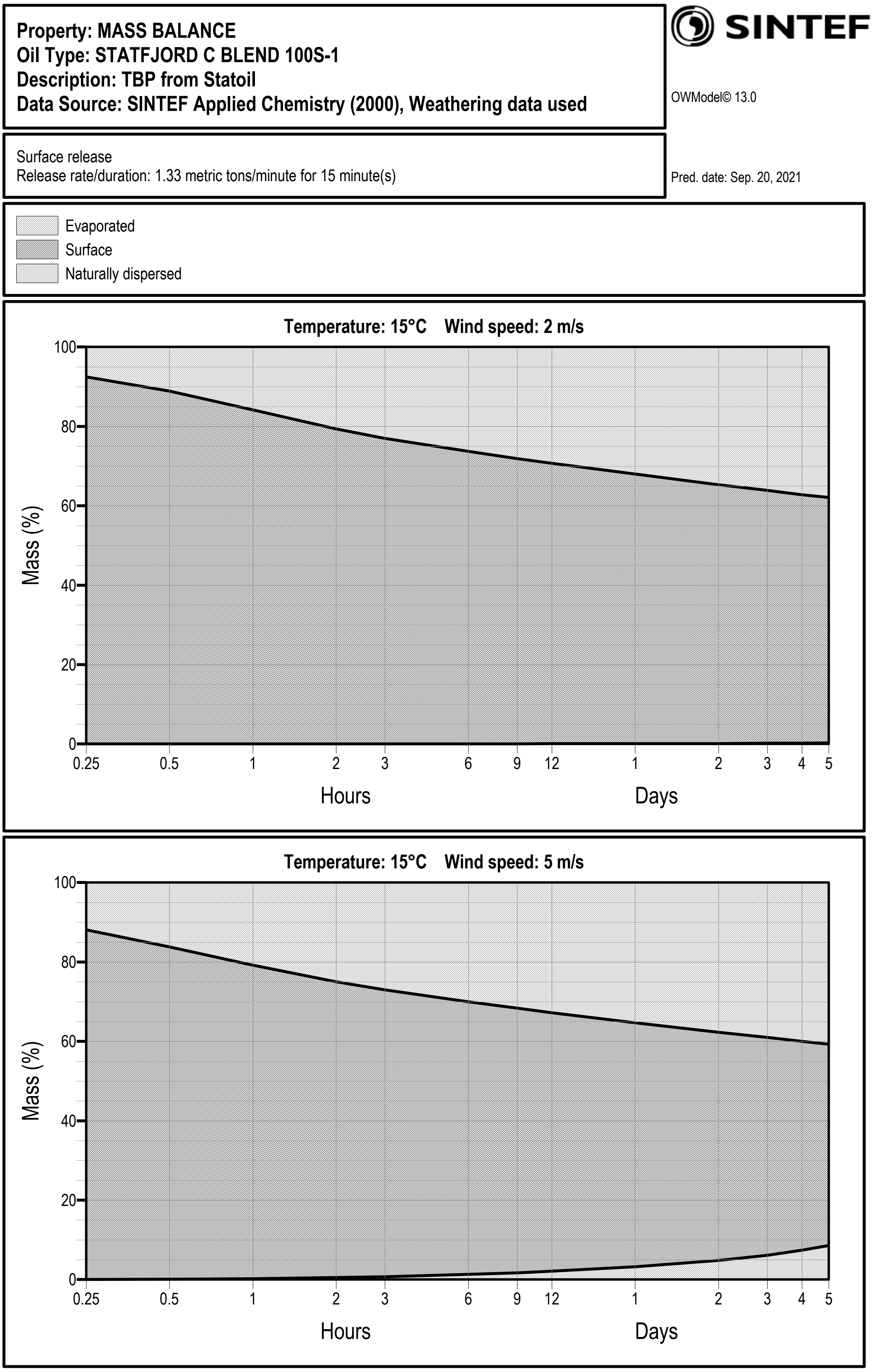

Figure 6-26 *Mass balance of Statfjord C Blend predicted at sea temperatures of 15 °C, wind speeds 2 and 5 m/s.*

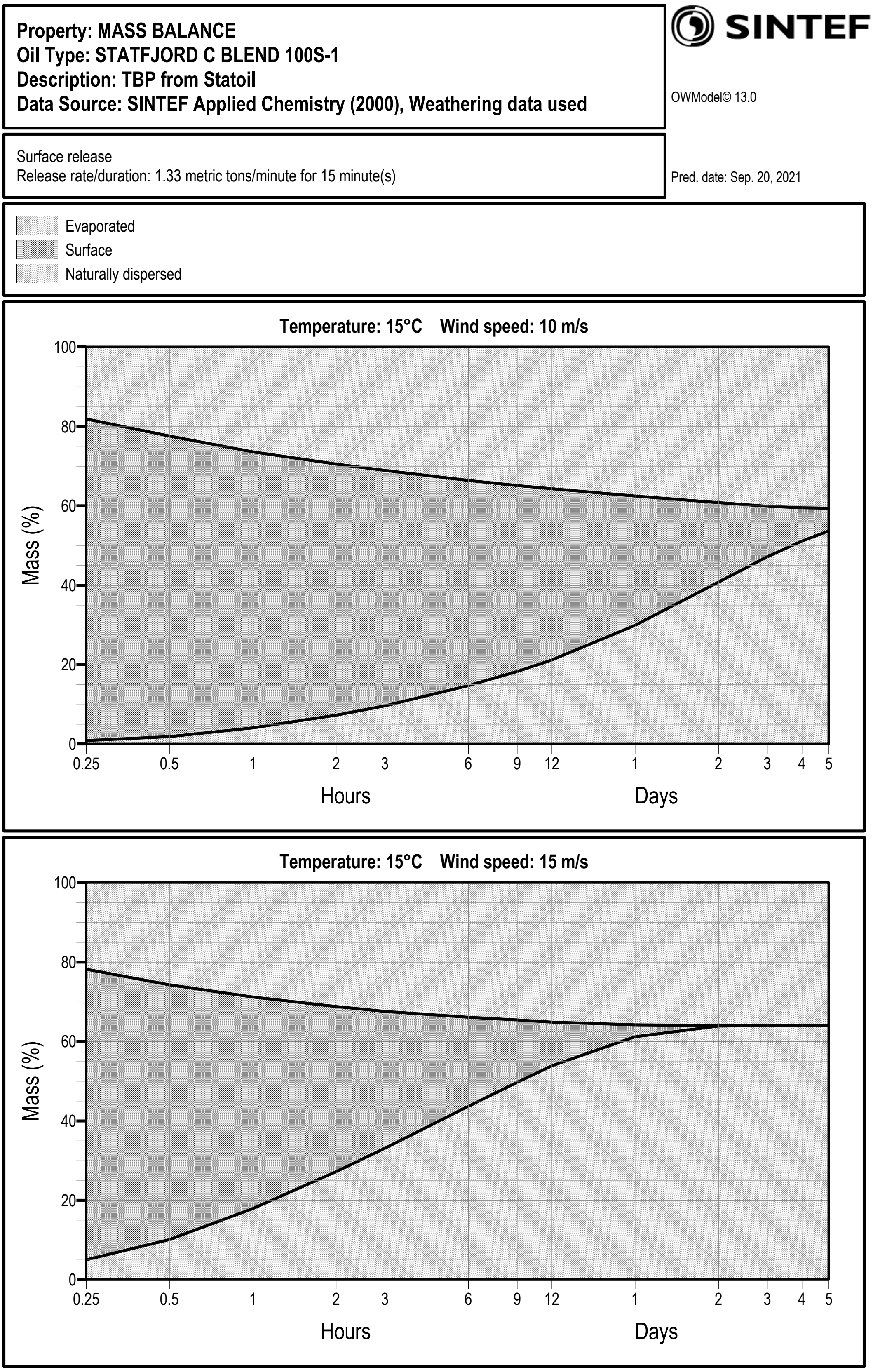

Figure 6-27 *Mass balance of Statfjord C Blend predicted at sea temperatures of 15 °C, wind speeds 10 and 15 m/s.*

7 Comparison of OWM predictions

Weathering predictions from surface releases of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) were compared with predictions of previous tested Statfjord C Blend and Tyrihans Sør. The predictions are based on sea temperature of 15 °C (summer temperature) and wind speed of 10 m/s.

7.1 Evaporative loss

Evaporation is one of the natural process that helps removing spilled oil from the sea surface (Statfjord C Blend has the highest evaporative loss, whilst Tyrihans Sør has the lowest among these oils for comparison. SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) exhibit very similar evaporative loss. However, the predicted evaporative losses are within expected range for medium paraffinic crude oils as shown in Figure 7-1.

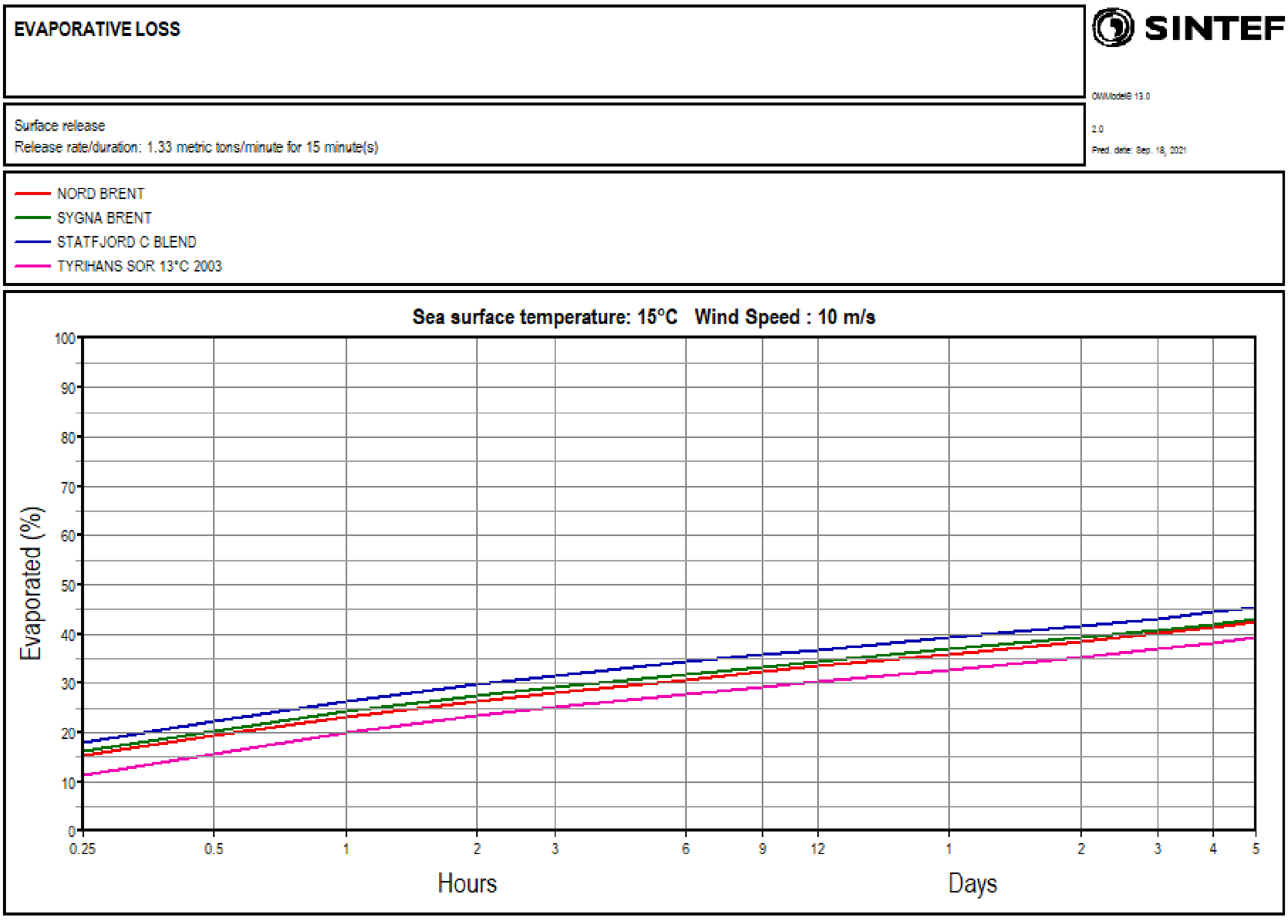

Figure 7-1 Predicted evaporative loss at 15 °C and 10 m/s for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) in comparison with Statfjord C Blend and Tyrihans Sør.

7.2 Pour point

Pour point depends on the oil's wax content and the content of light components that can keep the waxes dissolved in the oil. In addition, high asphaltene content prevents precipitation and lattice formation and lowers the pour point. The pour point of oil may influence the dispersant effectiveness as a high pour point may prevent the dispersant to soak into the oil slick.

SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) have similar and higher pour points compared with Statfjord C Blend and Tyrihans Sør (Figure 7-2). Residues form these crude oils may have a potential to solidify on the sea surface by time if spilled at sea, and most pronounced for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2).

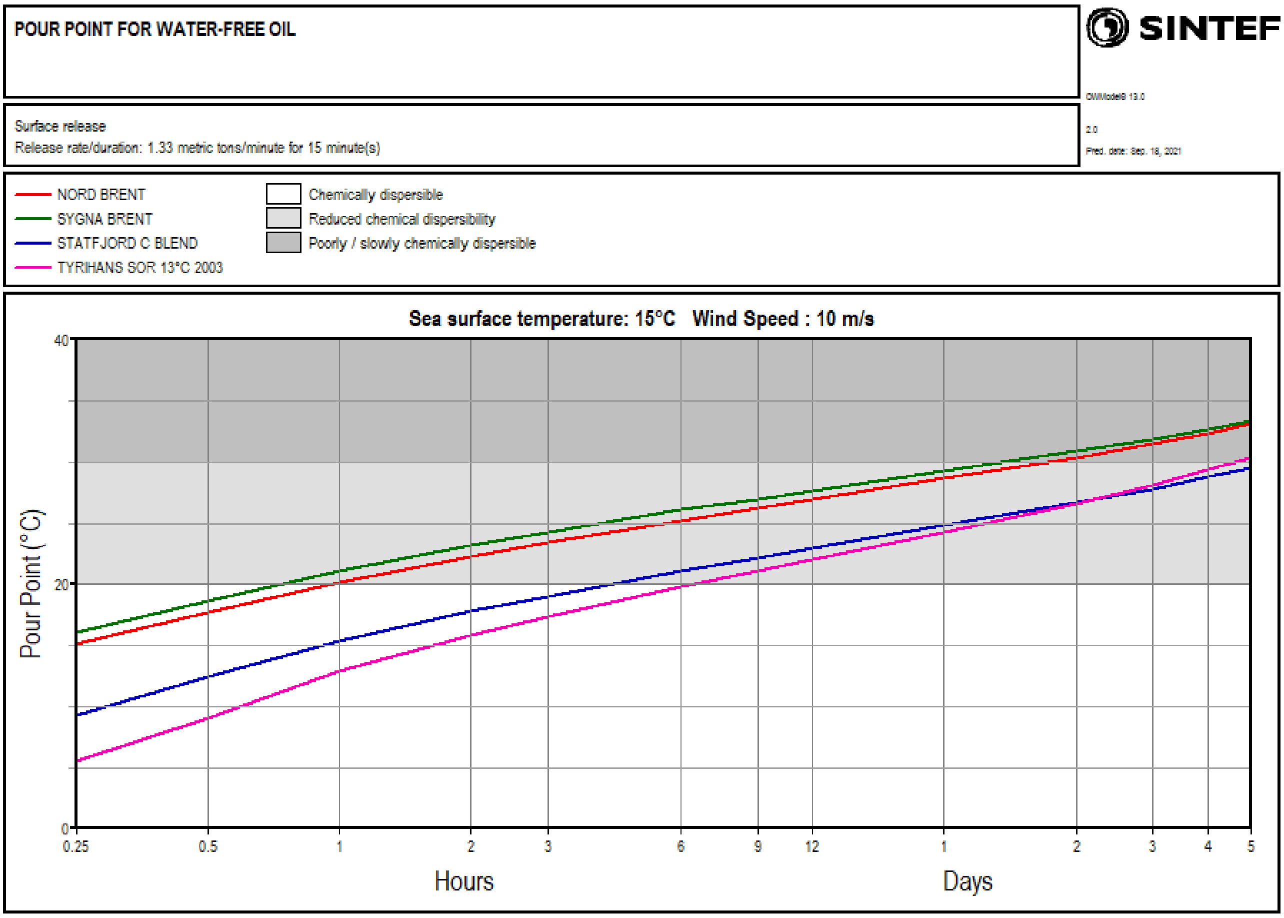

Figure 7-2 Predicted pour point at 15 °C and 10 m/s for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) in comparison with Statfjord C Blend and Tyrihans Sør.

7.3 Water content

The water uptakes of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) are very similar and reach a maximum water uptake of about 78 vol. % after 1 day of weathering at sea (Figure 7-3). Statfjord C Blend reaches a maximum water uptake of 70 vol. % whilst Tyrihans Sør reaches 75 vol. %. Tyrihans Sør has a slower rate of water uptake compared with the other oils.

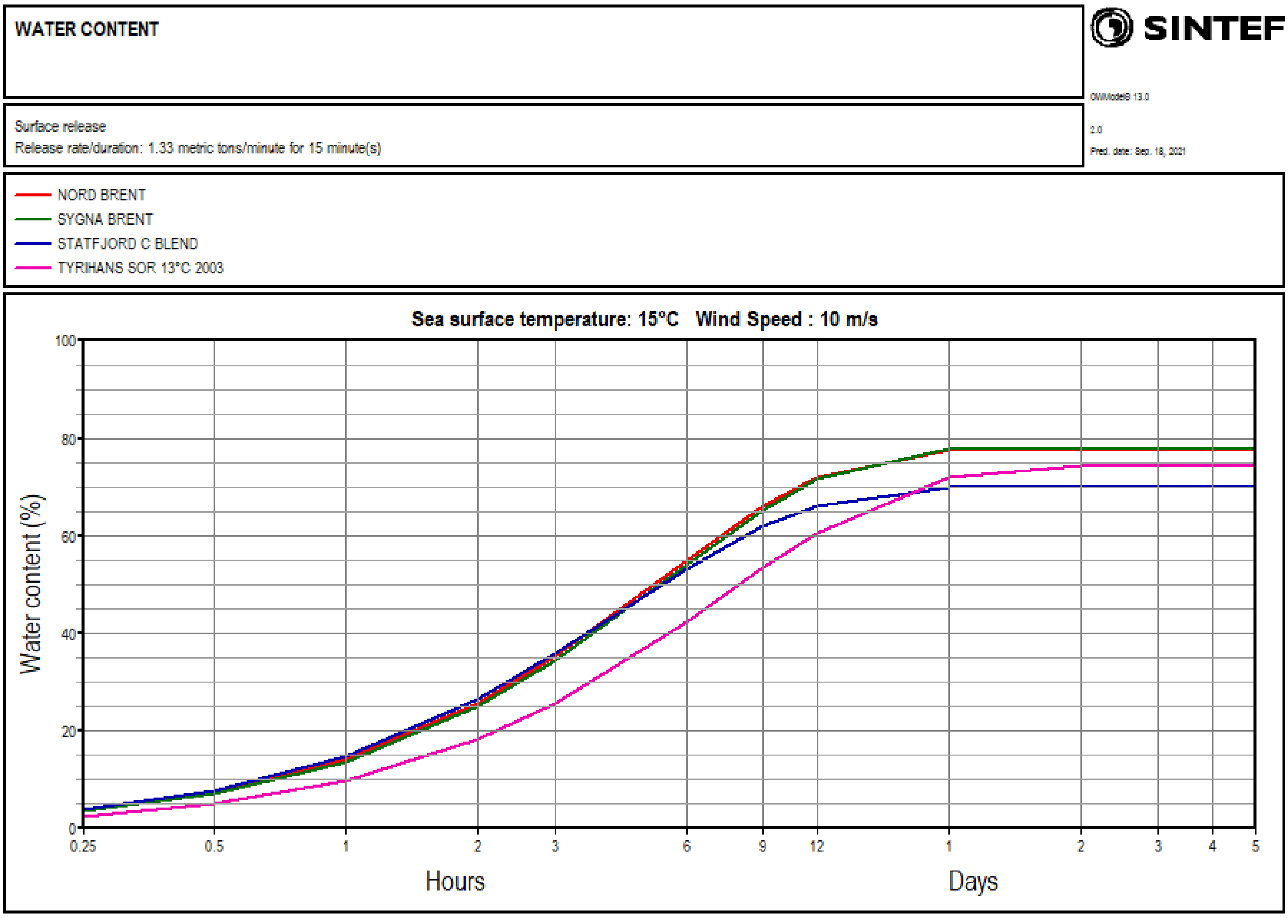

Figure 7-3 Predicted water content at 15 °C and 10 m/s for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) in comparison with Statfjord C Blend and Tyrihans Sør.

7.4 Emulsion viscosity

Figure 7-4 shows the predicted (emulsion) viscosities of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) in comparison with Statfjord C Blend and Tyrihans Sør. The oils show viscosities in the same range; however, Statfjord C Blend has lower viscosity during the first 3 hours end up with slightly lower viscosities compared with the other oils. SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) exhibit very similar viscosities.

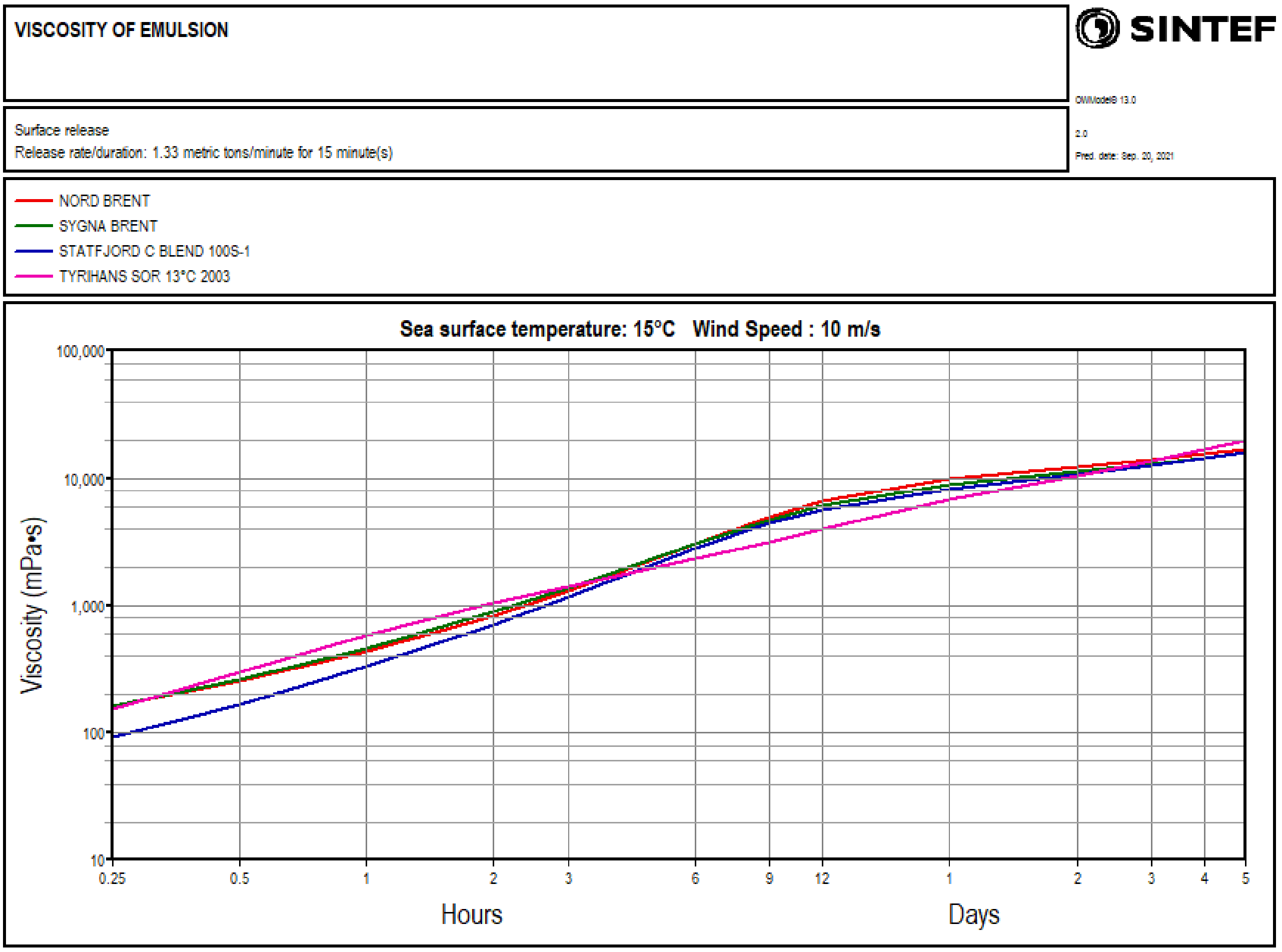

Figure 7-4 *Predicted emulsion at 15 °C and 10 m/s for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) in comparison with Statfjord C Blend and Tyrihans Sør.*

7.5 Surface oil and surface emulsion

The predicted surface oil is based on the evaporative loss, natural dispersion/entrainment, whilst surface emulsion also includes emulsification that may increase the oil volume subsequently. Figure 7-5 (above) shows the predicted mass balance of remaining surface oil as a function of weathering of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) in comparison with Statfjord C Blend and Tyrihans Sør, while the figure below shows the remaining surface emulsion. The predictions show that these crude oils are persistent on the sea surface with predicted lifetime >5 days for this scenario, however SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) have a higher increase of the oil volumes due to the higher water uptakes compared to Statfjord C Blend and Tyrihans Sør.

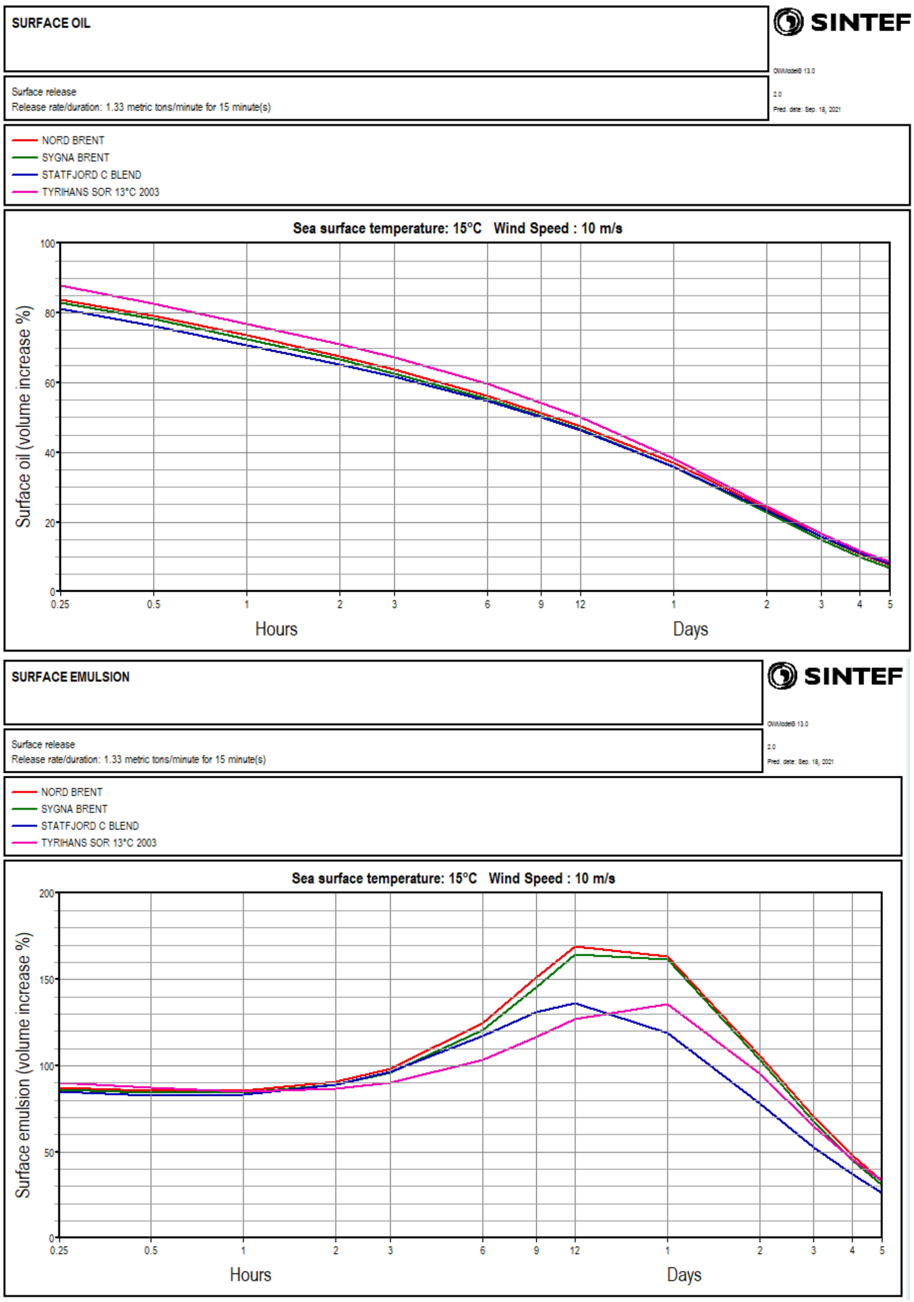

Figure 7-5 *Above: Predicted remaining surface oil at SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) in comparison with Statfjord C Blend and Tyrihans Sør.*
Below: Predicted remaining surface emulsion at 15 °C and 10 m/s for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) in comparison with Statfjord C Blend and Tyrihans Sør.

8 Weathering properties and response

In general, the relative content of heavy oil components within a spilled oil increases due to evaporation and the physical and chemical properties of the oil will change over time. Knowledge about how the oils properties change during weathering is therefore important in the management of oil spill response. Currently, mechanical recovery and the use of oil spill dispersants are the main oil spill response options at sea in the Norwegian sector today. The potential of using water-flushing (artificial energy) to disperse thin oil films and low viscous oils is also discussed in this report. In addition, the potential for *in-situ* burning (ISB) by use of the Response guide in SINTEF OWM is shown in Appendix F.

The weathering properties related to response of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) are given in the subchapters below.

8.1 Oil properties

The specific physico-chemical parameters of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) are input to SINTEF OWM.

SF Nord Brent (E-2&E-3)
The physico-chemical analysis of the fresh and topped residues shows that SF Nord Brent (E-2&E-3) is a paraffinic crude oil with a density of 0.845 g/mL with a medium content of asphaltenes (0.28 wt. %) and a medium wax content of 4.1 wt. %, compared with other Norwegian crude oils. SF Nord Brent (E-2&E-3) has a moderate evaporate loss of 43 vol. % of the 250°C+ residue. The fresh oil has a viscosity of 103 mPa.s at shear rate $10s^{-1}$ (13 °C) and increases by evaporation to 6348 mPa.s (10s-1) for the waterfree 250°C+ residue. The fresh oil has a low pour point of 3 °C, that increases significantly to + 27 °C upon evaporation (250°C+). SF Nord Brent (E-2&E-3) forms stable water-in-oil emulsions with moderate to high viscosities that partly or totally breaks with application of emulsion breaker (Aerosol OT-SE surfactant).

Sygna Brent (N-1&N-2)
The physico-chemical analysis of the fresh and topped residues shows that Sygna Brent (N-1&N2) is a paraffinic crude oil with a density of 0.843g/mL with a medium to high content of asphaltenes (0.48 wt. %) and a medium (to high) wax content of 5.3 wt. %, compared with other Norwegian crude oils. Sygna Brent (N-1&N2) has a moderate evaporate loss of 43 vol. % of the 250°C+ residue. The fresh oil has a viscosity of 45 mPa.s at shear rate $10s^{-1}$ (13 °C) and increases by evaporation to 7115 mPa.s (10s-1) for the waterfree 250°C+ residue. The fresh oil has a low pour point of 3 °C, that increases significantly to +27 °C upon evaporation (250°C+). Sygna Brent (N-1&N2) forms stable water-in-oil emulsions with moderate to high viscosities that partly or totally breaks with application of emulsion breaker (Aerosol OT-SE surfactant).

8.2 Flash point – Fire/explosion hazard

Flash point refers to the lowest temperature at which a fuel or oil can vaporize to form an ignitable mixture in the air. In case of an oil spill on the sea surface, the (heated) oil rapidly will be cooled to the ambient seawater temperature within a short period of time. The potential for fire/explosion hazard will be at its greatest if the flash point of the spilled oil is below the seawater temperature. The release rate may influence on the rate of evaporation, and for considerably larger (batch) release rates e.g.100 times higher (8000 m^3/h) than the standard rate of 80 m^3/h used for predictions. Such high batch release can be e.g. an incident scenario in connection to loading on vessels. The of evaporative loss can thus be reduced, as shown as examples for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) in the subchapter below.

As a general recommendation after an acute oil spill involving free gas (e.g. from a oil/gas blowout), a "safety" zone typically 1-2 km from the source should be established early on and downwind from the spill site before response actions are initiated in open seawaters. Prior to the initiation of spill response operations, an evaluation of fire/explosion hazard must always be conducted at the site. Explosimeters should always be utilized continuously, and one should be aware of the possibility for varying release rates if "free" gas is involved.

Moreover, some vessels/storage tanks engaged in oil recovery operations may not be classified to carry liquids with flash points lower than 60 °C, e.g. towing vessels, smaller cargo, or other vessels available in the emergency. This means that fuels or oils with the flash point less than 60 °C, are for those type of vessels not permitted as cargo. However, this limit is not considered as relevant for oil recovery vessels with A-class certification for transport of liquids (Class I/II, flashpoints < 60 °C), according to NFPA classification of Flammable and Combustible Liquids (http://www.thetankshop.ca). Refers to the flash point predictions in Figure 6-3 and Figure 6-12, and the figures below for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2).

The flash points for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) are expected to surpass the sea temperature within a few minutes at 5 and 15 °C, at wind speeds of 5, 10 and 15 m/s predicted with the standardized surface release as shown in Figure 6-3, Figure 6-12 and in Figure 8-1 (Left) and Figure 8-2 (Left). In calmer weather conditions (2 m/s), care should be taken during the first 0.5 hour and use of explosimeter is recommended. Less than 1-hour delay time can be predicted related to fire/explosion hazard related to the flash point of the drifting oil itself. Figure 8-1 (Right) and Figure 8-2 (Right) show that the rate of evaporative loss is reduced particularly for the first hours after the release for a considerably larger (batch) release rate (8000 m^3/h). For SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2), the time when the flash point has surpassed the sea temperature has now increased to 2 hours at 2 m/s wind speed.

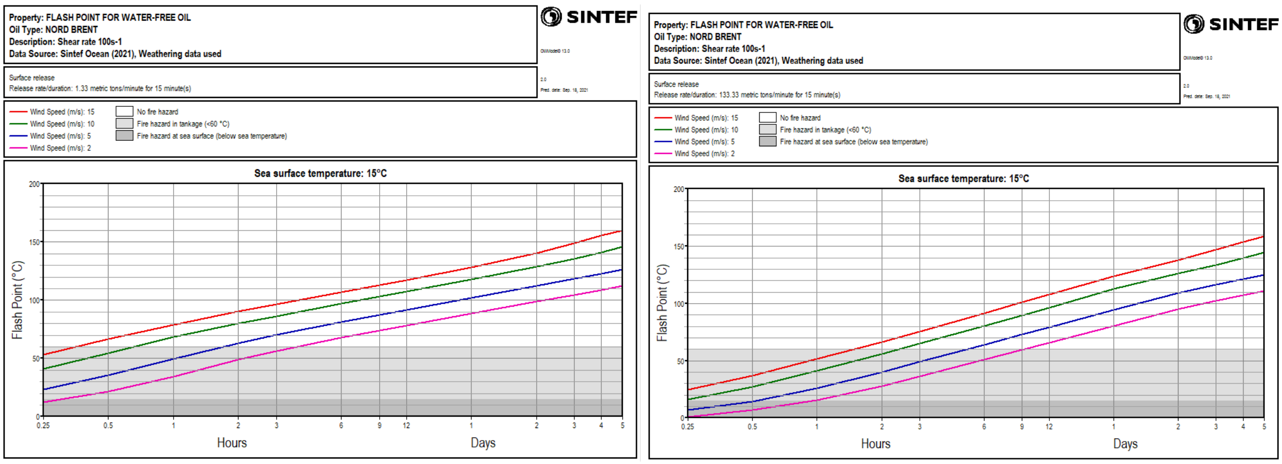

Figure 8-1 *Left: Predicted flash points for SF Nord Brent (E-2&E-3) at 15 °C (80 m^3/ h).*
Right: Predicted flash points for SF Nord Brent (E-2&E-3) at 15 °C (8000 m^3/ h).

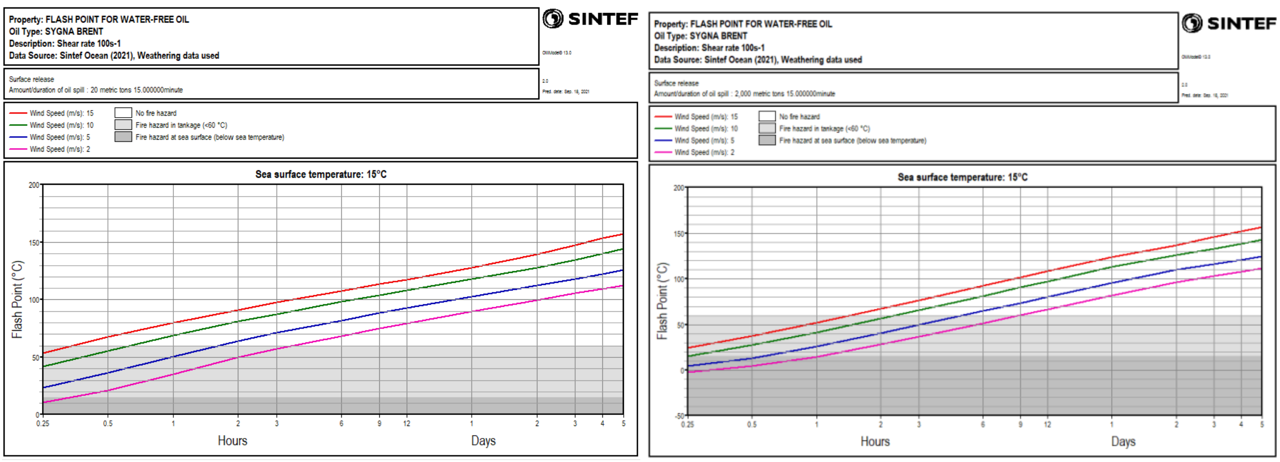

Figure 8-2 *Left: Predicted flash points for Sygna Brent (N-1&N-2)) at 15 °C (80 m^3/ h).*
Right: Predicted flash points for Sygna Brent (N-1&N-2) at 15 °C (8000 m^3/ h).

8.3 Solidification

Pour point depends on the oil's wax content and the amounts of light components that can keep the wax components dissolved in the oil phase. In addition, contents of asphaltenes may prevent or reduce precipitation and lattice formation and hence lowers the pour point. High pour points may prevent the dispersant to soak into the oil slick and influence the dispersant effectiveness and may also reduce the potential for flowability towards weir skimmers. In cases when high viscosities are not a limiting factor, high pour points may cause solidification (elastic properties) of semi-solid patches when oil is spilled on the sea surface. High pour point may therefore imply solidification on the sea surface immediately after the release, and this is pronounced when the pour point is typically 5-15 °C above sea temperature and in cold temperatures.

If the oil is mixed with the seawater by waves and forms w/o-emulsions, the wax lattice in the oil will likely be weakened and may break up. This is accordance with the emulsifying properties of oils from the laboratory experiments. SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) have high pour points of their residues, and a remaining residues at sea may therefore have a potential to solidify, particularly in winter condition as shown for the pour point predictions in Figure 6-4 and 6-13, respective.

8.4 Lifetime at sea – Submerged oil and evaporation

The lifetime of an oil spill at sea depends on the oil's composition, the release conditions (e.g. on the surface, underwater) and environmental conditions (temperature, wind, waves). Submerged oil (natural dispersion) and evaporation are the main weathering processes that remove an oil spill from the sea surface. The remaining surface oil after a release depends on the wind speeds and typically oils are more persistent on the sea surface with lower wind.

Figure 8-3 and Figure 8-4 show the predicted remaining surface oil over time (5 days) for different wind speeds and temperatures for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2), respective. Only minor difference in lifetime between 5 and 15 °C for both oils. At high wind speeds of 15 m/s, no oil is predicted to remain on the sea surface after about 2 days of weathering for both oils.

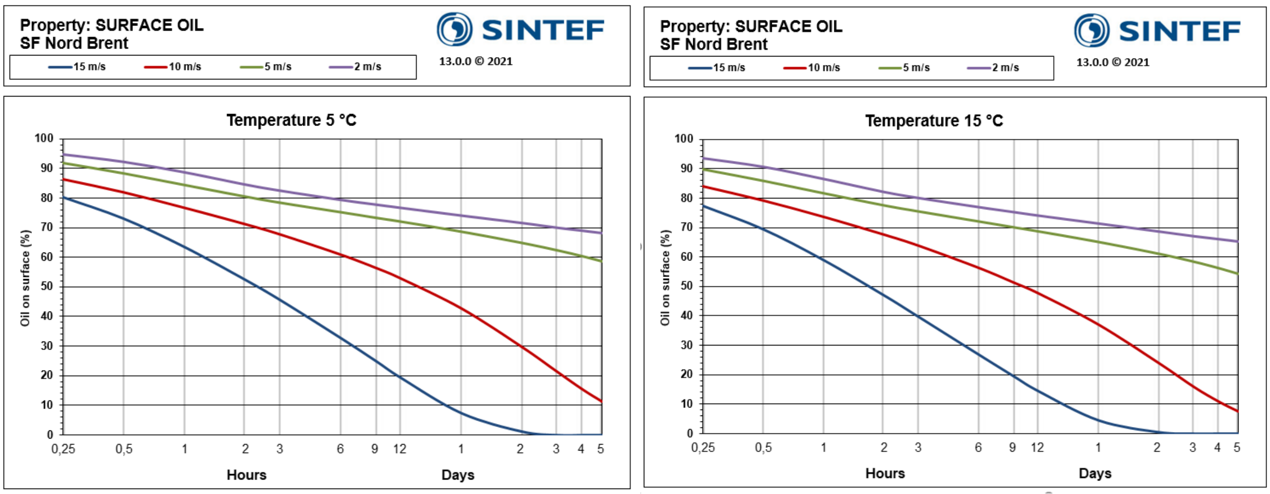

Figure 8-3 Predicted remaining surface oil for SF Nord Brent (E-2&E-3) at 5 and 15 °C.

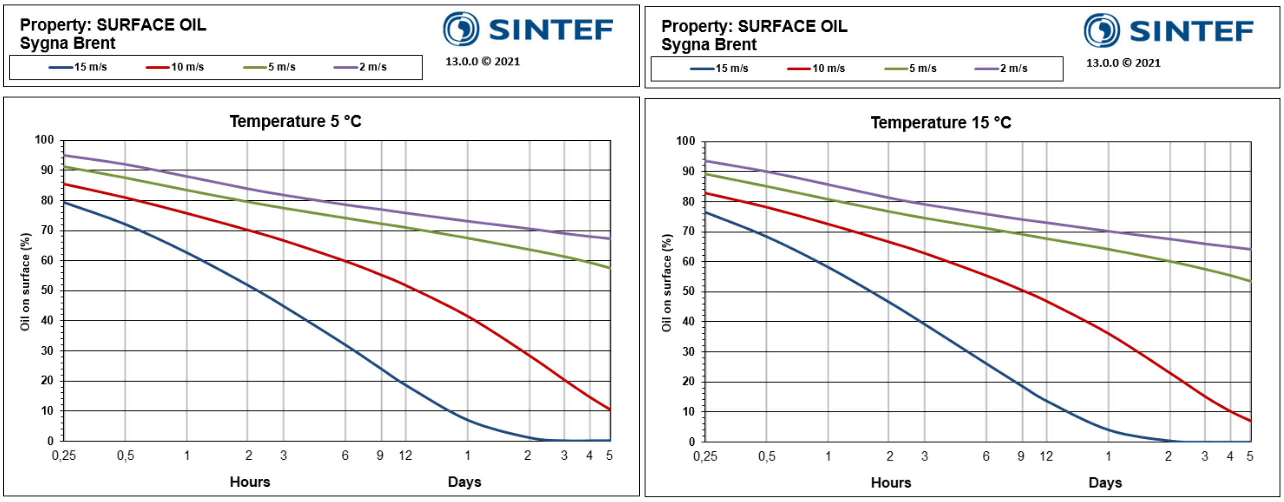

Figure 8-4 *Predicted remaining surface oil for Sygna Brent (N-1&N-2) at 5 and 15 °C.*

8.5 Film thickness from surface release

In general, mechanical recovery requires normal minimum film thicknesses >0.1-0.2 mm. Film thicknesses > 0.05-0.1 mm are considered for application of oil spill dispersants. Lower film thicknesses are likely to disperse naturally under breaking waves conditions and can be enhanced in non-breaking waves by mechanical dispersion (subchapter 8.7). Figure 8-5 and Figure 8-6 show the predicted film thickness of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2)for a surface release, respective. The increase in film thickness after 1-2 hours is due to emulsification. Other factors than film thickness should also be considered when evaluate response options, as described in the next chapters.

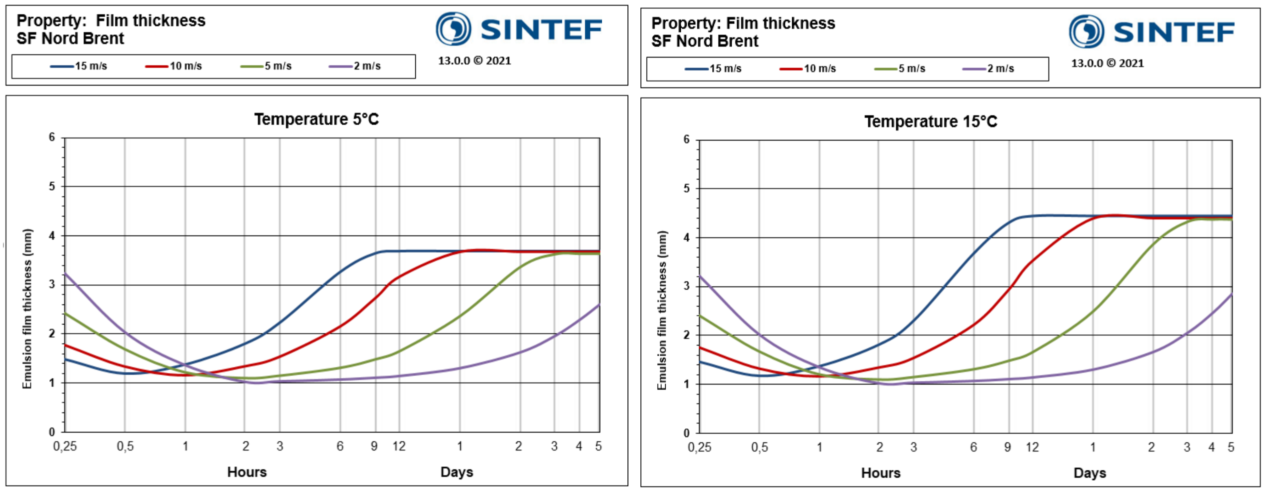

Figure 8-5 *Predicted film thickness of SF Nord Brent (E-2&E-3) from a surface (batch) release at 5 and 15 °C.*

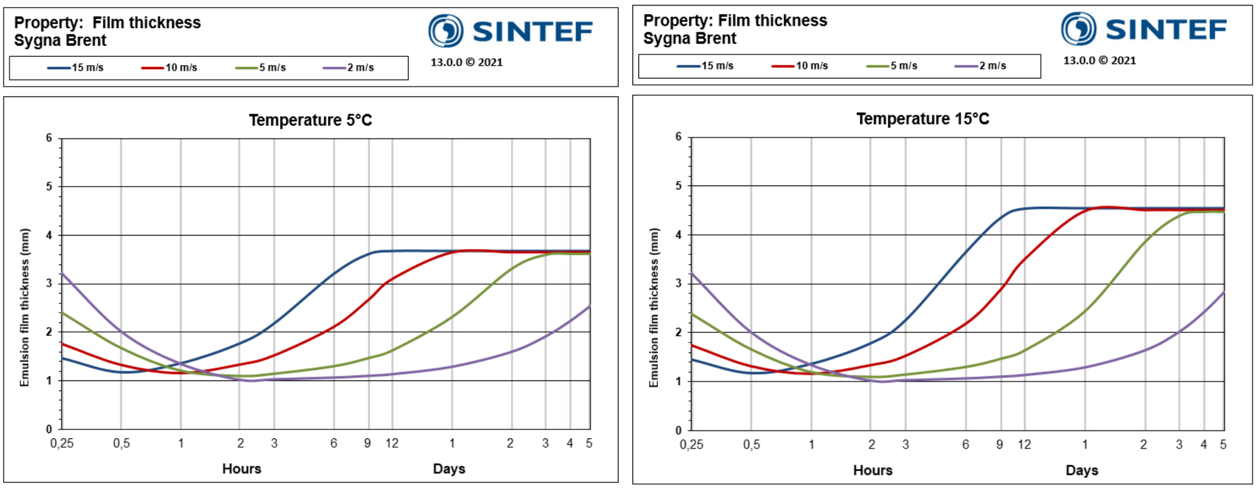

Figure 8-6 Predicted film thickness of Sygna Brent (N-1&N-2) from a surface (batch) release at 5 and 15 °C.

8.6 Mechanical recovery by boom and skimmer

Experiences from Norwegian field trials with booms have demonstrated that the effectiveness of various mechanical clean-up operations may be reduced due to the high degree of leakage of the confined oil or emulsion from the oil spill boom. Boom leakage is particularly pronounced if the viscosity of the oil or the w/o-emulsion is lower than 1000 mPa.s (Nordvik et al., 1992). The lower viscosity limit for an optimal mechanical clean-up operation has therefore been estimated to 1000 mPa.s. However, other factors like the operational speed of recovery vessel and current weather conditions will also influence on the risk of boom leakage. Weir skimmers may reduce recovery rates (m3/h) when skimming oils with viscosities in the range 15-20 000 mPa.s (Leirvik et al., 2001). NOFO is operating with viscosity limits for skimmer efficiency as followed: primary use of weir skimmers (< 20 000 mPa.s), combination of weir and high-visc. skimmers (20-50 000 mPa.s), and primary high visc. skimmer (> 50 000 mPa.s).

The emulsion viscosities of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) are shown in Figure 8-7 and Figure 8-8 at 5 and 5 and 15 °C, respective. For example, the emulsion viscosity exceeds 1000 mPa.s after 2 hours at 10 m/s wind speed but may be stretched up to 1 day in calm wind conditions (2 m/s). Overall, both crude oils have a wide window of opportunity for traditional weir-skimmer head due to viscosities < 20 000 mPa.s after 5 days of weathering at summer conditions at with speeds 2-15 m/s, except from 5 °C and 15 m/s the viscosities may reach > 20 000 mPa.s after 2 days for both oils.

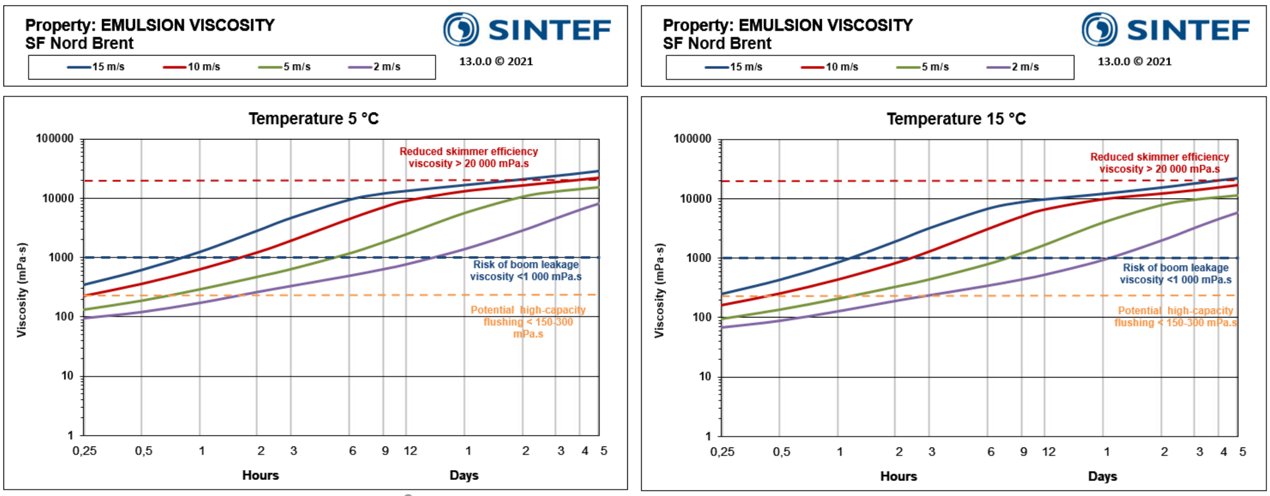

Figure 8-7 Expected time window for effective use of booms and skimmers and high-capacity water flushing (see subchapter 8.7) as a function of emulsion viscosity of SF Nord Brent (E-2&E-3) at 5 and 15 ºC.

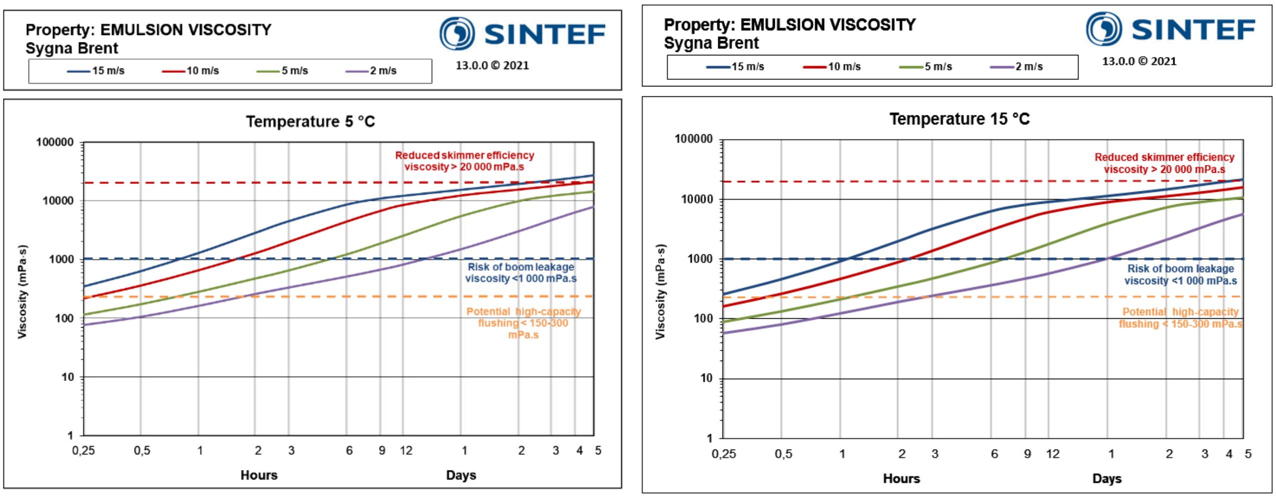

Figure 8-8 *Expected time window for effective use of booms and skimmers and high-capacity water flushing (see subchapter 8.7) as a function of emulsion viscosity of Sygna Brent (N-1&N-2) at 5 and 15 ºC.*

8.7 Mechanical dispersion by high-capacity water flushing

In general, mechanical dispersion by high-capacity water flushing without using dispersants could have a potential for oil spill with thin (initial) film thickness up to 0.2-0.3 mm and viscosities <150-300 mPa.s. In such cases, water flushing from high-capacity water flush booms and/or firefighting (Fi-Fi) systems could possibly break up the oil/residue into smaller droplets and enhance the dispersion into the water column. Moreover, water flushing could also be used in combination with application of dispersant in calm weather condition to enhance dispersant efficiency with use of artificial energy some minutes after the dispersant treatment. This technology was tested in a full-scale trial (NOFO Oil-on-Water trial) in 2016 and described by Daling et al., 2017 and Sørheim et al., 2017.

However, for surface releases of SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) high-capacity mechanical dispersion by water flushing is not considered as a strategy in oil spill response due to the formation of high emulsion film thicknesses by emulsification, even the oil has low emulsion viscosities in the very early stage after an oil spill, as shown in Figure 8-7 and Figure 8-8 . The rapidly emulsification of both crude oils are the limiting factor for this strategy. However, use of water-flushing can be a supplementary method in areas with thin oil films, e.g. metallic /rainbow appearance.

8.8 Chemical dispersion

SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) have both a potential for use of oil spill dispersant from aircraft and /or vessel.

The viscosity limit for effective dispersant use was estimated to 2500 mPa.s for SF Nord Brent (E-2&E-3) and 1700 mPa.s for Sygna Brent (N-1&N-2) by use of the low energy IFP-test. The viscosity limit for when the emulsified oil is not considered to be dispersible by use of the high energy MNS-test was estimated to 7000 mPa.s and 8000 mPa.s for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) respective. This indicates that SF Nord Brent (E-2&E-3) has reduced dispersibility for viscosities between 2500-7000 mPa.s, and similar 1700-8000 mPa.s for Sygna Brent (N-1&N-2). In cases were the oil (emulsion) is expected to be reduced dispersible, additional energy or use of a higher dispersant dosage and/or repeated dispersant application is recommended to possible enhance the dispersant efficiency. Providing additional energy through use of Fi-Fi systems, thrusters or MOB boats after dispersant application may increase the dispersion rate in calm weather condition.

The window of opportunity for use of dispersant Dasic Slickgone NS is presented in Figure 8-9 and Figure 8-10. SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) are predicted to be (reduced) dispersible up to 1-2 days with wind speeds 10-15 m/s at 5 and 15 °C, and longer time-window in calmer wind speeds.

High pour points could reduce the dispersant effectiveness, where the dispersant droplets have a reduced ability to diffuse into the oil and may appear as droplets on the surface of the solidified wax and be washed of by wave activity. In calm weather conditions, low emulsification rate may enhance formation of solidified residues at sea, particularly at 5 °C. In a spill situation, the use of a simplified dispersibility testing kit is therefore recommended to assess the potential for chemical dispersion.

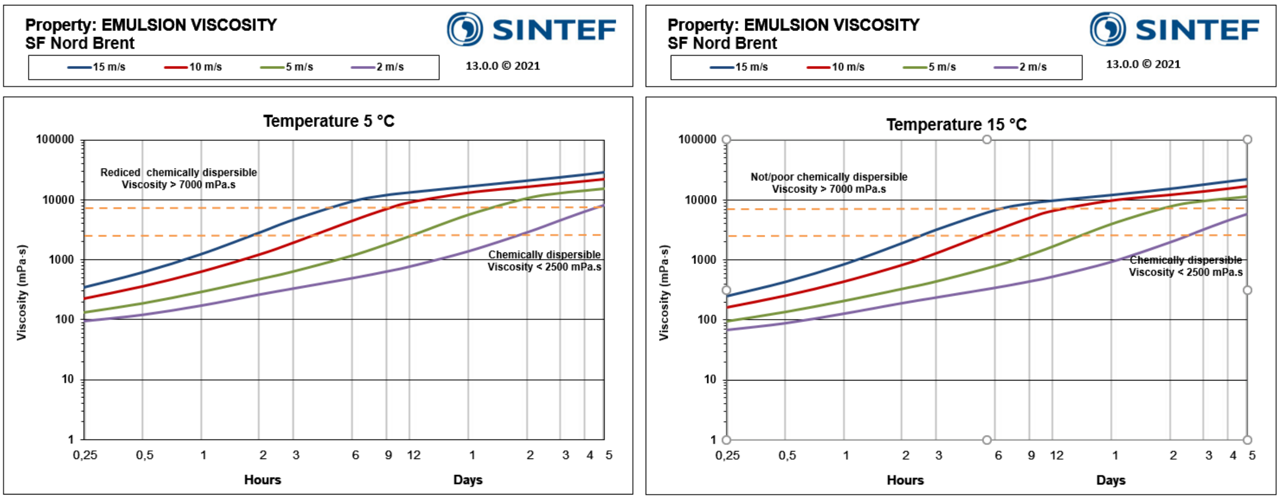

Figure 8-9 Expected time window for effective use of dispersants as a function of emulsion viscosity of SF Nord Brent (E2&E3) at 5 and 15 ºC.

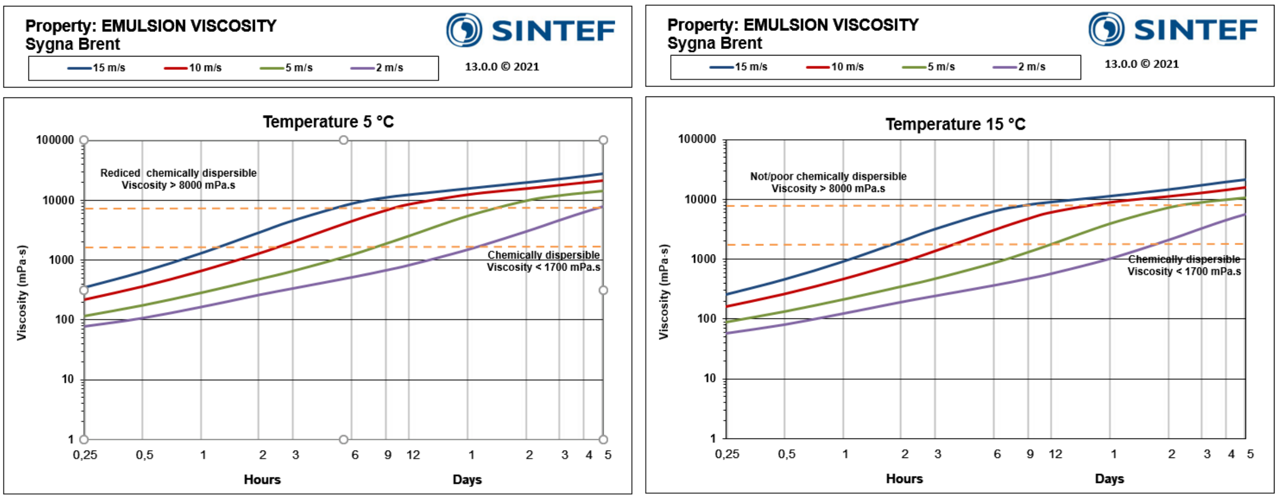

Figure 8-10 Expected time window for effective use of dispersants as a function of emulsion viscosity of SF Nord Brent (E2&E3) at 5 and 15 ºC.

9 Summary of response options from surface releases

SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) are medium density paraffinic crude oils that form stable water-in-oil (w/o) emulsions in scenarios where the (initial) film thickness > 0.1 mm, typically from surface releases. Certain scenarios from underwater releases depending on the water depth, gas to oil ratio (GOR), release rate etc. may also produce initial film thicknesses > 0.1 mm of surfaced oil, otherwise thinner initial oil films can be expected, however this has not been evaluated. The high pour points of surface residue may cause solidification at sea for both oils, particularly in calm conditions at low temperatures. High pour points typically prevent or reduce the dispersant efficiency.

Mechanical recovery:

- SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) exhibit a wide window of opportunity for mechanical recovery with use of skimmers, such as the Transrec equipped with traditional weir-skimmer head for emulsion viscosities < 20 000 mPa.s.
- Boom leakage and reduced recovery is expected for viscosities < 1000 mPa.s.

Use of chemical dispersants:

- SF Nord Brent ((E-2&E-3) is found to be dispersible with use of Dasic Slickgone NS for viscosities < 2500 mPa.s (DOR 1:25), and not (poorly) dispersible for viscosities > 7000 mPa.s.
- Sygna Brent (N-1&N-2) is found to be dispersible with use of Dasic Slickgone NS for viscosities < 1700 mPa.s (DOR 1:25), and not (poorly) dispersible for viscosities > 8000 mPa.s.
- In the field particularly in calm conditions, additional energy or higher DOR and/or repeated dispersant application may increase the dispersant effectiveness when viscosities showing reduced dispersible.

High-capacity water flushing (mechanical dispersion):

- The emulsification is the limiting factor for this strategy.
- The predicted film thickness is > 0.2-0.3 mm from surface release which is the estimated upper limit for effective use of high-capacity water flushing.
- Water flushing is therefore not considered as a main response option for emulsions of neither SF Nord Brent (E-2&E-3) nor Sygna Brent (N-1&N-2).
- Mechanical dispersion can be used a supplementary /secondary method on areas of thin oil films e.g. metallic/rainbow appearance in calm weather conditions.

In-situ burning (ISB):

- ISB has not been specific evaluated in this report and refers to the Response guide summary in Appendix F for estimated time windows for contained oil with use of fire-resistant booms.

Monitoring and remote sensing:

- Monitoring and remote sensing should always be used a support in a response operations for SF Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2).

10 Comparison of tested oils to other Norwegian crude oils and condensates

A semi-quantitative categorization has been developed by SINTEF to map crude oils into four main groups: Paraffinic, waxy, naphthenic, and asphaltenic oils, based on their typically physiochemical properties, as described below.

Naphthenic oils typically exhibit disrupted n-alkane (paraffins) patterns due to high degree of biodegradation of the oil in the reservoir. The content of paraffins is therefore normally low in for these oils and have low pour points (typically <-10 °C) with corresponding low wax content. Such biodegraded crude oils may have high densities and a high degree of UCM (Unresolved Complex Mixture) consisting of a wide range of complex components, such as resins and naphthenes, but this is not true for all naphthenic oils.

Paraffinic oils are often characterized by low to medium density, which reflects high content of light and saturated components, such as paraffins (n-alkanes). Paraffinic crudes differ mainly from the waxy crudes with a lower wax content (typically < 6 wt. %), hence the pour point of the fresh crude is often lower compared with waxy crude oils. Paraffinic crudes exhibit medium to high evaporation loss, with rapid and high-water uptake, and normally form stable emulsions.

Asphaltenic oils have high content of heavier components reflected by high densities (typically > 0.9 g/mL) and low evaporation loss. The asphaltenic crudes often exhibit low pour points (typically >-4 °C) due to the high asphaltene content (> 1 wt. %) preventing wax precipitation and formation of a wax lattice structure. Compared with paraffinic and waxy crudes the asphaltenic crude oils usually have both a slower and a lower maximum water uptake. The asphaltenic crude oils form very stable, highly viscous, and persistent blackish emulsions with long expected lifetime on the sea surface. The high stability is caused by the stabilization by the polar components in the oil.

Waxy oils often exhibit high pour points due to large content of wax components (typically > 6 wt. %). These oils tend to solidify producing elastic properties on the sea surface, particularly observed at low seawater temperatures. Solidification is typically pronounced if the seawater temperature is 5-15 ºC below the pour point. Waxy crude oils typically exhibit a light to medium evaporative loss. The water uptake can vary extensively, whereas the emulsions can be very stable or even highly unstable depending on the content of stabilizing and polar surface-active components like the asphaltenes and resins.

The categorization of a selection of Norwegian crude oils including the eight Statfjord crude oils from this project are given in Figure 9-1.

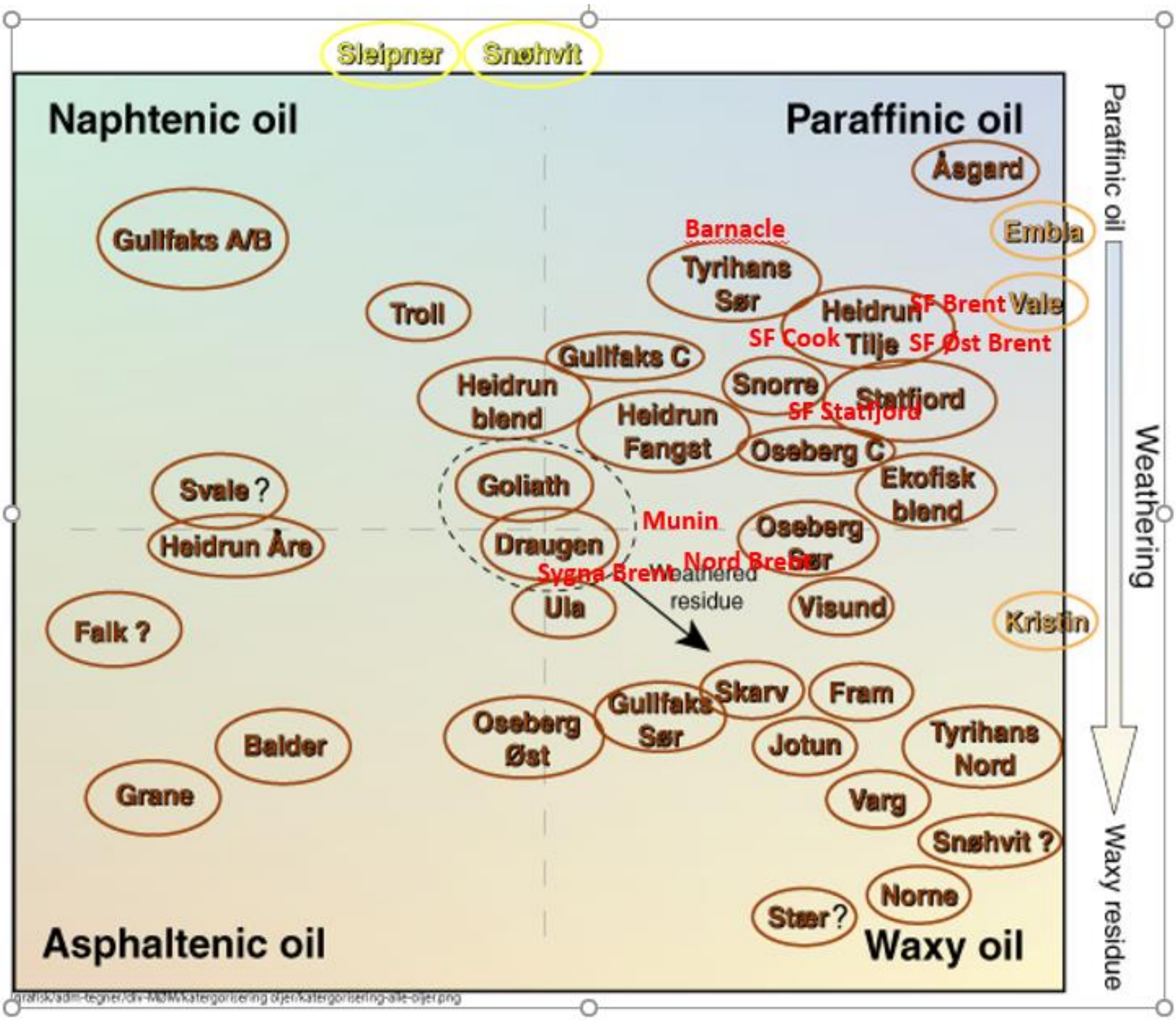

Figure 9-1 Categorization of Statfjord crude oils.

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A The behaviour of crude oil on the sea surface

A.1 The chemical composition of crude oils and condensates

Crude oil is a complex mixture of thousands of chemical components. The relative compositions vary, giving rise to crude oils with different chemical and physical properties. The components found in crude oil are classified into two main chemical groups: hydrocarbons and heteroatomic organics see Figure A-1.

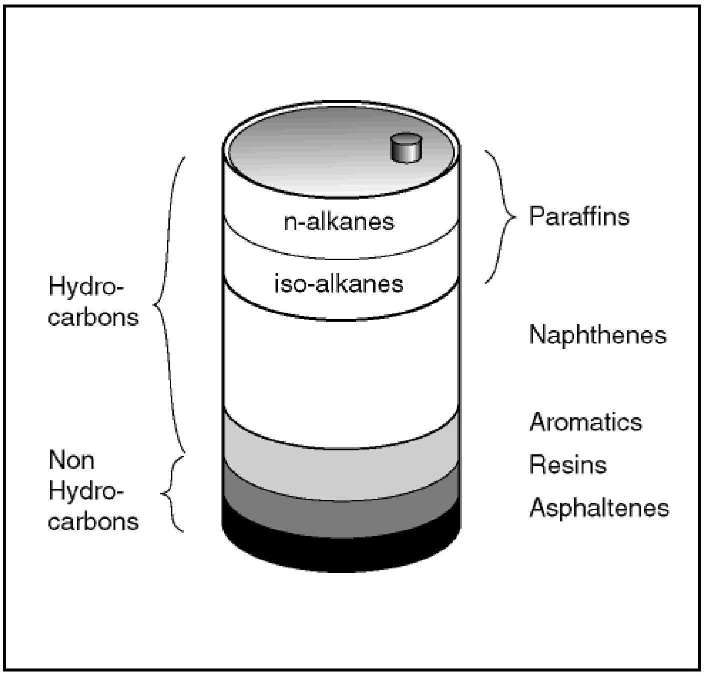


Figure A-1 The chemical composition of crude oils.

A.1.1 Hydrocarbons

The majority of compounds in crude oils are hydrocarbons, which are composed of hydrogen (10-15 wt. %) and carbon (85-90 wt. %). These range from simple, volatile gases, such as methane with only one carbon atom to large, complex molecules with more than 100 carbon atoms. The hydrocarbons in crude oils include saturated and unsaturated molecules in linear, branched and cyclic configurations.
Hydrocarbons are further classified into aliphatic and aromatic compounds. The two main groups of aliphatic compounds are paraffins and naphthenes.

Paraffins include *n*-alkane and iso-alkane aliphatic compounds. Waxes are an important subgroup of paraffins, containing more than 20 carbon atoms. The wax components of a crude oil will be present in a solution at elevated temperatures. At low temperatures, they may precipitate from the solution. These are principally n-alkanes. The wax content of crude oils can vary from 0.5 wt.% up to 40 or 50 wt.% in extreme cases, although the majority of the world's crude oils have a wax content of 2-15 wt.%.

Naphthenes include cycloalkanes containing one or more saturated rings. Each ring may have one or more paraffinic side chains, which are chiefly five- and six-membered rings.

Aromatics are a specific type of unsaturated cyclic hydrocarbons. Benzene, toluene and xylenes are examples of mono-ring aromatics, naphthalenes are di-ring aromatics and polycyclic aromatic hydrocarbons (PAH) contain three or more aromatic rings.

A.1.2 Heteroatomic organics

In addition to pure hydrocarbons, some organic compounds in crude oils also contain small amounts of oxygen, nitrogen or sulphur, as well as some trace metals such as vanadium and nickel. The two most important groups of heteroatomic organic compounds are resins and asphaltenes.

Resins are relatively polar compared to the hydrocarbons, and often have surface active properties. Resins have molecular weights ranging from 700-1000. Carboxylic acids (naphthenic acids), sulphoxides and phenol-like compounds can be found in this group as well.

Asphaltenes are a complex group of poorly characterized chemical compounds that consist of condensed polycyclic aromatic compounds. They are large molecules with 6-20 aromatic rings and side chains (molecular weight 1000-10000). Asphaltenes may be classified as "hard" or "soft" based on the analytical method. Crude oils may contain up to 6 wt. % "hard" and 10 wt. % "soft" asphaltenes.

A.2 Main oil categories – Related to weathering

The relative composition of oils will differ extremely, resulting in great variations in physical properties and following, behaviour after a spill at sea.
Related to weathering oils can roughly be divided into 3 main categories:

- Crude oils
- Light oils
- Condensates

Crude oils contain relatively more of the heavier components than the other two categories, and the 250˚C+ residue (corresponds to 0.5 to 1 week after a spill at sea) evaporates less than 50 vol. %. The heavier components make possible formation of stable water-in-oil (w/o) emulsions, which reduces the oil spreading at the sea surface. The final (terminal) film thickness of a crude oil depends on the emulsion's physical properties, and will be in the order of 1 mm.

Light oils and crude oils are not differentiated in the reservoir terminology. However, related to weathering studies, it is suitable to deal with the light oils as a separate category. Light oils have a high content of light components, and the 250˚C+ residue evaporates less than 50 - 70 vol. %. In contrast to condensates light oils also contain heavier components. The content of these heavier, emulsion-stabilizing components cause that light crudes may emulsify water. These w/o emulsions are, however, very unstable. A light oil will spread less than a condensate, and a final film thickness of 0.5 mm is estimated.

Condensates evaporates typically more than 70 vol. % for the 250˚C+ residue. Condensates will not contain components as asphaltenes and heavier waxes and will not emulsify significantly amounts of water. The spreading is vast, with a final film thickness in the order of 0.05 mm.

A.3 Physical properties of crude oils

The physical properties of specific oils are a result of their chemical composition. The most important physical properties in oil spill scenarios are discussed below.

Density

The density of a crude oil is dependent on the density of all its components. The density of the hydrocarbons increases with increasing molecular weight. Furthermore, paraffinic oils have lower density than those containing large amounts of high molecular weight aromatics, naphthenes and asphaltenes. Specific gravity is defined as the oil density at 60°F (15.5°C) divided by water density at 60°F. In American literature, the density of the oil is often expressed as °API, where:

$$°\text{API} = \frac{141.5}{Secific\ gravity} - 131.5$$

In the present study, the density of the oil is presented as specific gravity.
The density of fresh crude oils normally lies in the range 0.78 to 0.95 g/mL (50 to 10 °API).

A.3.1 Rheological properties

The viscosity of crude oils expresses its resistance to flow and is of special interest when pumping oil.
Absolute viscosity is *force distance/area speed* and has the unit: dyn·sec/cm^2 = 1 Poise. The industry is often using the unit mPa·s = centipoise (cP). The viscosity of fresh crude oils can vary from less than 1 to more than 2000 mPa·s (cP) at ambient sea temperature. In comparison water has an "absolute" viscosity of 1 cP and syrup 120 000 cP at 20°C.
Kinematic viscosity is absolute viscosity divided by density. 1 centistoke (cSt) = 1 cP / density. Because the density of weathered oils and emulsion are typically 0.9 – 1 g/mL, the units cSt and cP will often have similar values.

The viscosity is temperature dependent. For liquids, the viscosity decreases with increasing temperatures. Viscous and waxy crude oils can exhibit non-Newtonian behaviour (viscosity varies with shear rate), especially close to, or below, their pour-point. Water-in-oil (w/o) emulsions exhibits this non-Newtonian behaviour with shear-thinning. In an oil spill situation, an emulsion may be quite liquid under turbulent conditions at sea, but can become much more viscous, or even semi-solid in calmer water conditions, or on beaches. Thus, the measurements of the viscosity of w/o-emulsions must be carried out under strictly controlled conditions (defined shear rates and thermal and mechanical history of the sample). At SINTEF a shear rate of 10 s^{-1} is routinely used for expressing viscosity data on w/o-emulsions. The viscosity of an oil increases with evaporation since the heavier, more viscous components remain in the residue (Mackay et al, 1982). The difference in viscosity for crude oils is approximately 3 to 2000 mPa·s for fresh crude oils and several hundred/thousand mPa·s for their residues. Water-in-oil (w/o) emulsions are generally more viscous than the parent crude oil; this is illustrated in Figure A-2.

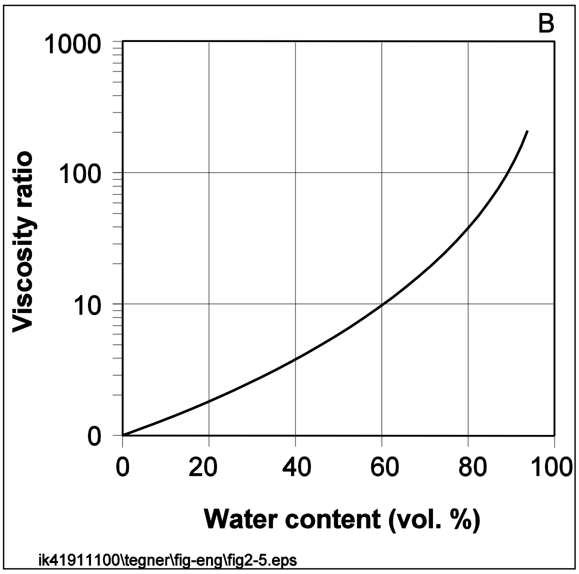


Figure A-2 Example of viscosity ratio as a function of water content.

A.3.2 Pour point

The temperature at which oil ceases to flow when cooled without disturbance under standardized conditions in the laboratory is defined as the oil's pour point (ASTM-D97). The method accurately determines the temperature at which the oil become semi-solid under the specified laboratory conditions. Due to the movement at the sea surface, the oil may remain a liquid at sea at temperatures as low as *10 to 15˚C lower* than the pour point of the oil. The pour point of oil with high wax content will increase dramatically with evaporation as the lower weight molecules, which contribute to keeping the wax in solution, evaporate. The pour point for oils with high wax contents can reach 30 °C, while low viscous naphthenic oils may have pour points as low as – 40 °C. In an oil spill clean-up situation, the pour point provides important information when determining the efficiency of various skimmers, pumping rates and the use of dispersing agents.

A.3.3 Distillation curve (True Boiling Point curve)

The distillation curve, which is obtained by measuring the vapour temperature as a function of the amount of oil distilled, shows the relative distribution of volatile and heavier components in the oil. The boiling point of a particular chemical component depends on its vapour pressure, which is a function of its molecular weight and chemical structure. Low molecular weight oil components have a higher vapour pressure, thus lower boiling points than higher molecular weight components of a similar type. Aromatic compounds boil at a higher temperature than paraffinic compounds of the same molecular weight, and iso-alkanes boil at a lower temperature than the equivalent *n*-alkanes. Hence, the distillation curve is an indicator of the relative amount of different chemical components, principally as a function of molecular weight, but also as determined by the chemical composition.

A.3.4 Flash point

The flash point is the lowest temperature at which the gas or vapour generated by the heating of oil will form an ignitable mixture in air. The flash point depends on the proportion of low molecular weight components. Fresh crude oils normally have a low flash point (from -40°C to 30°C). From a safety point of view, flash points are most significant at, or slightly above, the maximum temperature that may be encountered in storage or transport. The flash point is an approximate indicator of the relative fire and explosion hazard of oil.

Rule of thumb:
Moving in an oil slick where the oil's flash point is close to or lower than the sea temperature implies a fire and/or explosion hazard.

Natural weathering processes such as evaporation and emulsion formation contribute to reducing the potential hazard by increasing the flash point. Thus, it will be a relatively short fire and/or explosion danger in the initial stages of oil spill. In the laboratory, the flash point is measured in a closed system with the components in the oil and gas equilibrated. In the field, however, the weather situation will influence the flammability of the air above the slick. The gas concentration will be high just above the oil film in calm weather and high temperatures, whereas the concentration will be low in cold and windy weather due to dilution and transport and a lower degree of evaporation.

A.4 The behaviour of crude oil spilled at sea

This chapter gives a general description of the main weathering processes when oil is spilled at sea. There is a number of natural processes take place that change the volume and chemical properties of the oil. These natural processes are evaporation, water-in-oil (w/o) emulsification, oil-in-water (o/w) dispersion and the release of oil components into the water column, spreading, sedimentation, oxidation and biodegradation. A common term for all these natural processes is weathering. The relative contribution of each process varies during the duration of the spill. The weathering of oil depends on the oil type (chemical and physical properties), the weather conditions (wind, waves, temperature and sunlight) and the properties of the seawater (salinity, temperature, bacterial flora, etc.). Figure A-3 illustrates the various weathering processes, and Figure A-4 shows their relative importance over time.

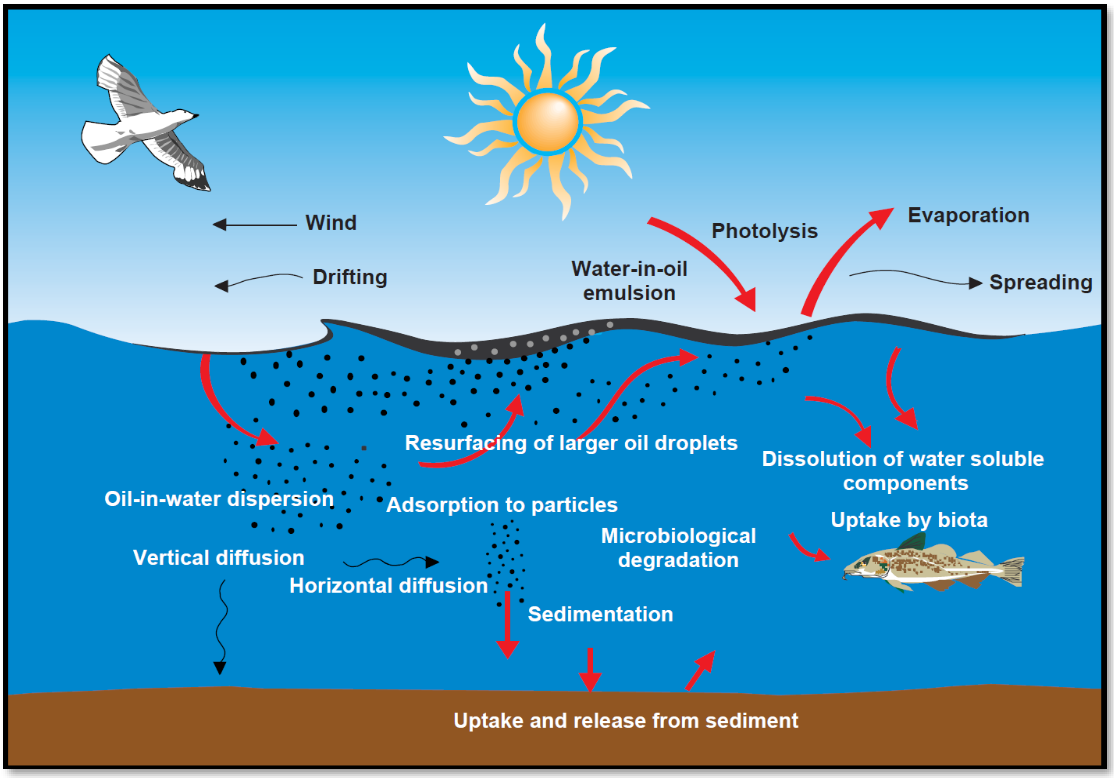


Figure A-3 Illustrating the weathering processes that take place when oil is spilled on the sea surface.

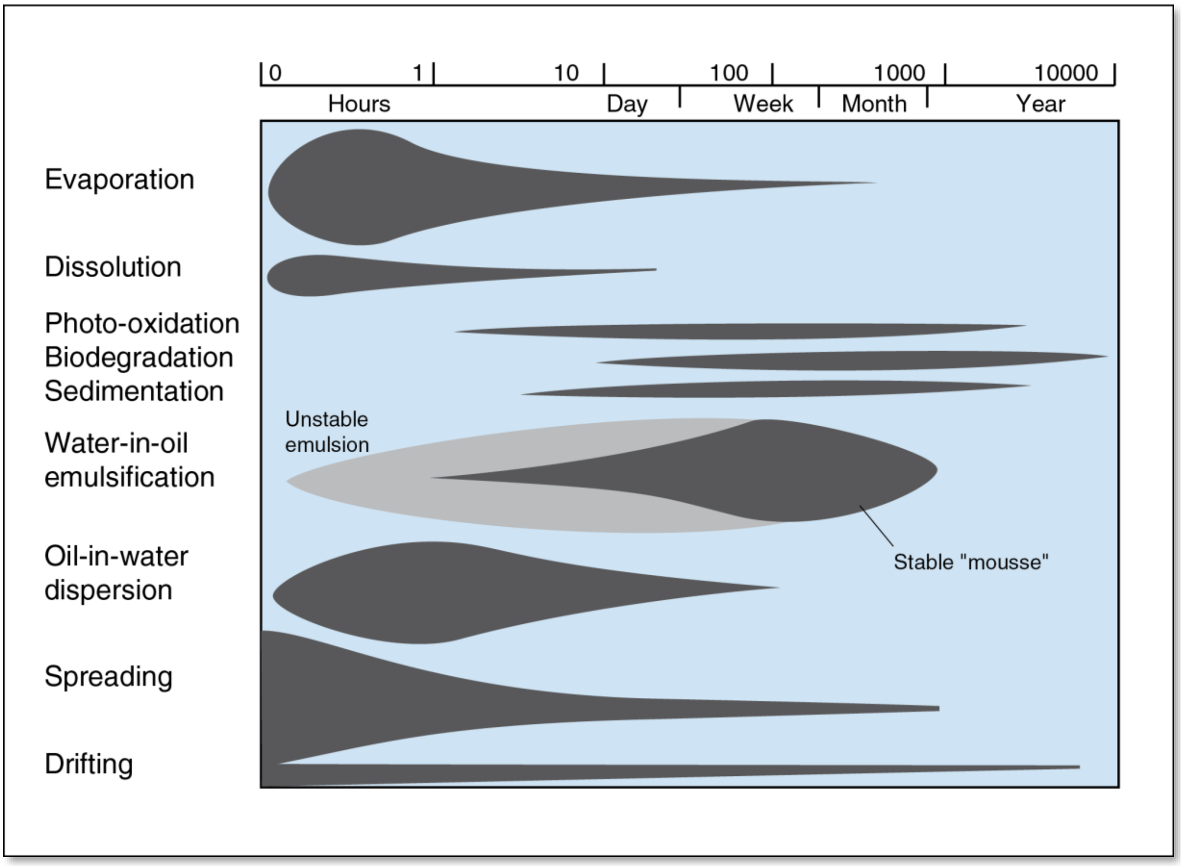


Figure A-4 Weathering processes' relative importance over time. Note: logarithmic scale.

A.4.1 Evaporation

Evaporation is one of the natural processes that support the removal of spilled oil from the sea surface. The evaporation process starts immediately after the oil is spilled, and the evaporation rate decreases exponentially throughout the duration of the oil spill. The evaporated amount depends on the chemical composition of the oil in addition to the prevailing weather conditions, sea temperature and oil film thickness. The rate of evaporation varies for different oil types. Light refinery products (e.g. gasoline and kerosene) may completely evaporate after a few hours/days on the sea surface. Condensates and lighter crude oils can lose 50% or more of their original volume during the first days after an oil spill. The most significant difference caused by evaporation is the loss of volatile and semi-volatile compounds, which increases the relative amounts of higher molecular weight compounds. With evaporations, the chemical and physical properties of the remaining oil will change. The density, viscosity, pour point and wax and asphaltene content, will all increase with increased evaporation.

A.4.2 Spreading

Oil spilled at sea will spread on the sea surface. Spreading is often the dominant process in the initial stages of an oil spill and decreases as the viscosity and density of the remaining oil increases. The spreading process is also retarded if the oil's pour point is 10-15 °C below the sea temperature. Oceanographic conditions (e.g. wind, waves and currents) affect the spreading process. The oil slick will be broken into windrows aligned in the direction of the wind, see Figure A-5. The thickness of the oil slick varies, often differing by a factor of several thousand. Experience has shown that e.g. 90 vol.% of the oil spilled may consist of patches of w/o emulsion with a film thickness of 1 to 5 mm, which often constitutes less than 10% of the total oil slick area. The remaining 5-10 vol. % usually covers 90% of the spill area in the form of a sheen (<1 µm oil thickness).

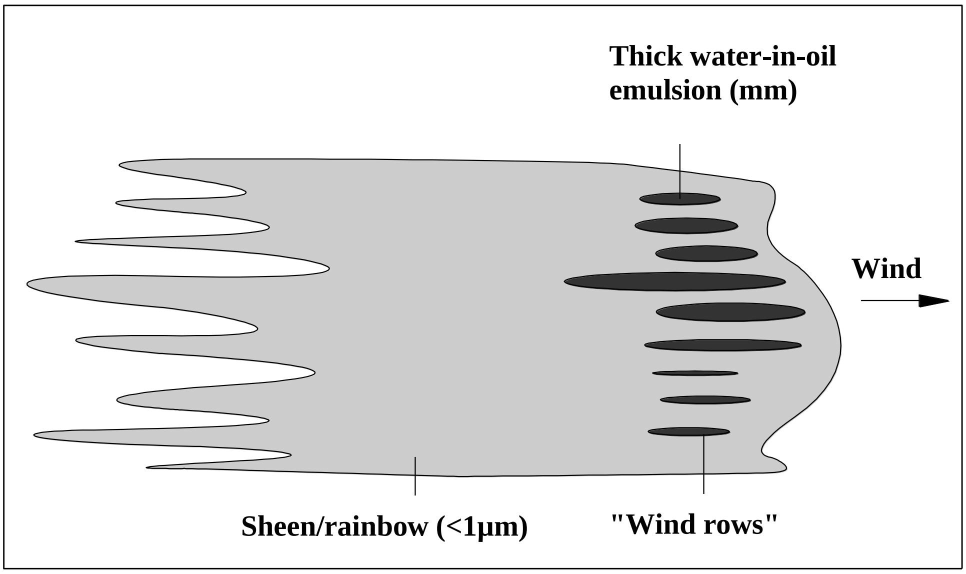


Figure A-5 *The spreading of oil spilled on the sea surface and the distribution within the oil slick.*

A.4.3 Drift of an oil slick

The oil slick will drift as the weathering processes continue. The wind and current conditions cause the oil slick to drift, as illustrated in Figure A-6. Waves and wind create a current in the mass of water which amounts to approximately 3% of the wind speed at the sea surface. The influence of the wind decreases rapidly with the depth of the water below the surface. At 1 to 2 meters the current reduces to approximately 1% of the wind speed. This means that oil on the surface of the open sea, will move faster than the water below (e.g. Reed and Turner, 1991; Reed et al, 1994). In the absence of wind, the oil drift is governed by the prevailing (background) current.

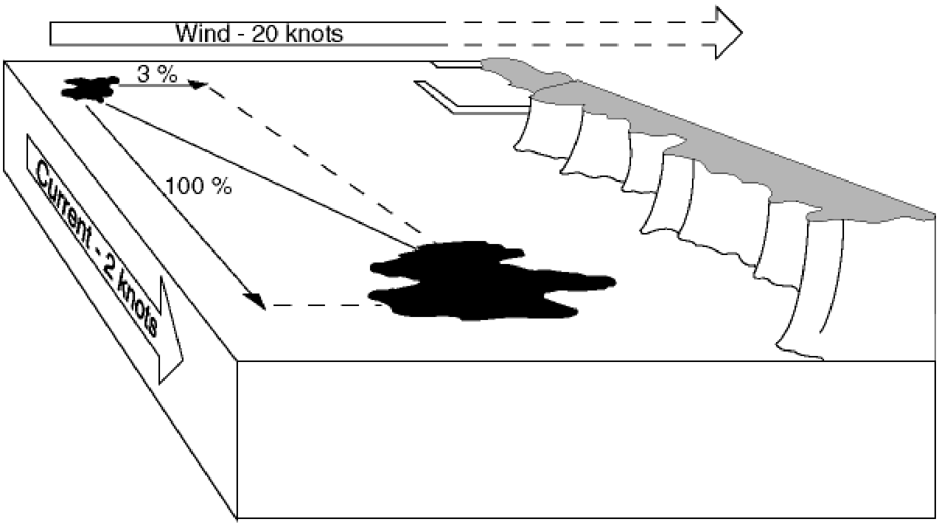


Figure A-6 *An illustration showing how wind and current can influence the drifting of an oil slick.*

A.4.4 Water-in-oil (w/o) emulsion

The formation of water-in-oil emulsions significantly affects the behaviour and clean-up of oil spilled at sea. As a result of emulsification, the total emulsion volume may increase to as much as six times the original spilled oil volume depending on the properties of the oil. The formation of w/o emulsions also contributes to keeping oil on the sea surface. A w/o emulsion normally has a higher viscosity than the parent crude oil, so the emulsification process will therefore retard/delay evaporation and the natural dispersion process. The minimum criterion for the formation of w/o emulsions is the presence of breaking waves (i.e. a wind speed of >5 m/s). Nonetheless, a slow water uptake can also take place during calmer weather. Figure A-7 shows how wind speed influences the w/o formation rate. Surface active compounds present in crude oil will promote the formation of w/o emulsions and contribute to stabilizing the emulsion. These components contain both hydrophilic and hydrophobic groups. The maximum water uptake will vary for different crude oils. Tests performed at SINTEF have revealed that the maximum water uptake is independent of the prevailing weather conditions if the lower energy barrier for the formation of w/o emulsions is exceeded. The rate, however, depends highly on the weather conditions. In the laboratory the $t_{1/2}$-value is determined, which is the time in hours it takes before the oil has emulsified half of its maximum water content. The w/o emulsion formation rate depends on the oil's chemical composition, which varies for different oil types.

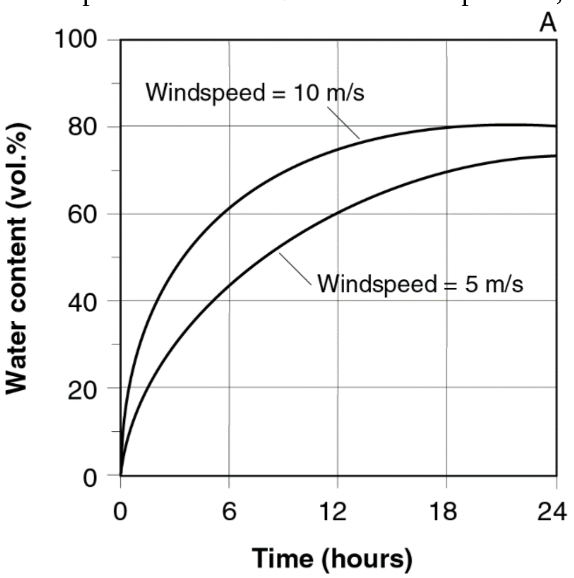


Figure A-7 *Example of how weather conditions influence the w/o emulsion formation for typical oils.*

The stability of the w/o emulsion depends on the water droplet size, since not all water droplets in the emulsion are stable. Larger water droplets may be reduced in size by the flexing, stretching and compressing motion of the slick due to wave action, whereas the largest droplets may coalesce and be squeezed out of the w/o emulsion. After a certain period, the emulsion may only contain small water droplets with diameters of 1 to 10 µm, yielding a more stable emulsion.

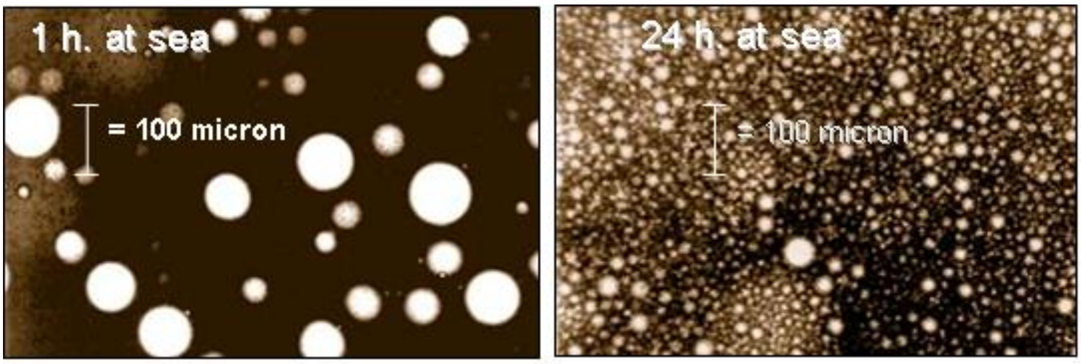


Figure A-8 Microscope pictures of w/o emulsion after (A) 1 h. and (B) 24 h. in a rotating cylinder.

Thus, the formation of emulsions is the result of water retention by oil as an effect of both viscous and interfacial forces. The interfacial forces are the most important, and asphaltenes are largely responsible for this. Resins are similar compounds to asphaltenes and can stabilize an emulsion, but not to the same extent. Resins and asphaltenes have hydrophobic and hydrophilic properties, which will cause them concentrate at the interface between the water and oil, thereby forming a layer that stabilizes the water droplets. The hydrophobic properties can lead to the concentration of wax along the water droplets, which further stabilizes the interfacial "skin" layer. The interfacial layer between the oil and water forms a physical barrier that hinders the coalescence of the water droplets and will stabilize the w/o emulsion. The stabilization of the water droplets by asphaltenes and wax is shown in Figure A-9.

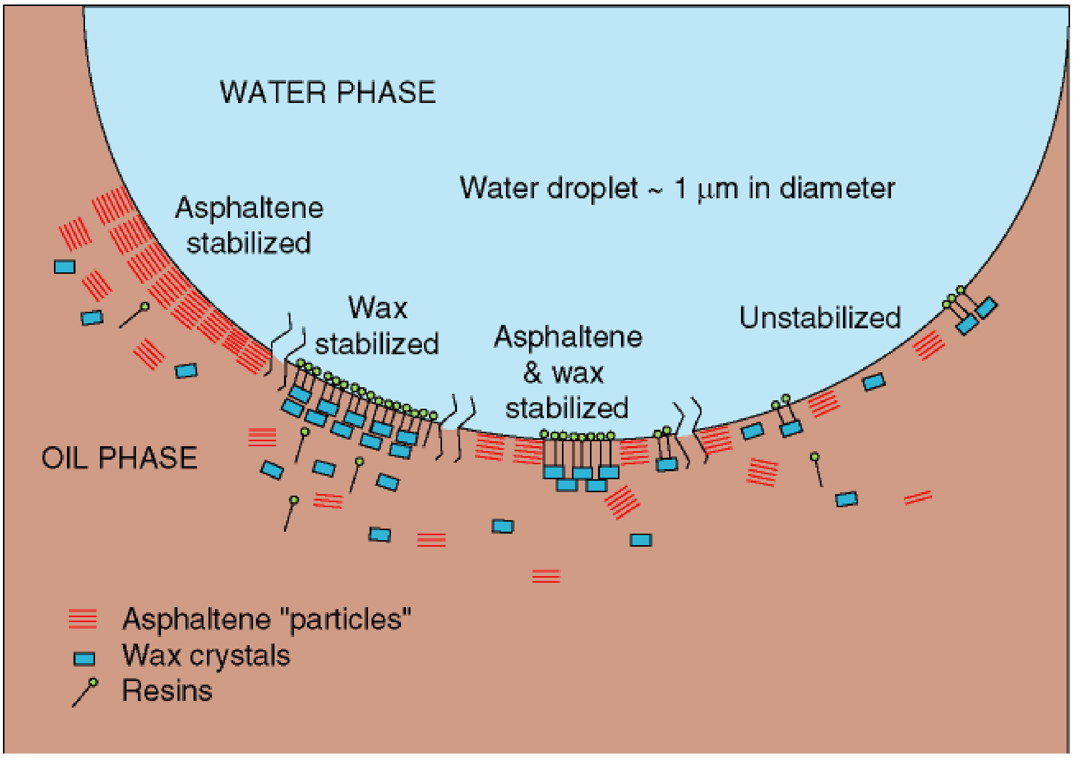


Figure A-9 Interfacial layer stabilized by wax and asphaltenes in w/o emulsion.

Oils that contain large amounts of wax and small amounts of asphaltenes can form w/o emulsions stabilized by a continuous phase's rheological strength (viscosity and elasticity) due to wax structure formed by precipitated wax. Wax stabilized emulsions are characterized by large water droplets and are fairly stable when stored, although they may break down when stress is applied and/or when the emulsion is heated to, e.g. 40-50°C. Crude oil- and sea water interfacial tension (IFT) plays a key role in the process of oil droplet formation. The need to understand and control droplet formation in dispersant system is extremely important. Addition of dispersants reduces the interfacial tension between oil and water that subsequently promotes the formation of a larger number of small oil droplets when surface waves entrain oil into the water column. These small, submerged oil droplets are then subject to transport by subsurface currents and other natural removal processes, such as dissolution, volatilization from the water surface, biodegradation, and sedimentation resulting from interactions with suspended particulate material.

A.4.5 Oil-in-water (o/w) dispersion

Natural oil-in-water (o/w) dispersion will take place if there is sufficient energy on the sea surface, i.e. if there are breaking waves present. The waves will break the slick into droplets of diameters, typically 1 µm - 1 mm, which are then mixed into the water mass. The largest oil droplets will resurface and form a thin oil film (typically <50 µm) behind the oil slick. This thin oil film will be rapidly dispersed again by breaking waves as smaller droplets into the water column and will be available for rapid biodegradation. The natural dispersion rate depends highly on the oil type and can be one of the main processes that determine the lifetime of an oil slick on the sea surface. Natural o/w dispersion will gradually decrease since the evaporation of the lighter compounds will increase the viscosity of the remaining oil. The purpose of applying chemical dispersing agents is to increase, or enhance, the natural dispersion rate. The dispersant reduces the interfacial tension between water and oil and thus promotes dispersion. When effective chemical dispersion is achieved, small oil droplets are formed with diameters typical from 5 to 100 µm. These are retained in the upper layers of the water column by the prevailing turbulence of wave action.

A.4.6 Water solubility

The water solubility of saturated hydrocarbons is generally very low, while lower molecular weight aromatic compounds are water-soluble to some extent; particularly aromatics, such as BTEX, 2-ring PAH and paraffin's up to C_7) have a potential to be dissolved in the water column (McAuliffe, 1987). Within the various types of hydrocarbons, the water solubility decreases from aromatics to naphthenes and from iso-alkanes to *n*-alkanes. In each series the water solubility decreases with *increasing* molecular weight.

Evaporation and the release of oil components into the water mass are competitive processes since most of the water-soluble components are also volatile. The evaporation process is approximately 10 to 100 times faster than the release in the water column. The concentration of soluble oil components into the water column during an oil spill is quite low (< 1 mg/L), while the dissolution of oil components into the water column does not contribute to removing the oil from the sea surface. However, the water-soluble fraction is of great interest since it has a high bioavailability and thus the potential to cause acute toxic effects on marine organisms.

A.4.7 Photo-oxidation

Under the influence of sunlight, some of the oil components will slowly oxidize to resins and finally asphaltenes. This contributes to the stability of w/o emulsions, therefore exerting a large influence on the oil's persistence on the sea surface. The photo-oxidized components will stabilize the w/o emulsions. After a long period of weathering at sea, tar balls, mainly consisting of asphaltenes, may be formed and can break down very slowly, both at sea and on beaches.

A.4.8 Biodegradation

Seawater contains an abundance of micro-organisms that can break down all types of oil components. The various micro-organisms prefer specific oil components as their energy source. Bacteria can only degrade oil in contact with water and depend on the water/oil interface area. The interface area increases as the oil is spread over the sea surface in a thin layer or by chemical or natural dispersion of oil in the water mass.

Important factors influencing the biodegradation rate are temperature, the nutritive supply that contain nitrogen and phosphorus, the oxygen supply, oil type and the degree of weathering. Low molecular compounds are degraded more rapidly than the heavier compounds in the oil, thus giving the following order for biodegradation: straight-chain *n*-alkanes > branched iso-alkanes > cyclic alkanes > cyclic naphthenes > aromatics> resins > asphaltenes (Perry, 1984). PAHs dissolved in water can be degraded within a few days (Brakstad and Faksness, 2000). Degradation of oil in contact with seawater depends highly on the water/oil interface area. The interfacial area increases as the oil is spread over the sea surface as a thin layer or by chemical or natural dispersion of oil into the water column.

At sea, the formation of oil droplets by natural or chemical enhanced dispersion will increase the biodegradation rate in the water mass by10 to >100 times compared to surface oil due to increased water/oil interfacial area, and it has been shown that n-alkanes are biodegraded within 2-4 weeks at North Sea conditions (Brakstad and Lødeng, 2005). Other higher molecular-weight oil compounds are biodegraded more slowly and some very high molecular-weight compounds (equivalent to the heavy residues in crude oil that are used to make bitumen) may not biodegrade to any significant degree.

A.4.9 Sedimentation

Crude oil and oil residues rarely sink into the water mass since there are few oils that have a density higher than water, even after extreme weathering. Oil can sink by sticking to a particular material present in the water mass. W/o emulsions that have a higher density value (e.g. emulsified bunker fuel oils) can more easily stick to a particular material, particularly if coming to the shore, and can sink to the bottom if washed out again from the shore. In connection to sub-sea blowout at the sea bottom, it is assumed that some of the oil droplets generated in the plume may adsorb to suspended particles or come in contact with the sea-bed sediment. This can cause some sedimentation of oil droplets to the sea-bed in the vicinity of the release. It is assumed that sub-sea dispersant treatment will reduce the potential for such sedimentation, due to lower adsorption /stickiness to sediment particles.

A.4.10 Deep water releases

Size distribution of the oil droplets formed during a subsurface release strongly influences the subsequent fate of the oil in the environment. Large droplets (typically larger than 5 mm) reach the surface after a couple of hours rise time from a depth of approximately 1000 m, while smaller droplets (down to 0.5 mm) may rise for up to a day before they will come to the surface. Fine droplets (below 100 microns) may stay in the water for weeks or even month before they eventually reach the surface. However, factors like vertical turbulence mixing in the water column, density stratification and cross flows will contribute to keep such fine small droplets submerged for even prolonged periods (Johansen et al., 2003).

In case of deep-water releases, large droplets (mm range) will usually rise to the surface and form an oil layer with sufficient thickness to emulsify (form water-in-oil emulsions). This is usually caused by loss of buoyancy and more horizontal entrainment of the gas/oil/water plume due to dissolution of gas, possible hydrate formation, cross currents and density layers. However, large droplets (mm range) will leave the entrained plume and rise to the surface, illustrated in Figure A-10. This was observed both during the DeepSpill experiments in 2000 (Figure A-11) and the DWH oil spill in 2010 (Figure A-12). This emulsification will be dependent on oil properties and environmental conditions, such as temperature and sea state.

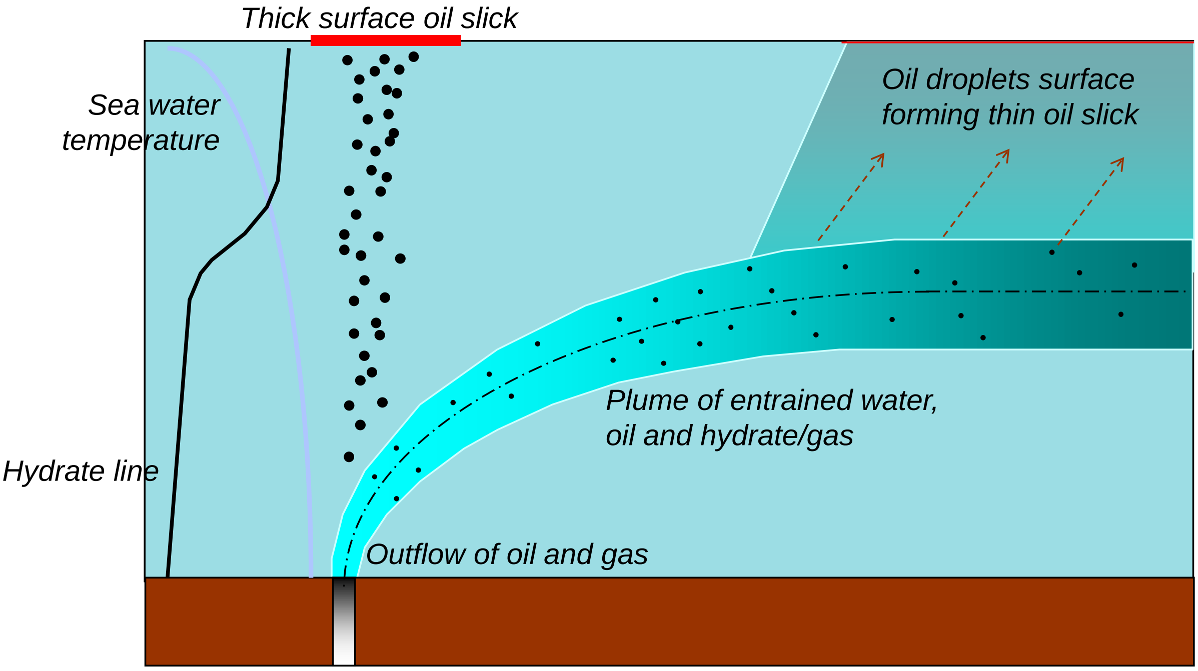


Figure A-10 Illustration of possible creation of thick surface oil slick (> 200 µm) from deep water release of oil.

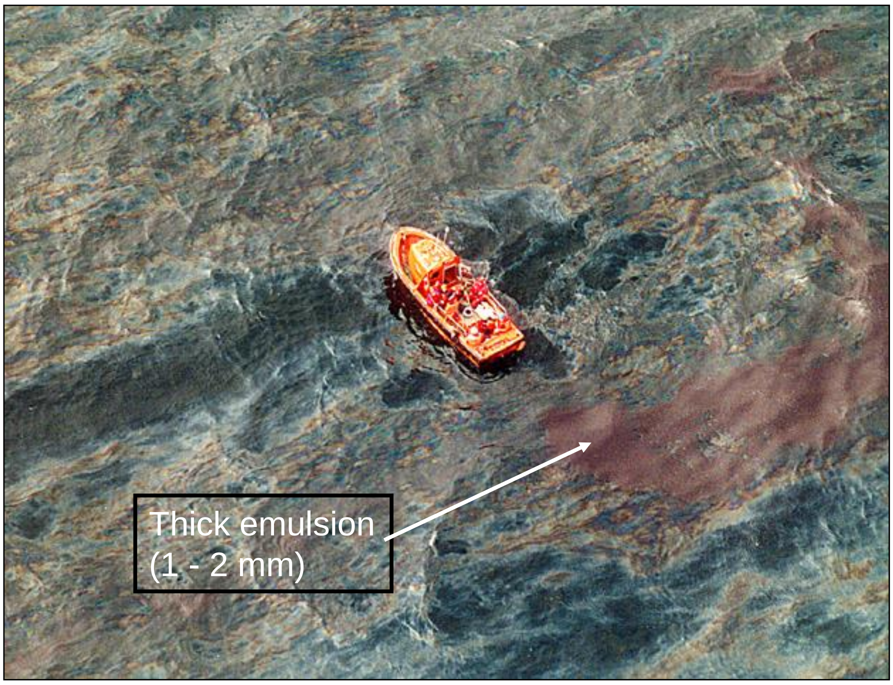


Figure A-11 Surface oil slick (initial thickness > 200 µm) from the experimental deep-water release DeepSpill in 2000. Surface oil is emulsifying similar to an oil slick from a surface batch release (from Leirvik et al., 2011).

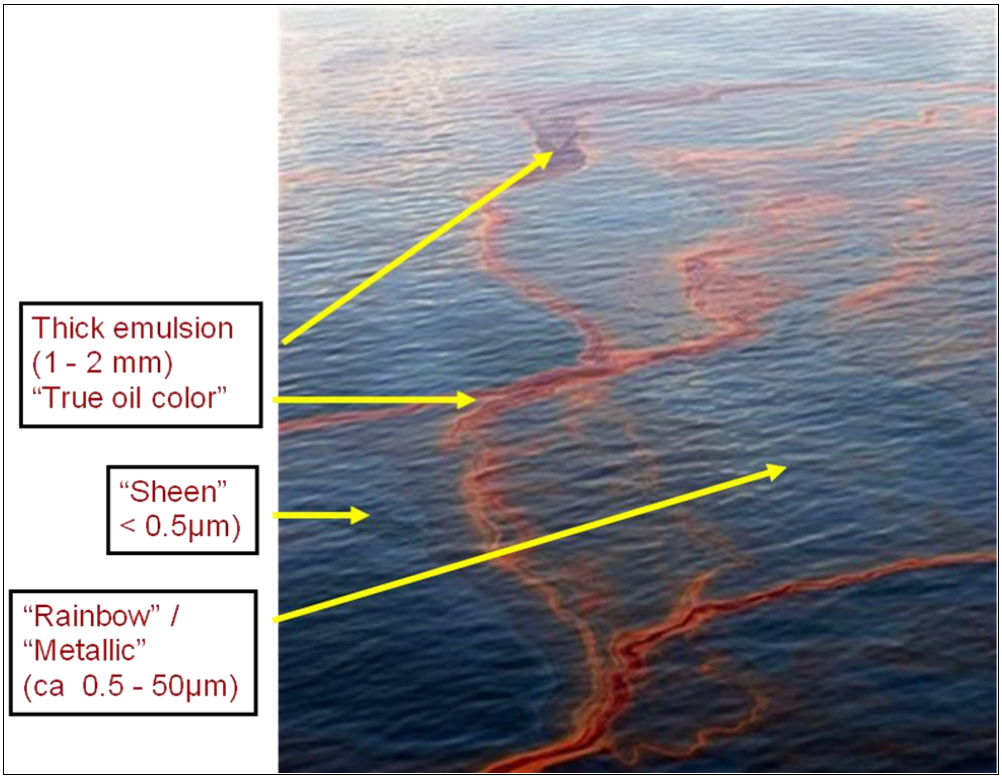


Figure A-12 Surface oil slick (initial thickness > 200 µm) from the DWH deep water release. Surface oil is emulsifying similar to an oil slick from a surface batch release.

A.4.11 Shallow releases

In case of a sub-surface release of oil and gas in shallower water (<500 meter) the buoyancy of the rising water/gas/oil plume is usually sufficient to reach the surface. The gas will be released to the atmosphere, while the large volumes of water will set up a horizontal current that will create a wide and thin surface oil slick (see Figure A-13, Figure A-14 and Rye et al, 1997). This surface oil slick will in many cases be too thin to emulsify (< 200 microns) and evaporation and natural dispersion will be the predominant weathering processes.

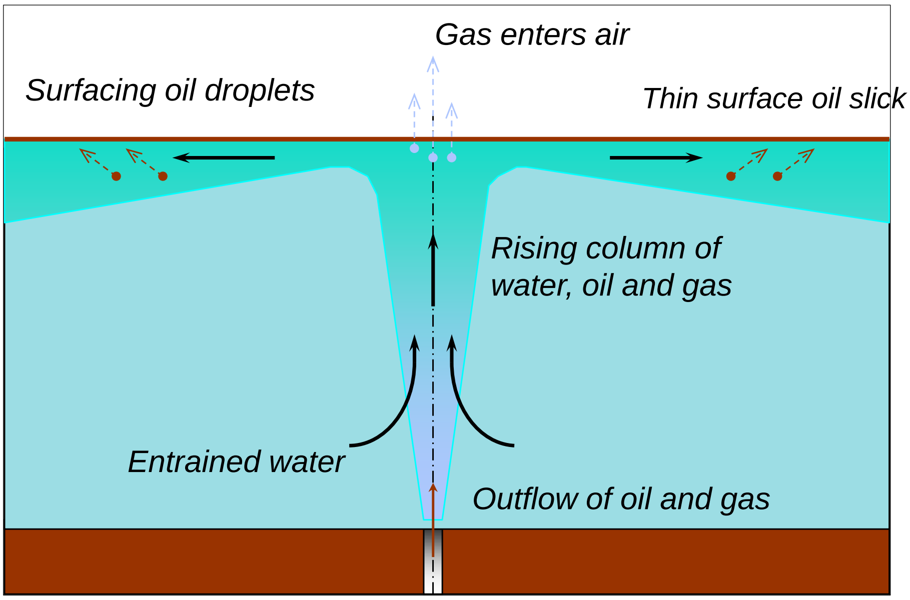


Figure A-13 Illustration of possible creation of thin surface oil slick (< 200 µm) from a shallow subsurface release (<500 m).

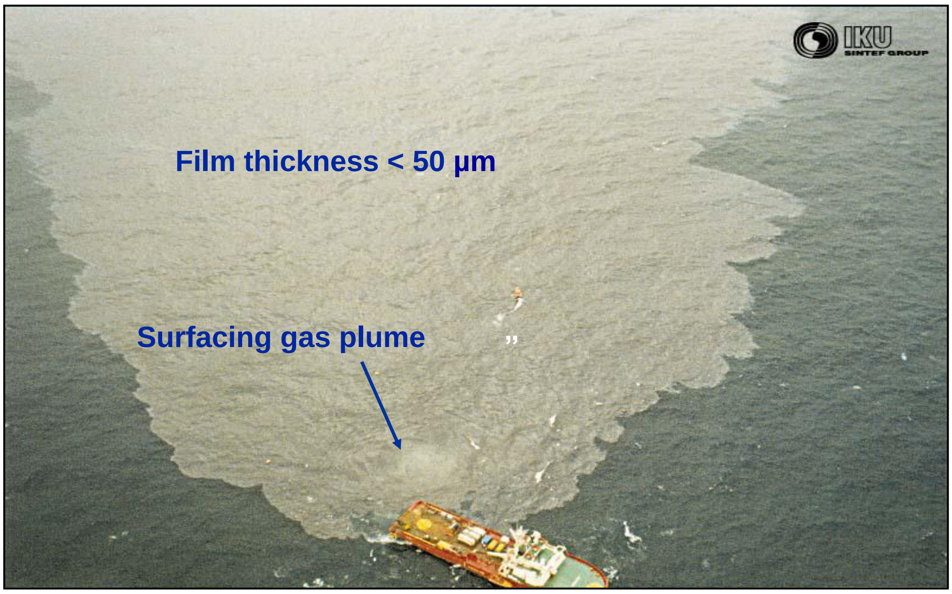
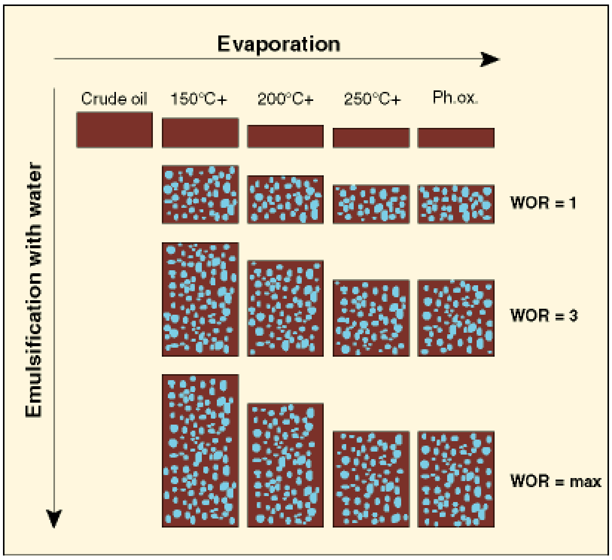


Figure A-14 Surface oil slick (< 50 µm) from experimental subsurface release at 106 m in 1996. The surface oil didn't emulsify and had a very limited lifetime (hours) due to the low film thickness and high rate of natural dispersion (even at < 10 m/s wind.

B Experimental setup

B.1 Small-scale laboratory testing

To isolate and map the various weathering processes at sea, the crude oil is exposed to a systematic, stepwise procedure developed at SINTEF (Daling et al., 1990). The general procedure is illustrated in Figure B-1.



WOR: Water to Oil Ratio

WOR=1: 50 vol.% water

WOR=3: 75 vol.% water

WOR=max: the maximum water content

Figure B-1 Small-scale laboratory weathering flow chart of oil.

B.1.1 Evaporation

The density of the oil was monitored during the degassing. This was performed before evaporation by standard procedure. The evaporation procedure used is described in Stiver and Mackay (1984). Evaporation of the lighter compounds from the fresh oil was carried out as a simple one-step distillation to vapour temperatures of 150°C, 200°C and 250°C, which resulted in oil residues with an evaporation loss corresponding to approximately 0.5-1 hour, 0.5-1 day and 0.5-1 week of weathering on the sea surface. These residues are referred to as 150°C+, 200°C+ and 250°C+, respectively.

B.1.2 Physical and chemical analysis

The viscosity, density, pour point and flash point of the fresh and water-free residues was analysed. Wax content and "hard" asphaltenes were measured for the 250°C+ residue. Viscosity for all the w/o emulsions was determined. The analytical methods used are given in Table B-1 and Table B-2.

Table B-1 Analytical methods used to determine the physical properties.

Physical property	Analytical method	Instrument
Viscosity	McDonagh et al, 1995	Physica MCR 300
Density	ASTM method D4052-81	Anton Paar, DMA 4500
Pour point	ASTM method D97	-
Flash point	ASTM D 56-82	Pensky-Martens, PMP1, SUR

Table B-2 Analytical methods used to determine the chemical properties

Chemical property	Analytical method
Wax content	Bridiè et al, 1980
“Hard” asphaltene	IP 143/90

Chemical characterization by GC/FID and GC/MS

- The distribution of hydrocarbons (nC_5-nC_{40}) was analysed using a Gas Chromatograph coupled with a Flame Ionisation Detector (GC/FID). The Gas Chromatograph used was an Agilent 6890N with a 30m DB1 column.
- The analysis and quantification of PAHs, phenols and alkylated phenols (C_0-C_4) were completed using an Agilent 6890 Gas Chromatograph coupled with a, 5973 MSD detector (GC/MS) operating in SIM mode (Selected Ion Monitoring)

The volatile components were in the range of nC_5-nC_{10} and were quantified by use of PT-GC-MS (Purge and Trap Gas chromatograph Mass Spectrometer operating in full-scan mode, and using a modified version of the EPA 8260 analysis method)

B.1.3 Emulsification properties

The w/o emulsification studies were performed by the rotating cylinders method developed by Mackay and Zagorski (1982), which is described in detail by Hokstad et al,1993. The method includes the measuring of the following parameters:

- Relative water uptake (kinetics)
- Maximum water uptake
- Stability of the emulsion
- Effectiveness of emulsion breaker (Alcopol 60%)

The principle of the rotating cylinders method is illustrated in Figure B-2. Oil (30 mL) and seawater (300 mL) are mixed and rotated with a rotation speed of 30 rpm in separating funnels (0.5 L). The emulsification kinetics is mapped by measuring the water content at fixed rotation times. The maximum water content is determined after 24 hours of rotation.

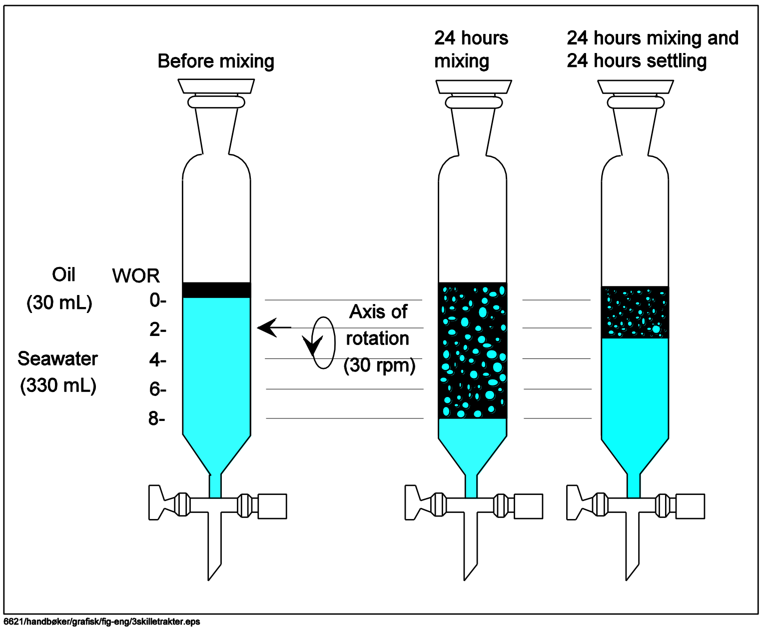


Figure B-2 Principle of the rotating cylinder method.

B.1.4 Chemical dispersibility testing

There are several different tests for evaluating the effect of chemical dispersants. The energy input will differ in the different tests, and the obtained efficiency will be representative of different wave energies. At SINTEF the IFP and MNS test is used in dispersibility testing.

IFP (Institute Français du Pétrole test, Bocard *et al.*, 1984) is a low energy test estimated to represent low wave energies (2-5 m/s wind speed). A surge beating up and down in the test vessel at a given frequency, gives energy input to the seawater column. The water column is continuously diluted, which gives a more realistic approach to field conditions, compared to other tests.

MNS (Mackay and Szeto, 1980) is estimated to correspond to a medium to high sea-state condition. The energy input in this system, applied by streaming air across the oil/water surface, produces a circular wave motion. The sample of the oily water is taken under dynamic conditions after a mixing period of 5 min.

Both IFP and MNS test apparatus is shown in Figure B-3**.**

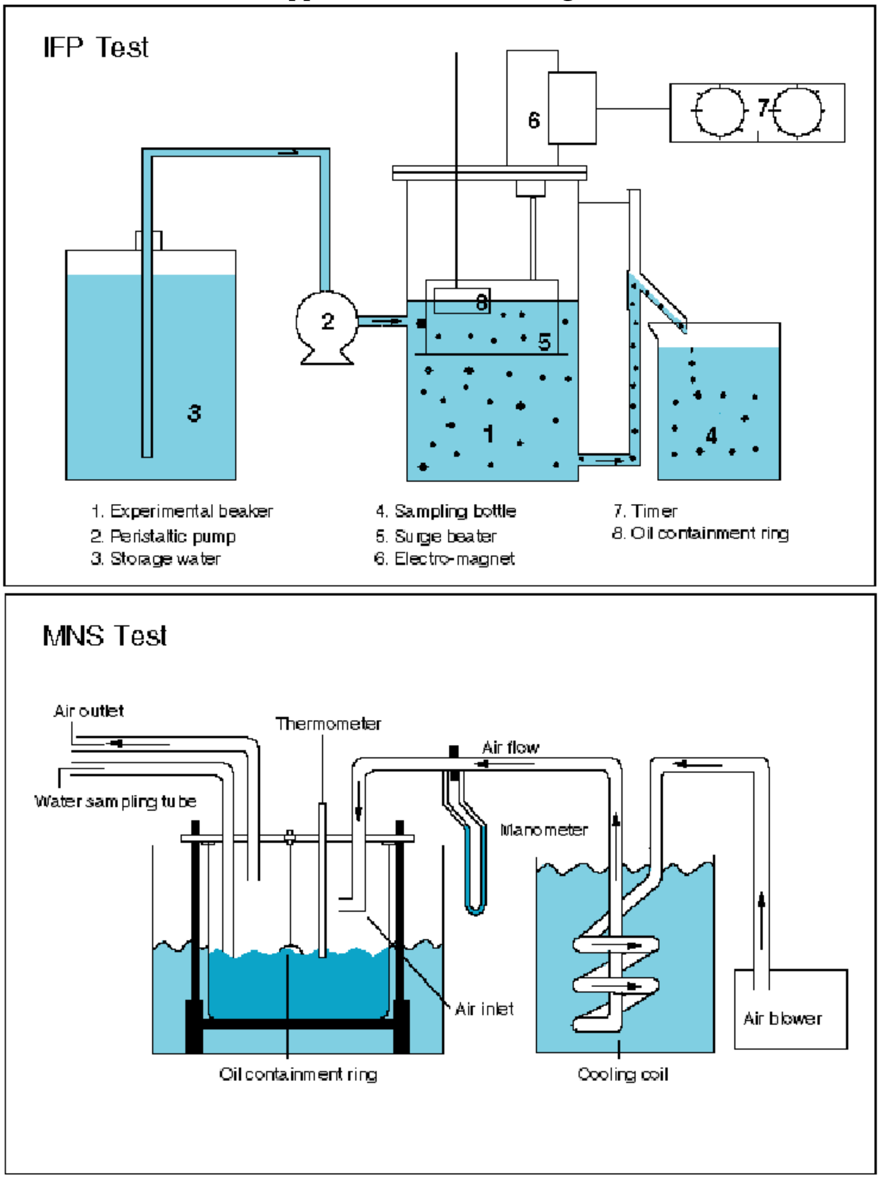


Figure B-3 IFP and MNS test apparatus.

C Input data to SINTEF Oil Weathering Model (OWM)

The laboratory data used as input to the SINTEF OWM for Nord Brent (E-2&E-3) and Sygna Brent (N-1&N-2) are given in C-1 to C-6.

C.1 Nord Brent (E-2&E-3)

Table C-1 Physical and chemical properties for Nord Brent (E-2&E-3).

Properties of fresh oil	Value
Density (g/ml)	0.84483
Pour point (°C)	3
Reference temperature (°C)	13
Viscosity at ref. temp. (mPa·s = cP) *	50
Asphaltenes (wt. %)	0.28
Flash Point (°C)	-
Wax Content (wt. %)	4.13
Dispersible for visc. <	2500
Not dispersible for visc. >	7000
Maximum water uptake (%)	-

** Measured at shear rate 100s^{-1}*

- No data available

Table C-2 True boiling point (TBP) curve for Nord Brent (E-2&E-3) TBP based on Equinor report 120-0031.

Temperature (°C)	Volume (%)
1	2
37	5
69	7
99	12
151	22
217	34
271	45
317	55
369	64
423	73
481	82
551	91
615	96
661	98
710	100

Table C-3 Lab weathering data for Nord Brent (E-2&E-3) at 13 °C.

Property	Fresh	150°C+	200°C+	250°C+
Boiling Point Temp. (°C)	-	201.3	275.6	325.2
Vol. Topped (%)	0	18.9	32.6	43.0
Weight Residue (wt. %)	100	84.0	71.2	61.3
Density (g/ml)	0.845	0.875	0.893	0.907
Pour point (°C)	3	18	27	27
Flash Point (°C)	-	41	94	126.5
Viscosity of water-free residue (mPa·s =cP)	103	212	2584	6348
*Viscosity of 50% emulsion (mPa·s = cP)**	-	580	1922	6386
*Viscosity of 75% emulsion (mPa·s = cP)**	-	1892	5300	-
*Viscosity of max water (mPa·s = cP)**	-	1849	7391	15766
Max. water cont. (vol. %)	-	90.9	81.7	74.6
(T1/2) Halftime for water uptake (hrs)	-	0.33	0.67	0.79
Stability ratio	-	0.98	0.98	0.99

** Measured at shear rate 100 s^{-1}*
** Measured at shear rate 10 s^{-1}*
- *No data*

C.2 Sygna Brent (N-1&N-2)

Table C-4 Physical and chemical properties for Sygna Brent (N-1&N-2).

Properties of fresh oil	Value
Density (g/ml)	0.84286
Pour point (°C)	3
Reference temperature (°C)	13
Viscosity at ref. temp. (mPa·s = cP) *	31
Asphaltenes (wt. %)	0.48
Flash Point (°C)	-
Wax Content (wt. %)	5.28
Dispersible for visc. <**	1700
Not dispersible for visc. > **	8000
Maximum water uptake (%)	-

** Measured at shear rate 100s^{-1}*
*** Estimated*
- *No data available*

Table C-5 True boiling point (TBP) curve for Sygna Brent (N-1&N-2).
The TBP based on Sim.Dist-analysis (Intertek Sunbury, report no. 3965979.

Temperature (°C)	Volume (%)
36	3
69	7
101	13
159	24
217	35
270	45
317	55
372	64
428	74
490	83
577	92
645	96
687	98
748	100

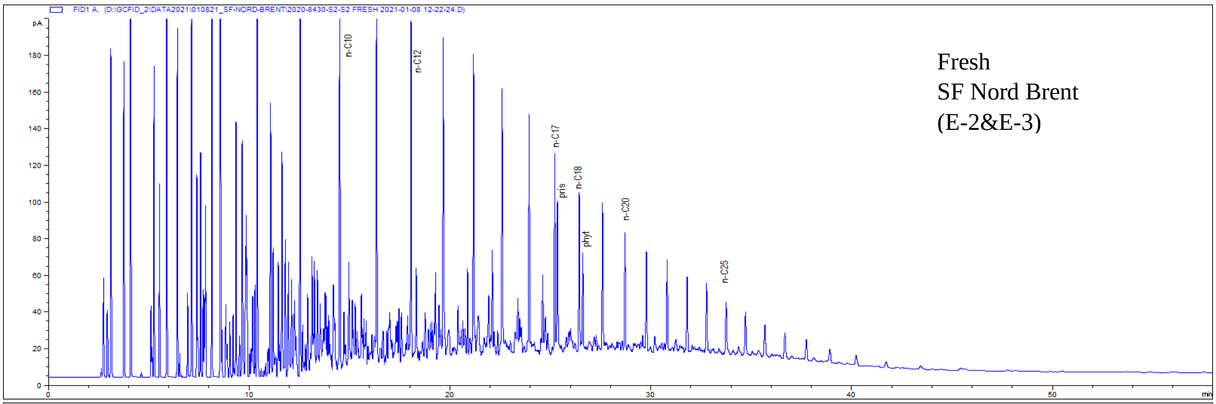
Table C-6 Lab weathering data for Sygna Brent (N-1&N-2) at 13 °C.

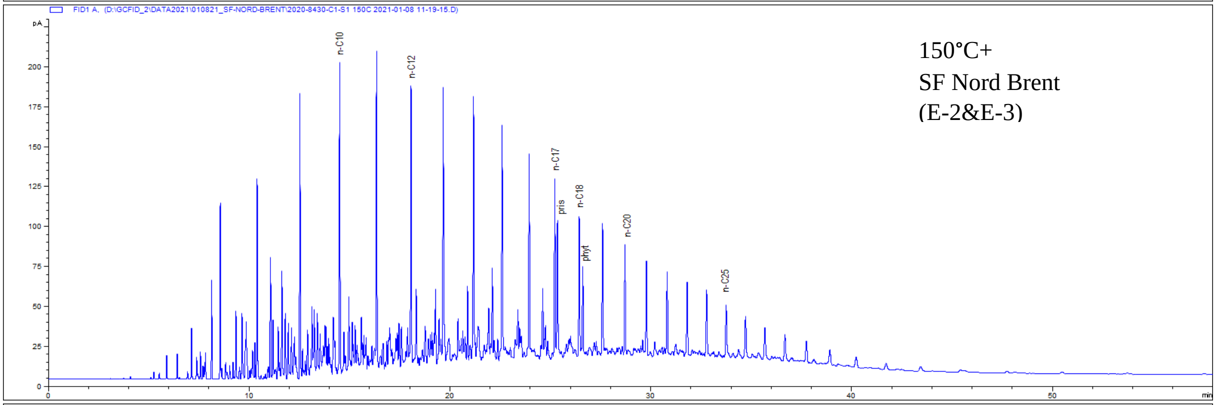
Property	Fresh	150°C+	200°C+	250°C+
Boiling Point Temp. (°C)		201.5	256.1	321.7
Vol. Topped (%)	0	19.8	29.9	42.5
Weight Residue (wt. %)	100	83.1	73.8	61.7
Density (g/ml)	0.843	0.873	0.887	0.903
Pour point (°C)	3	21	24	27
Flash Point (°C)	-	42.5	78.5	123
Viscosity of water-free residue (mPa·s =cP)	45	518	1409	7115
*Viscosity of 50% emulsion (mPa·s = cP)**	-	679	1442	6006
*Viscosity of 75% emulsion (mPa·s = cP)**	-	1430	3993	15516[a)]
Viscosity of max water (mPa·s = cP)	-	1568	4973	15516
Max. water cont. (vol. %)	-	90.9	85	75.8
(T1/2) Halftime for water uptake (hrs)	-	0.49	0.73	0.62
Stability ratio	-	0.95	1	1

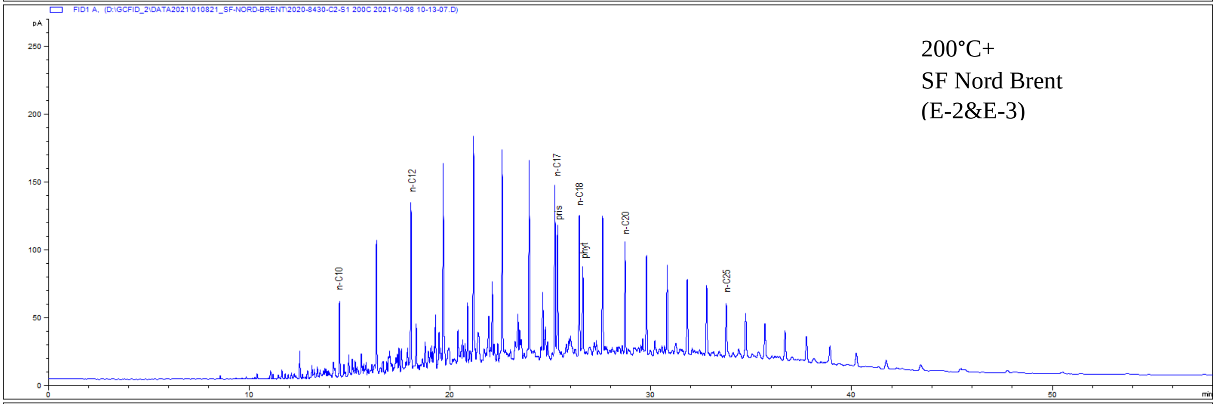
** Measured at shear rate 100 s^{-1}*
*** Measured at shear rate 10 s^{-1}*
- No data; a)estimated value

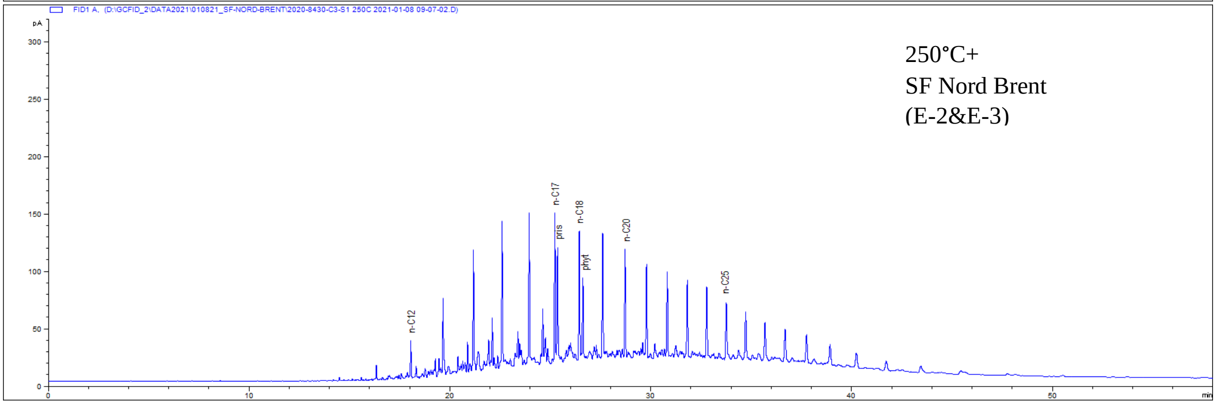
D GC/FID chromatograms of fresh oils and residues

D.1 SF Nord Brent (E-2&E-3)

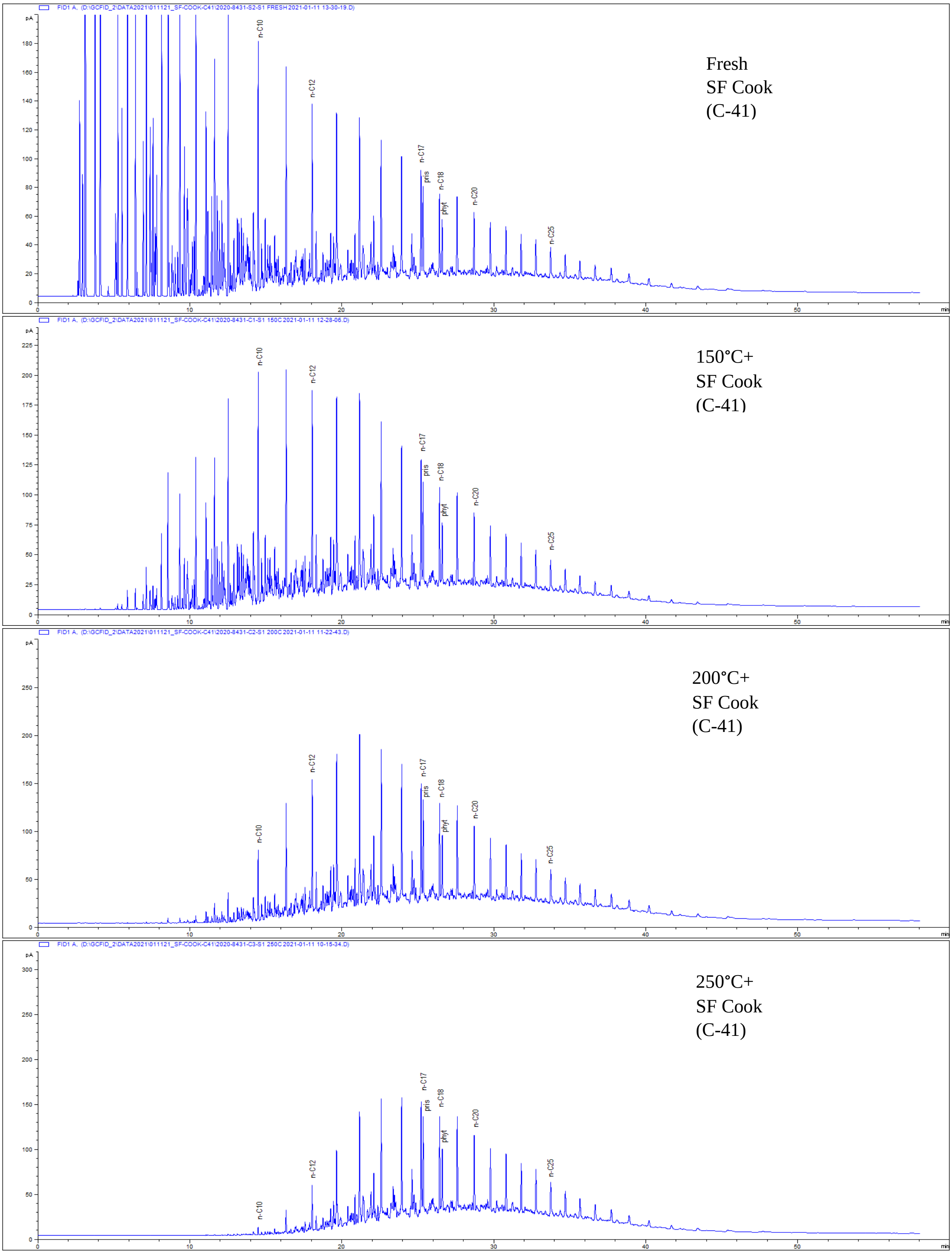




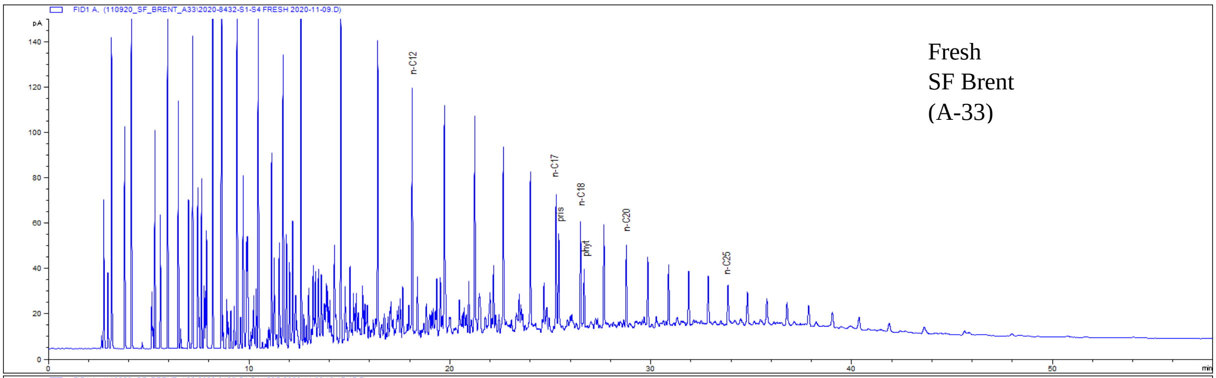


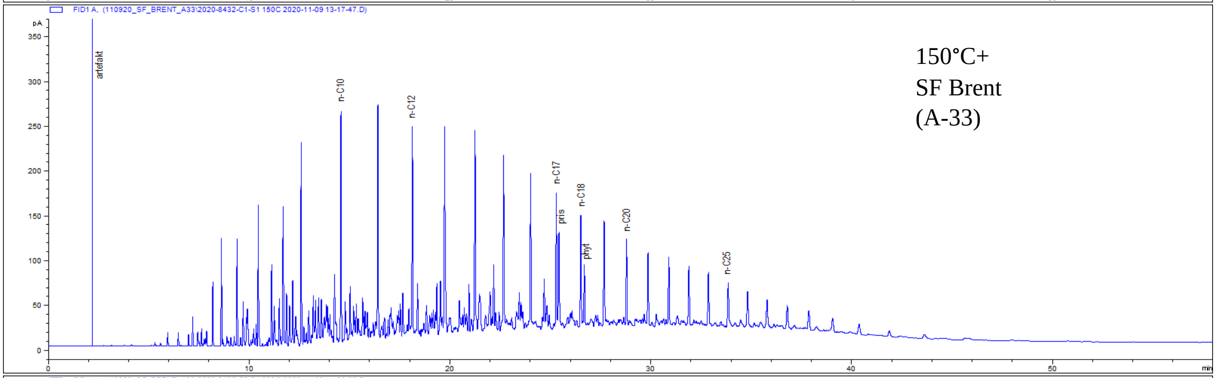


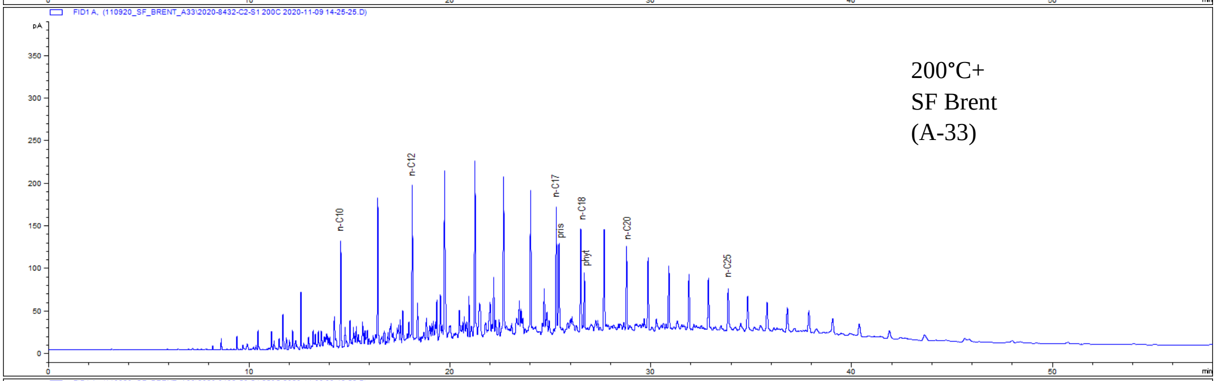
D.2 SF Cook (C-41)

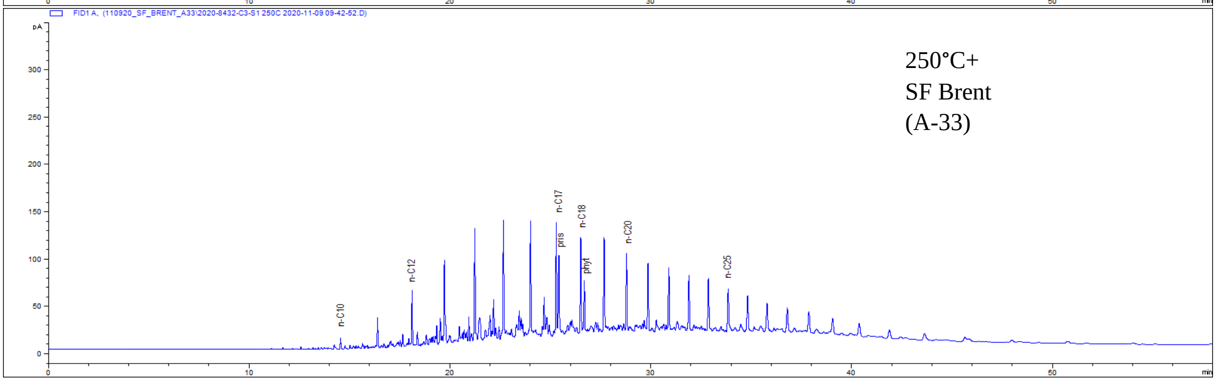


D.3 SF Brent (A-33)

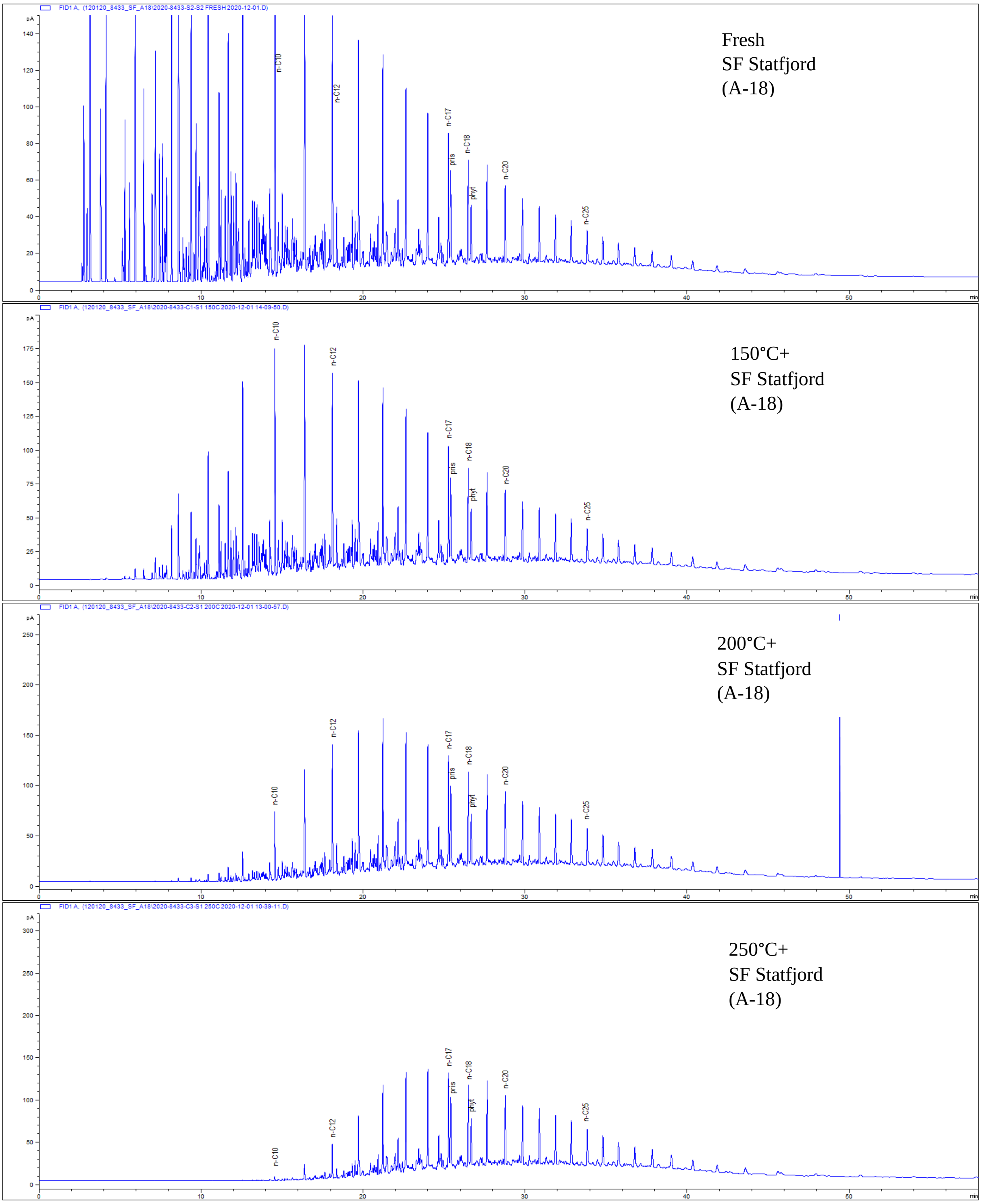




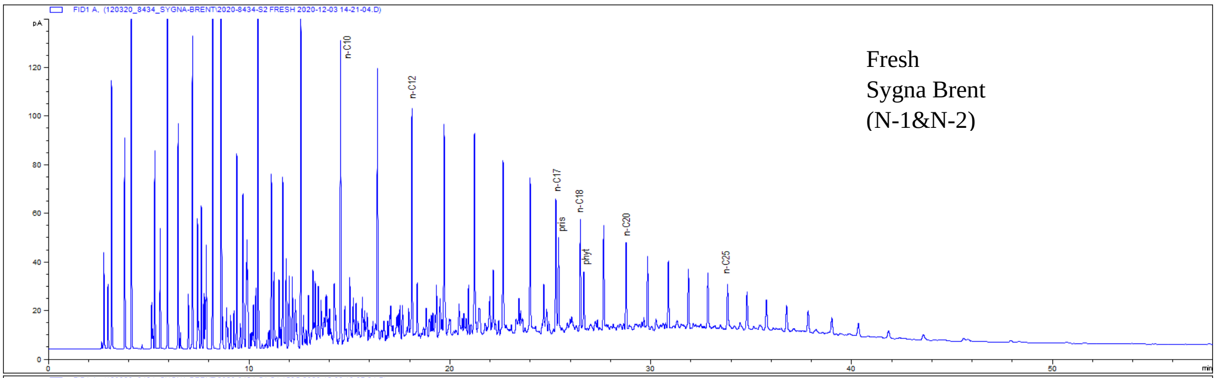


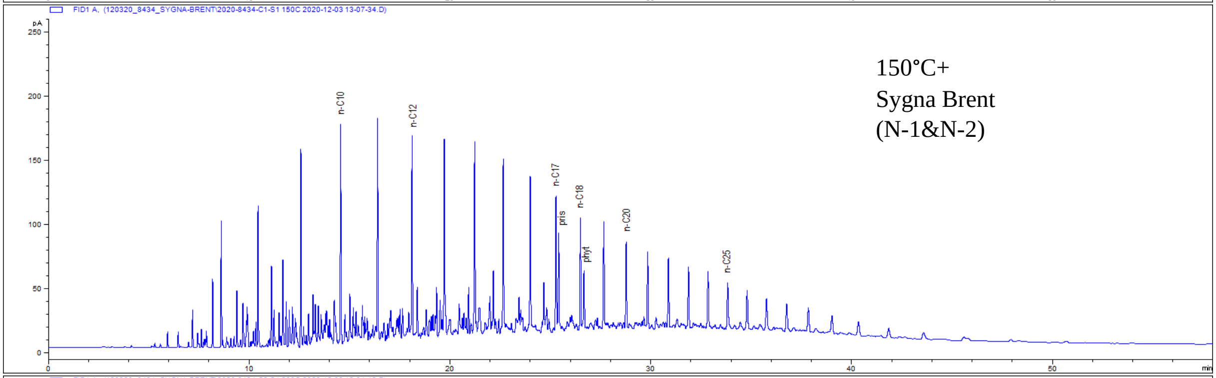


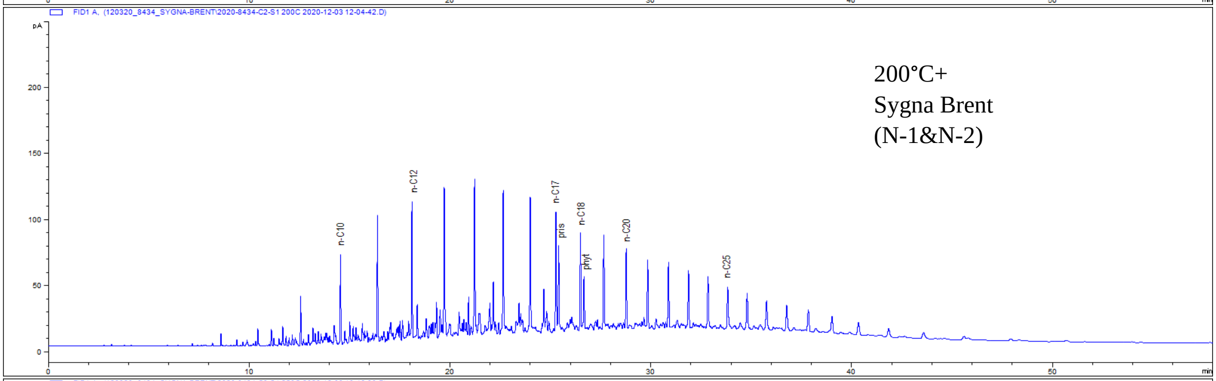
D.4 SF Statfjord (A-18)

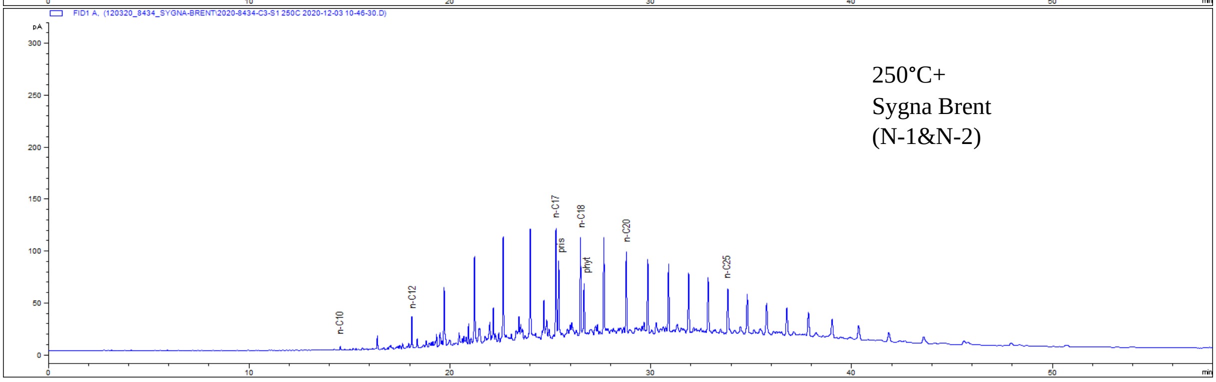


D.5 Sygna Brent (N-1&N-2)

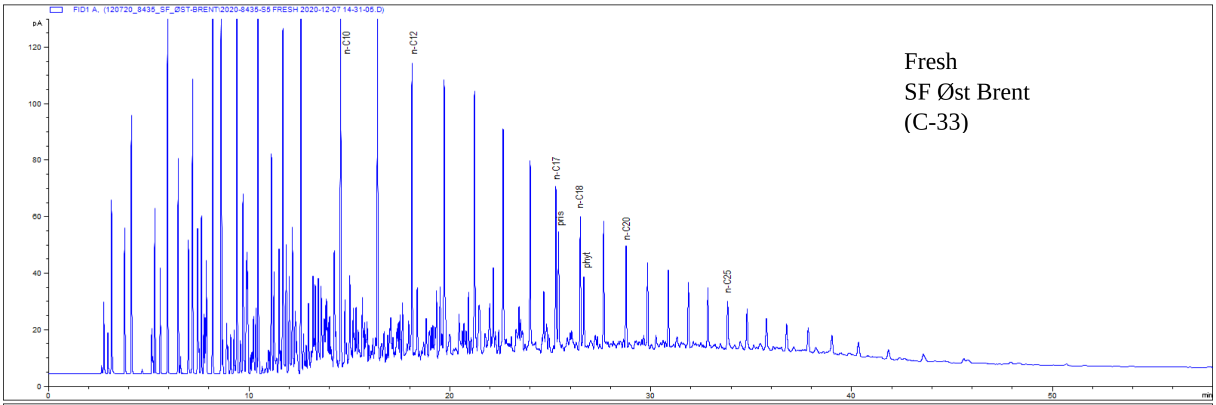


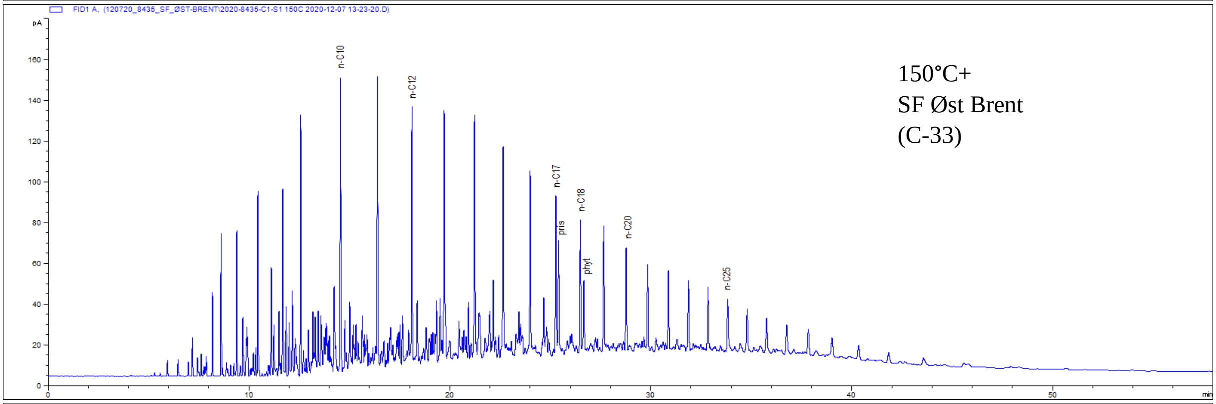


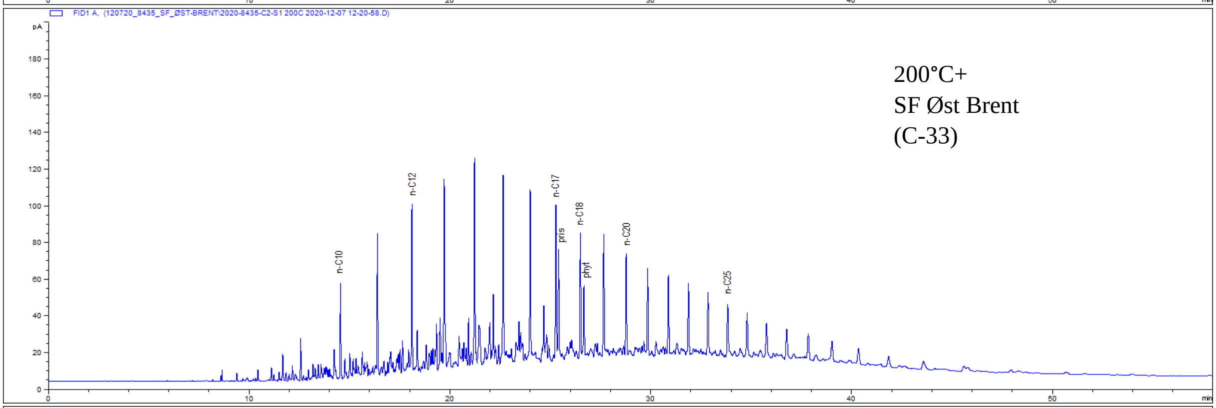


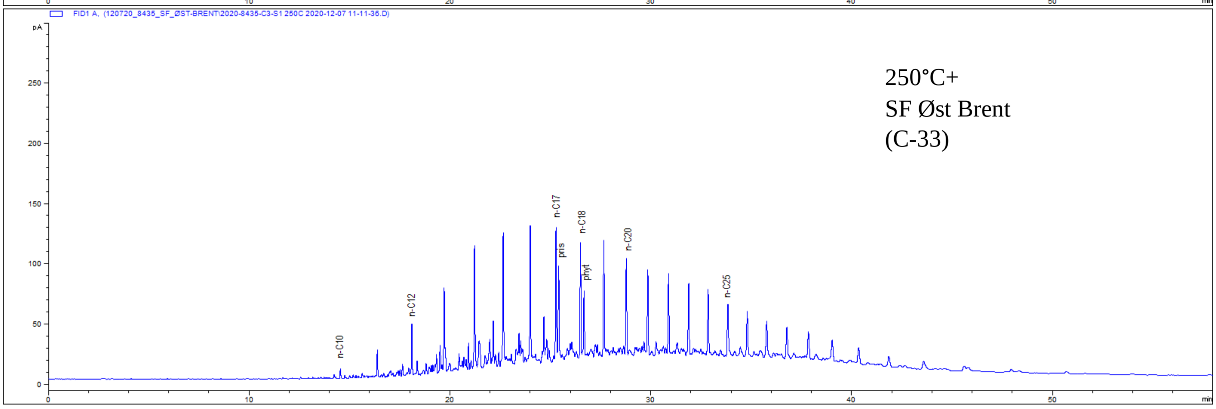


D.6 SF Øst Brent (C-33)

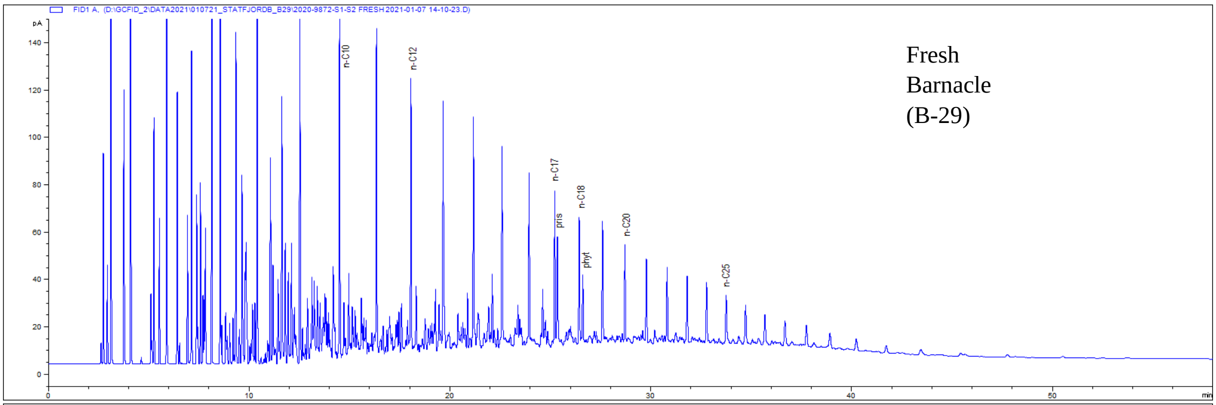


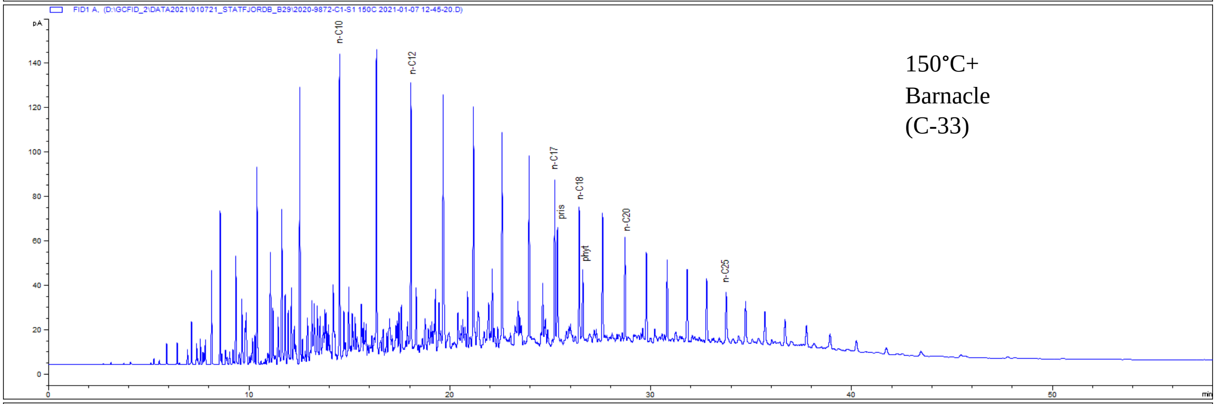


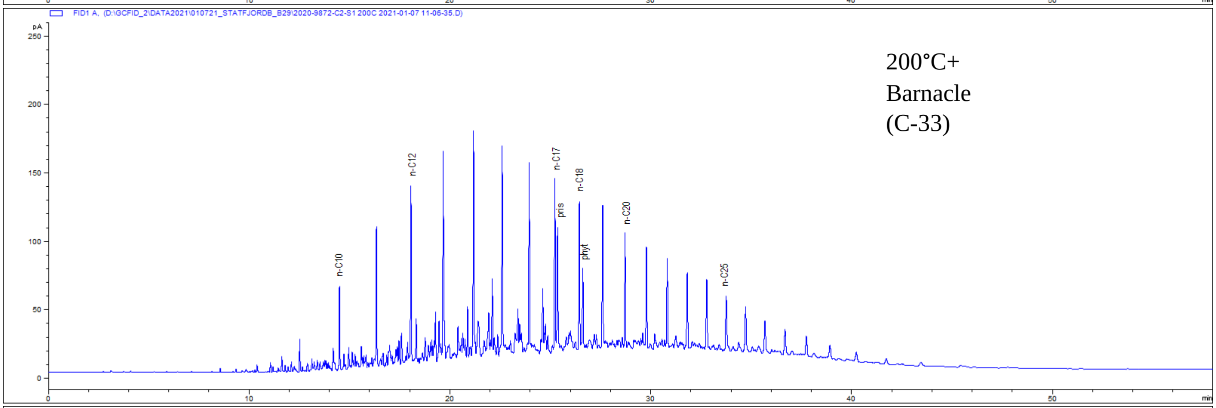


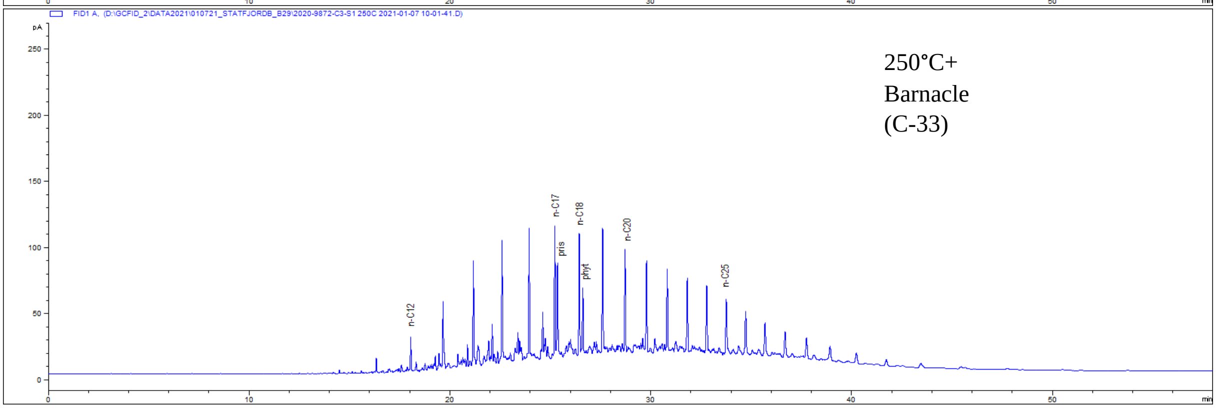


D.7 Barnacle (B-29)

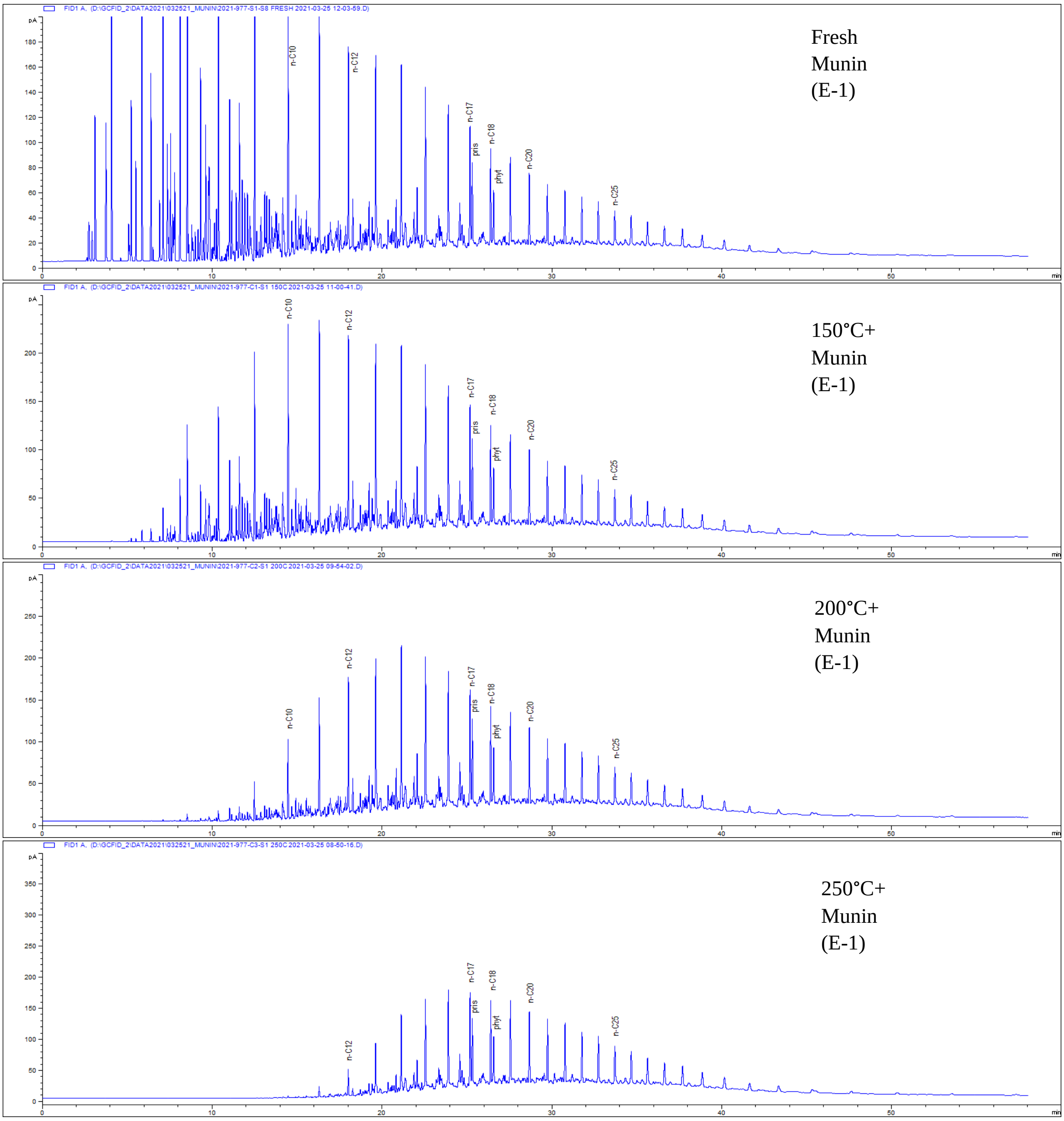








D.8 Munin (E-1)


Fresh
Munin
(E-1)
n-C10
n-C12
n-C17
pris
n-C18
phyt
n-C20
n-C25
150°C+
Munin
(E-1)
200°C+
Munin
(E-1)
250°C+
Munin
(E-1)

E Chemical characterisation of the fresh oil on GC/MS

The method for generating the chemical composition is based on the quantification of semi-volatile organic hydrocarbons (SVOC) and volatile organic hydrocarbons (VOC). The composition is divided into individual pseudo-component groups (OSCAR groups) representing the oil, based on the TBP (True Boiling Point) and the chemical characterization by GC/MS analysis.

The SINTEF OSCAR model is a 3-dimensional Oil Spill Contingency And Response model system that calculates and records the distribution (as mass and concentrations) of contaminants on the water surface, on shore, in the water column and in sediments. The model allows multiple release sites, each with a specified beginning and end to the release. This allows time-variable releases at a given location, as well as throughout the study area. The model computes surface spreading, slick transport, entrainment into the water column, evaporation, emulsification and shore interactions to determine oil drift and fate at the surface. In the water column, horizontal and vertical transport by currents, dissolution, adsorption, settling and degradation are simulated. By modelling the fate of individual 25 pseudo-components, changes in the oil composition due to evaporation, dissolution and degradation are accounted for. OSCAR may compute oil weathering from crude assay data, although the most reliable results are produced if the target oil has been through a standardized set of laboratory weathering procedures established by the SINTEF laboratories. Alternatively, the model may use oil weathering properties from oils for which data already exist, selecting the oil in the oil database that most closely matches the composition of the oil of concern.

Table E-1 Chemical composition of Nord Brent (E2&E3) crude oil based on GC/MS analysis of fresh oil

Group no.	Composition	Nord Brent (E2&E3) wt.%
1	C1-C4 gasses (dissolved in oil)	3.000
2	C5-saturates (n-/iso-/cyclo)	1.800
3	C6-saturates (n-/iso-/cyclo)	2.067
4	Benzene	0.133
5	C7-saturates (n-/iso-/cyclo)	2.800
6	C1-Benzene (Toluene) et. B	0.370
7	C8-saturates (n-/iso-/cyclo)	6.730
8	C2-Benzene (xylenes; using O-xylene)	0.599
9	C9-saturates (n-/iso-/cyclo)	4.037
10	C3-Benzene	0.464
11	C10-saturates (n-/iso-/cyclo)	3.500
12	C4 and C5 Benzenes	0.050
13	C11-C12 (total sat + aro)	4.949
14	Phenols (C0-C4 alkylated)	0.001
15	Naphthalenes 1 (C0-C1-alkylated)	0.331
16	C13-C14 (total sat + aro)	7.969
17	Unresolved Chromatographic Materials (UCM: C10 to C36)	0.000
37	metabolite 1	0.000
38	metabolite 2	0.000
18	Naphthalenes 2 (C2-C3-alkylated)	0.484
19	C15-C16 (total sat + aro)	5.716
20	PAH 1 (Medium soluble polyaromatic hydrocarbons (3 rings-non-alkylated;<4 rings)	0.297
21	C17-C18 (total sat + aro)	5.903
22	C19-C20 (total sat + aro)	5.400
23	C21-C25 (total sat + aro)	8.959
24	PAH 2 (Low soluble polyaromatic hydrocarbons (3 rings-alkylated; 4-5+ rings)	0.341
25	C25+ (total)	34.100

Table E-2 Chemical composition of Sygna Brent (N-1&N-2) crude oil based on GC/MS analysis of fresh oil

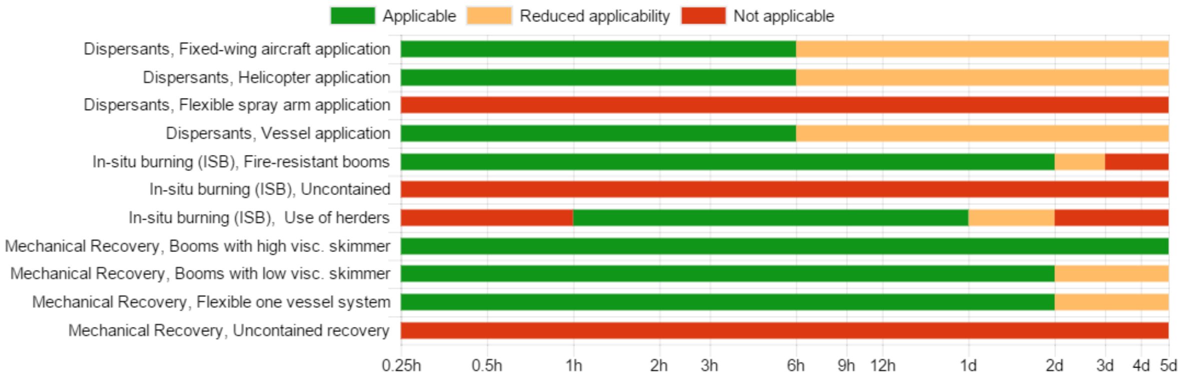
Group no.	**Composition**	**Sygna Brent (N-1&N-2) wt.%**
1	C1-C4 gasses (dissolved in oil)	1.500
2	C5-saturates (n-/iso-/cyclo)	2.700
3	C6-saturates (n-/iso-/cyclo)	2.311
4	Benzene	0.189
5	C7-saturates (n-/iso-/cyclo)	3.100
6	C1-Benzene (Toluene) et. B	0.631
7	C8-saturates (n-/iso-/cyclo)	6.369
8	C2-Benzene (xylenes; using O-xylene)	0.715
9	C9-saturates (n-/iso-/cyclo)	3.966
10	C3-Benzene	0.519
11	C10-saturates (n-/iso-/cyclo)	3.300
12	C4 and C5 Benzenes	0.050
13	C11-C12 (total sat + aro)	5.150
14	Phenols (C0-C4 alkylated)	0.000
15	Naphthalenes 1 (C0-C1-alkylated)	0.291
16	C13-C14 (total sat + aro)	7.409
17	Unresolved Chromatographic Materials (UCM: C10 to C36)	0.000
37	metabolite 1	0.000
38	metabolite 2	0.000
18	Naphthalenes 2 (C2-C3-alkylated)	0.383
19	C15-C16 (total sat + aro)	5.617
20	PAH 1 (Medium soluble polyaromatic hydrocarbons (3 rings-non-alkylated;<4 rings)	0.257
21	C17-C18 (total sat + aro)	6.043
22	C19-C20 (total sat + aro)	5.500
23	C21-C25 (total sat + aro)	8.744
24	PAH 2 (Low soluble polyaromatic hydrocarbons (3 rings-alkylated; 4-5+ rings)	0.256
25	C25+ (total)	35.000

F Response guide summary

The Response guide module was developed through the Petromaks FateIce project (Singsaas and Daling, 2019) and linked to SINTEF Oil Weathering Model (OWM). This system combines physico-chemical data, predictions of weathering properties with a set of decision rules for applicability of different oil spill response options. The decision rules have partly been documented through laboratory testing and/or verified through field testing and based on best available knowledge.

F.1 Nord Brent (E-2&E-3), 15°C

Decision parameter	Value
Oil type	NORD BRENT
Wind speed	2m/s
Sea temperature	15°C
Ice coverage	0%
Dispersants effective below viscosity	2500 cP
Dispersants ineffective above viscosity	7000 cP



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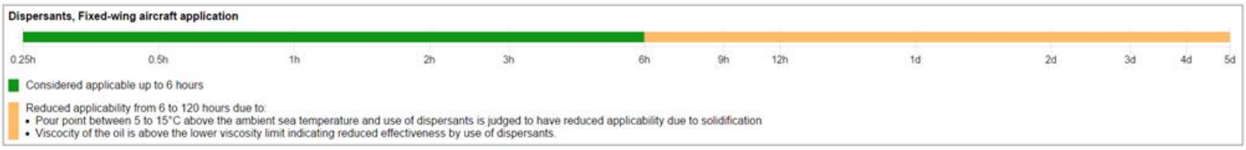
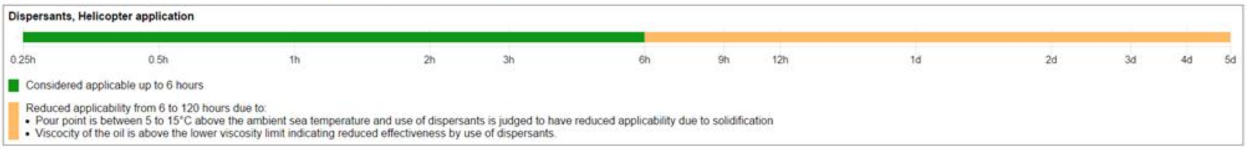
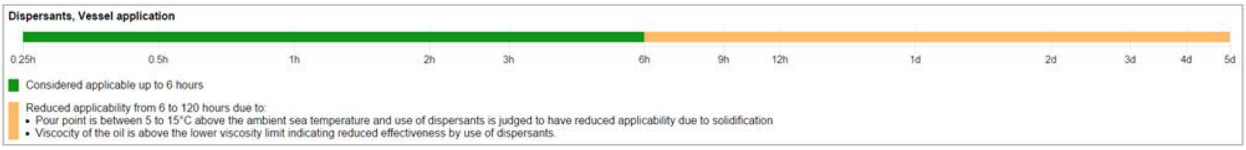
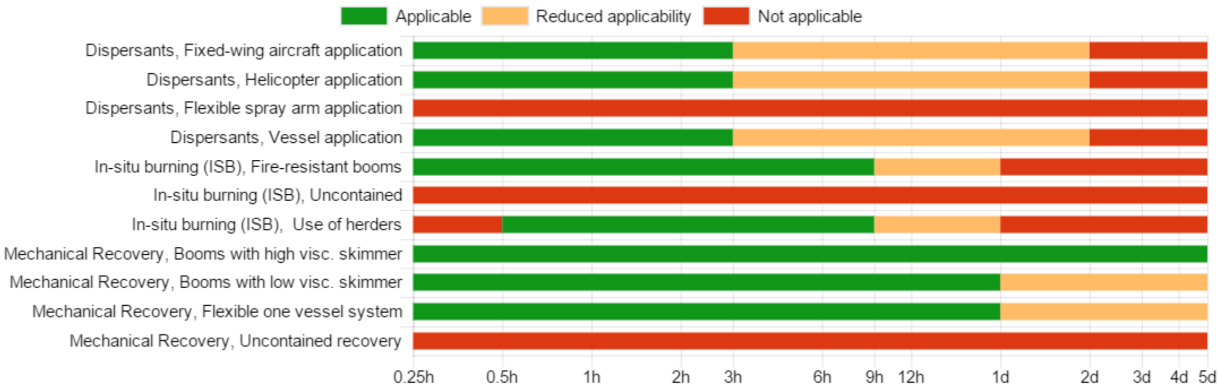






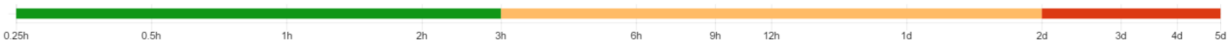

In-situ burning (ISB), Fire-resistant booms
0.25h 0.5h 1h 2h 3h 6h 9h 12h 1d 2d 3d 4d 5d
Considered applicable up to 48 hours
Reduced applicability from 48 to 72 hours due to:
• Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.
Not applicable from 72 to 120 hours due to:
• Water content is above 50% and ignition and ISB is judged not to be applicable.
In-situ burning (ISB), Uncontained
0.25h 0.5h 1h 2h 3h 6h 9h 12h 1d 2d 3d 4d 5d
Not applicable up to 120 hours due to:
• Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
• Water content is above 50% and ignition and ISB is judged not to be applicable.
In-situ burning (ISB), Use of herders
0.25h 0.5h 1h 2h 3h 6h 9h 12h 1d 2d 3d 4d 5d
Not applicable up to 1 hours due to:
• Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
Considered applicable from 1 to 24 hours
Reduced applicability from 24 to 48 hours due to:
• Pour point is between 8 - 10°C above the ambient sea temperature and use of herders is judged to have reduced applicability.
Not applicable from 48 to 120 hours due to:
• Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
• Water content is above 50% and ignition and ISB is judged not to be applicable.
• Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.
Mechanical Recovery, Booms with high visc. skimmer
0.25h 0.5h 1h 2h 3h 6h 9h 12h 1d 2d 3d 4d 5d
Considered applicable up to 120 hours
Mechanical Recovery, Booms with low visc. skimmer
0.25h 0.5h 1h 2h 3h 6h 9h 12h 1d 2d 3d 4d 5d
Considered applicable up to 48 hours
Reduced applicability from 48 to 120 hours due to:
• Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.
Mechanical Recovery, Flexible one vessel system
0.25h 0.5h 1h 2h 3h 6h 9h 12h 1d 2d 3d 4d 5d
Considered applicable up to 48 hours
Reduced applicability from 48 to 120 hours due to:
• Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.
Mechanical Recovery, Uncontained recovery
0.25h 0.5h 1h 2h 3h 6h 9h 12h 1d 2d 3d 4d 5d
Not applicable up to 120 hours due to:
• Ice coverage is below 30% and uncontained recovery is judged not to be applicable.

Decision parameter	Value
Oil type	NORD BRENT
Wind speed	5m/s
Sea temperature	15℃
Ice coverage	0%
Dispersants effective below viscosity	2500 cP
Dispersants ineffective above viscosity	7000 cP



Details

Dispersants, Fixed-wing aircraft application

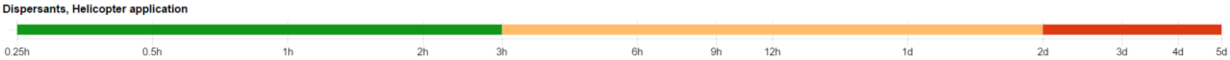


Considered applicable up to 3 hours

Reduced applicability from 3 to 48 hours due to:
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

Not applicable from 48 to 120 hours due to:
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Helicopter application



Considered applicable up to 3 hours

Reduced applicability from 3 to 48 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

Not applicable from 48 to 120 hours due to:
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application

Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Vessel application

Considered applicable up to 3 hours

Reduced applicability from 3 to 48 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

Not applicable from 48 to 120 hours due to:
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

In-situ burning (ISB), Fire-resistant booms

Considered applicable up to 9 hours

Reduced applicability from 9 to 24 hours due to:
- Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.

Not applicable from 24 to 120 hours due to:
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained

Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Use of herders

Not applicable up to 0.5 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.

Considered applicable from 0.5 to 9 hours

Reduced applicability from 9 to 24 hours due to:
- Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.
- Pour point is between 8 - 10°C above the ambient sea temperature and use of herders is judged to have reduced applicability.

Not applicable from 24 to 120 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

Mechanical Recovery, Booms with high visc. skimmer

Considered applicable up to 120 hours

Mechanical Recovery, Booms with low visc. skimmer

Considered applicable up to 24 hours

Reduced applicability from 24 to 120 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.
- Viscosity is between 10.000 - 20.000 cP and low viscosity skimmers are judged to have reduced applicability.

Mechanical Recovery, Flexible one vessel system

Considered applicable up to 24 hours

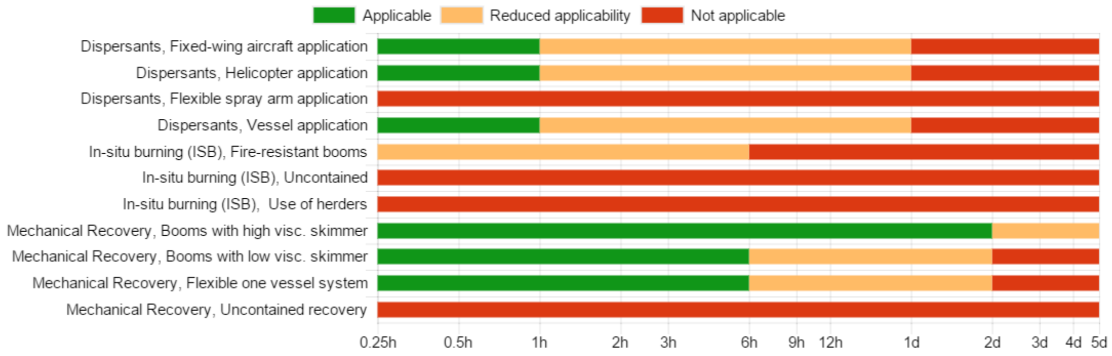
Reduced applicability from 24 to 120 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

Mechanical Recovery, Uncontained recovery

Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.

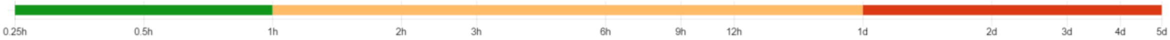
SINTEF

Decision parameter	Value
Oil type	NORD BRENT
Wind speed	10m/s
Sea temperature	15°C
Ice coverage	0%
Dispersants effective below viscosity	2500 cP
Dispersants ineffective above viscosity	7000 cP



Details

Dispersants, Fixed-wing aircraft application

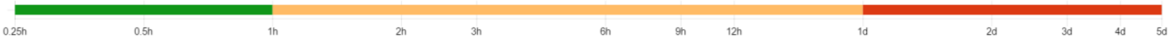


Considered applicable up to 1 hours

Reduced applicability from 1 to 24 hours due to:
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

Not applicable from 24 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Helicopter application

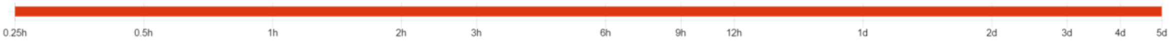


Considered applicable up to 1 hours

Reduced applicability from 1 to 24 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

Not applicable from 24 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application

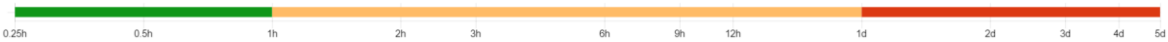


Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application

Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Vessel application

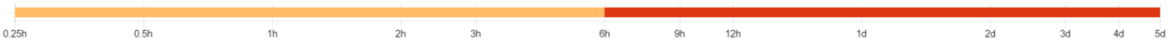


Considered applicable up to 1 hours

Reduced applicability from 1 to 24 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

Not applicable from 24 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

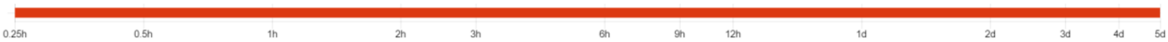
In-situ burning (ISB), Fire-resistant booms



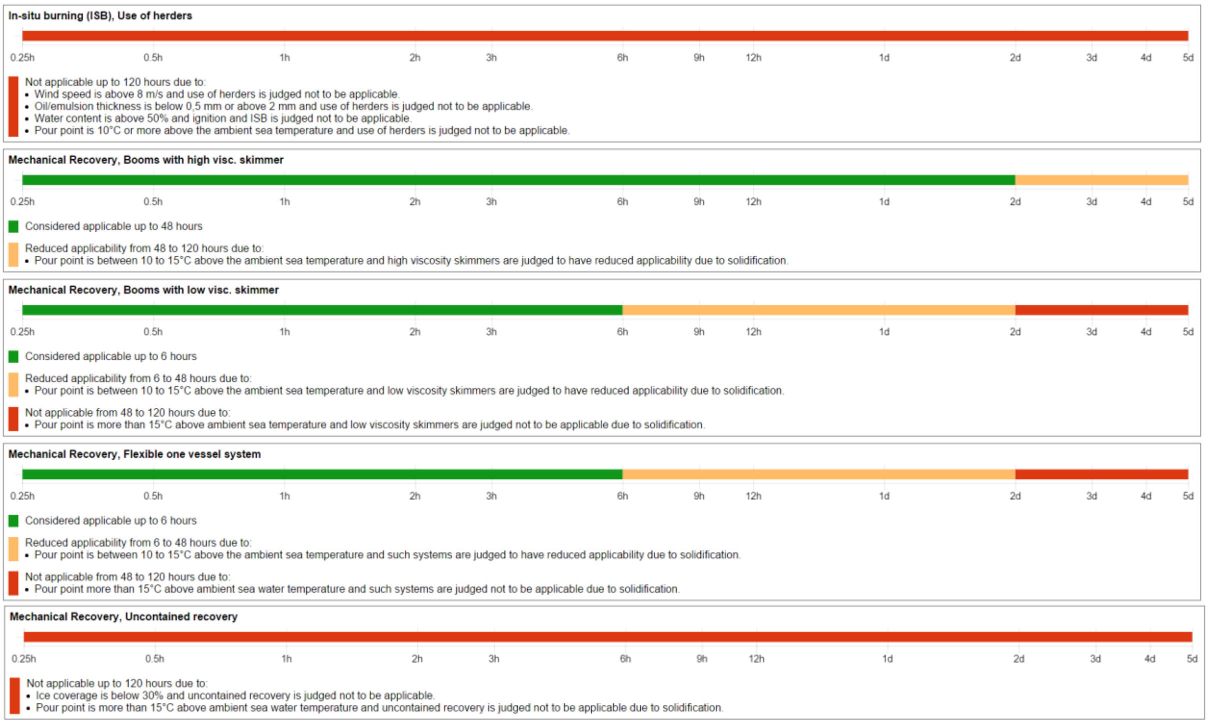
Reduced applicability up to 6 hours due to:
- Wind speed is between 8 and 12 m/s and ignition and ISB is judged to have reduced applicability.
- Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.

Not applicable from 6 to 120 hours due to:
- Water content is above 50% and ignition and ISB is judged not to be applicable.

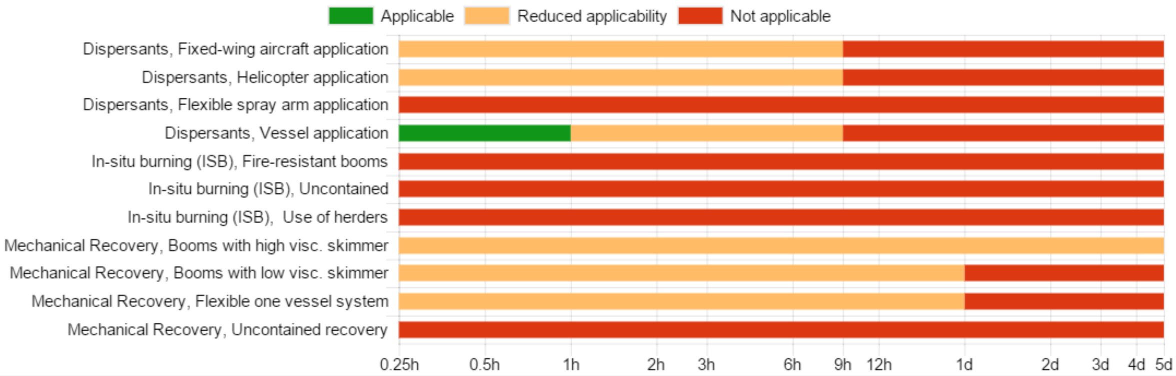
In-situ burning (ISB), Uncontained



Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.


In-situ burning (ISB), Use of herders
0.25h
0.5h
1h
2h
3h
6h
9h
12h
1d
2d
3d
4d
5d
Not applicable up to 120 hours due to:
• Wind speed is above 8 m/s and use of herders is judged not to be applicable.
• Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
• Water content is above 50% and ignition and ISB is judged not to be applicable.
• Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.
Mechanical Recovery, Booms with high visc. skimmer
Considered applicable up to 48 hours
Reduced applicability from 48 to 120 hours due to:
• Pour point is between 10 to 15°C above the ambient sea temperature and high viscosity skimmers are judged to have reduced applicability due to solidification.
Mechanical Recovery, Booms with low visc. skimmer
Considered applicable up to 6 hours
Reduced applicability from 6 to 48 hours due to:
• Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.
Not applicable from 48 to 120 hours due to:
• Pour point is more than 15°C above ambient sea temperature and low viscosity skimmers are judged not to be applicable due to solidification.
Mechanical Recovery, Flexible one vessel system
Considered applicable up to 6 hours
Reduced applicability from 6 to 48 hours due to:
• Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.
Not applicable from 48 to 120 hours due to:
• Pour point more than 15°C above ambient sea water temperature and such systems are judged not to be applicable due to solidification.
Mechanical Recovery, Uncontained recovery
Not applicable up to 120 hours due to:
• Ice coverage is below 30% and uncontained recovery is judged not to be applicable.
• Pour point is more than 15°C above ambient sea water temperature and uncontained recovery is judged not to be applicable due to solidification.

Decision parameter	Value
Oil type	NORD BRENT
Wind speed	15m/s
Sea temperature	15℃
Ice coverage	0%
Dispersants effective below viscosity	2500 cP
Dispersants ineffective above viscosity	7000 cP



Details

Dispersants, Fixed-wing aircraft application

Reduced applicability up to 9 hours due to:
- Wind speed is between 12 - 15 m/s and use of dispersants is judged to have reduced applicability.
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

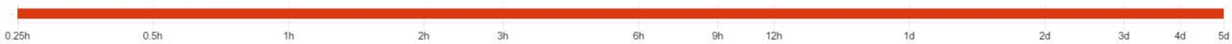
Not applicable from 9 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Helicopter application

Reduced applicability up to 9 hours due to:
- Wind speed is between 12 - 15 m/s and use of dispersants is judged to have reduced applicability.
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

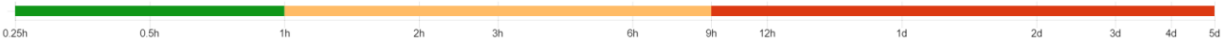
Not applicable from 9 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application



Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Vessel application

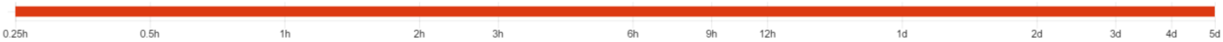


Considered applicable up to 1 hours

Reduced applicability from 1 to 9 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

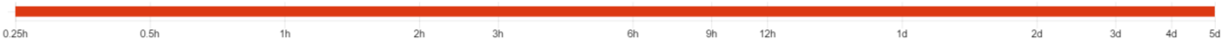
Not applicable from 9 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

In-situ burning (ISB), Fire-resistant booms



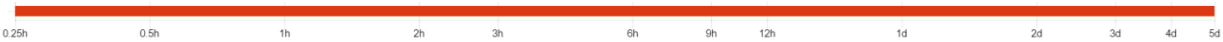
Not applicable up to 120 hours due to:
- Wind speed is above 12 m/s and ignition and ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained



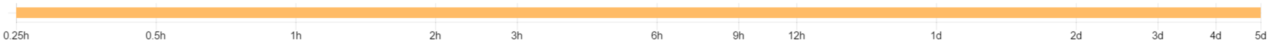
Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Wind speed is above 12 m/s and ignition and ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Use of herders



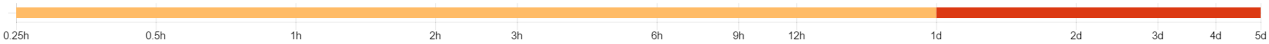
Not applicable up to 120 hours due to:
- Wind speed is above 8 m/s and use of herders is judged not to be applicable.
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

Mechanical Recovery, Booms with high visc. skimmer



Reduced applicability up to 120 hours due to:
- Wind speed is between 10 - 15 m/s and confinement by boom is judged to have reduced applicability.
- Pour point is between 10 to 15°C above the ambient sea temperature and high viscosity skimmers are judged to have reduced applicability due to solidification.

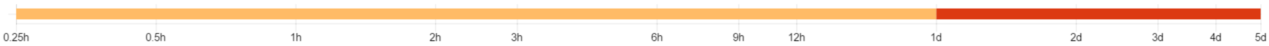
Mechanical Recovery, Booms with low visc. skimmer



Reduced applicability up to 24 hours due to:
- Wind speed is between 10 - 15 m/s and confinement by boom is judged to have reduced applicability.
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 24 to 120 hours due to:
- Pour point is more than 15°C above ambient sea temperature and low viscosity skimmers are judged not to be applicable due to solidification.
- Viscosity is above 20.000 cP and low viscosity skimmers are judged not to be applicable.

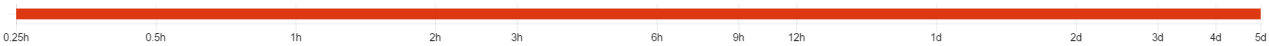
Mechanical Recovery, Flexible one vessel system



Reduced applicability up to 24 hours due to:
- Wind speed is between 10 - 15 m/s and confinement is judged to have reduced applicability.
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

Not applicable from 24 to 120 hours due to:
- Pour point more than 15°C above ambient sea water temperature and such systems are judged not to be applicable due to solidification.

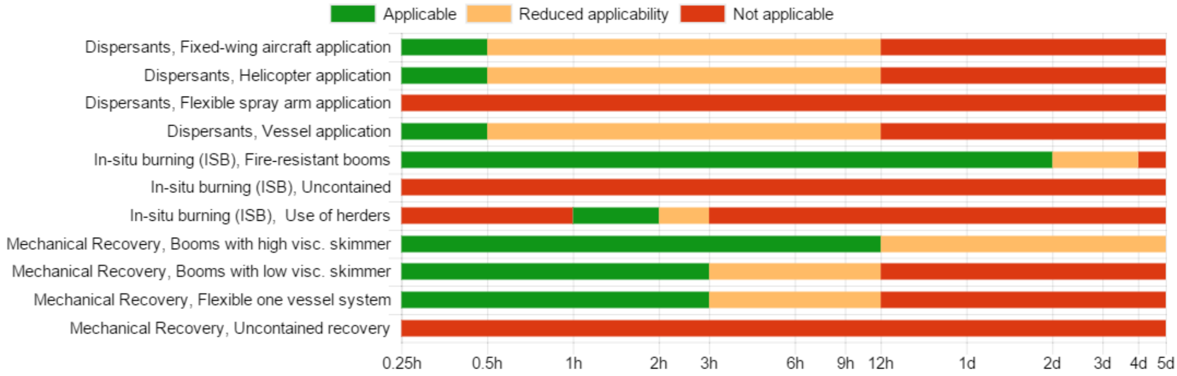
Mechanical Recovery, Uncontained recovery



Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and uncontained recovery is judged not to be applicable due to solidification.

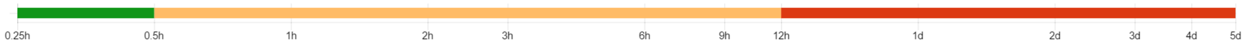
F.2 Nord Brent (E-2&E-3), 5°C

Decision parameter	Value
Oil type	NORD BRENT
Wind speed	2m/s
Sea temperature	5℃
Ice coverage	0%
Dispersants effective below viscosity	2500 cP
Dispersants ineffective above viscosity	7000 cP



Details

Dispersants, Fixed-wing aircraft application

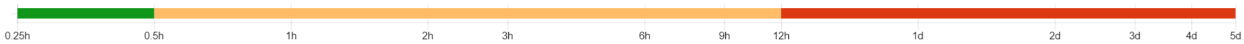


Considered applicable up to 0.5 hours

Reduced applicability from 0.5 to 12 hours due to:
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 12 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Helicopter application

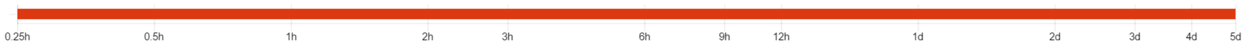


Considered applicable up to 0.5 hours

Reduced applicability from 0.5 to 12 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

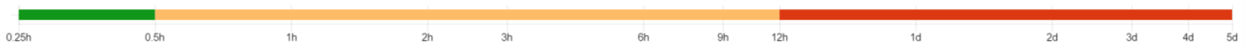
Not applicable from 12 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application



Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Vessel application

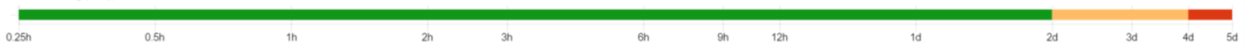


Considered applicable up to 0.5 hours

Reduced applicability from 0.5 to 12 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 12 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

In-situ burning (ISB), Fire-resistant booms

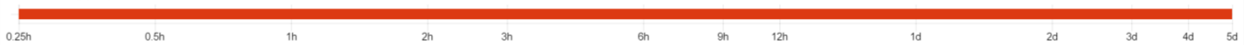


Considered applicable up to 48 hours

Reduced applicability from 48 to 96 hours due to:
- Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.

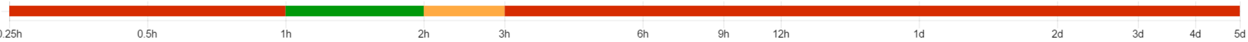
Not applicable from 96 to 120 hours due to:
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained



Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Use of herders



Not applicable up to 1 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.

Considered applicable from 1 to 2 hours

Reduced applicability from 2 to 3 hours due to:
- Pour point is between 8 - 10°C above the ambient sea temperature and use of herders is judged to have reduced applicability.

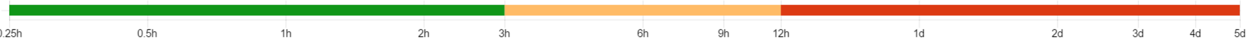
Not applicable from 3 to 120 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

Mechanical Recovery, Booms with high visc. skimmer

Considered applicable up to 12 hours

Reduced applicability from 12 to 120 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and high viscosity skimmers are judged to have reduced applicability due to solidification.

Mechanical Recovery, Booms with low visc. skimmer

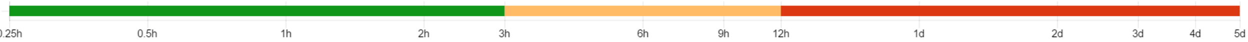


Considered applicable up to 3 hours

Reduced applicability from 3 to 12 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 12 to 120 hours due to:
- Pour point is more than 15°C above ambient sea temperature and low viscosity skimmers are judged not to be applicable due to solidification.

Mechanical Recovery, Flexible one vessel system

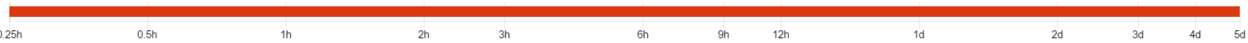


Considered applicable up to 3 hours

Reduced applicability from 3 to 12 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

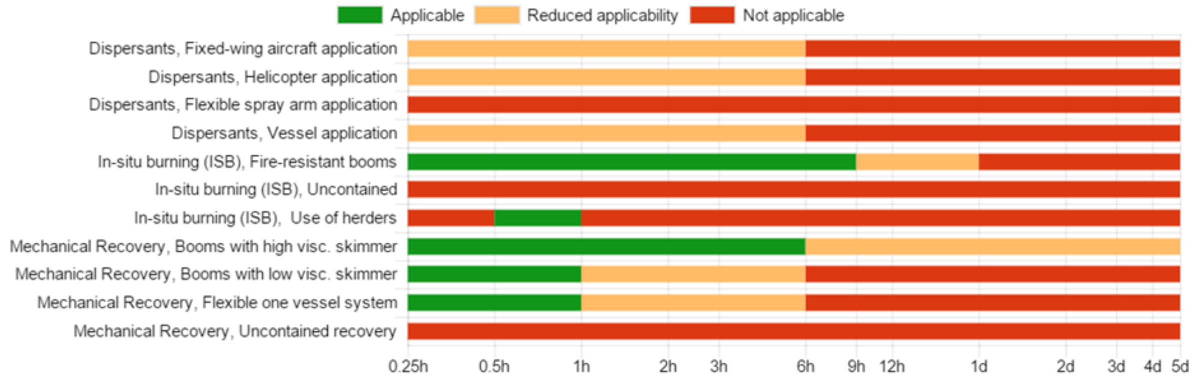
Not applicable from 12 to 120 hours due to:
- Pour point more than 15°C above ambient sea water temperature and such systems are judged not to be applicable due to solidification.

Mechanical Recovery, Uncontained recovery



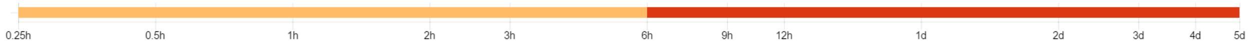
Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and uncontained recovery is judged not to be applicable due to solidification.

Decision parameter	Value
Oil type	NORD BRENT
Wind speed	5m/s
Sea temperature	5°C
Ice coverage	0%
Dispersants effective below viscosity	2500 cP
Dispersants ineffective above viscosity	7000 cP



Details

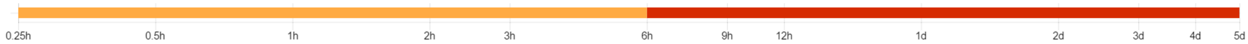
Dispersants, Fixed-wing aircraft application



Reduced applicability up to 6 hours due to:
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 6 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

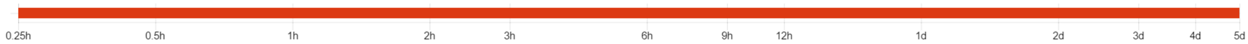
Dispersants, Helicopter application



Reduced applicability up to 6 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

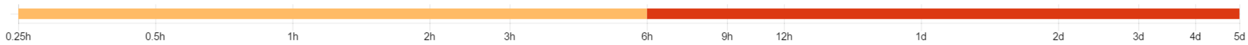
Not applicable from 6 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application



Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

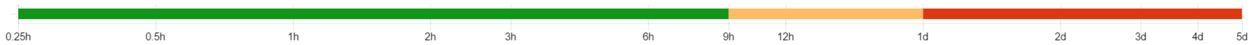
Dispersants, Vessel application



Reduced applicability up to 6 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 6 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

In-situ burning (ISB), Fire-resistant booms

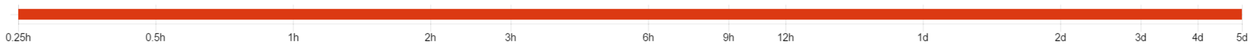


Considered applicable up to 9 hours

Reduced applicability from 9 to 24 hours due to:
- Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.

Not applicable from 24 to 120 hours due to:
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained



Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Use of herders

Not applicable up to 0.5 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.

Considered applicable from 0.5 to 1 hours

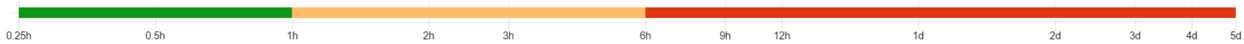
Not applicable from 1 to 120 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

Mechanical Recovery, Booms with high visc. skimmer

Considered applicable up to 6 hours

Reduced applicability from 6 to 120 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and high viscosity skimmers are judged to have reduced applicability due to solidification.

Mechanical Recovery, Booms with low visc. skimmer

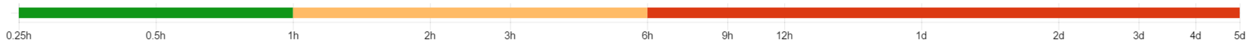


Considered applicable up to 1 hours

Reduced applicability from 1 to 6 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 6 to 120 hours due to:
- Pour point is more than 15°C above ambient sea temperature and low viscosity skimmers are judged not to be applicable due to solidification.

Mechanical Recovery, Flexible one vessel system

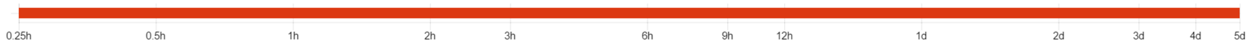


Considered applicable up to 1 hours

Reduced applicability from 1 to 6 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

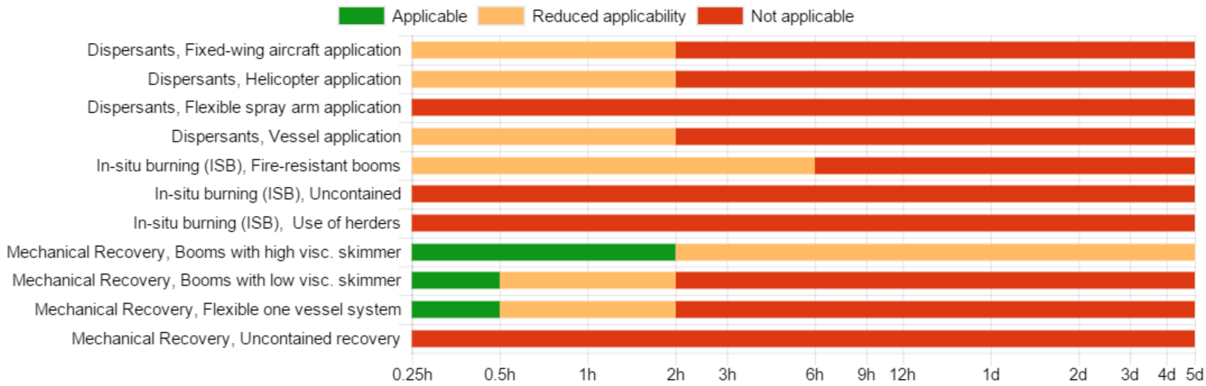
Not applicable from 6 to 120 hours due to:
- Pour point more than 15°C above ambient sea water temperature and such systems are judged not to be applicable due to solidification.

Mechanical Recovery, Uncontained recovery



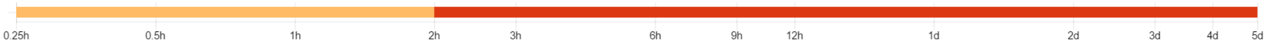
Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and uncontained recovery is judged not to be applicable due to solidification.

Decision parameter	Value
Oil type	NORD BRENT
Wind speed	10m/s
Sea temperature	5°C
Ice coverage	0%
Dispersants effective below viscosity	2500 cP
Dispersants ineffective above viscosity	7000 cP



Details

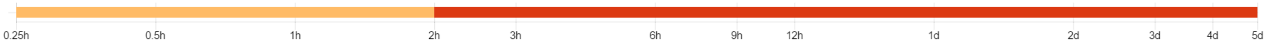
Dispersants, Fixed-wing aircraft application



Reduced applicability up to 2 hours due to:
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 2 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

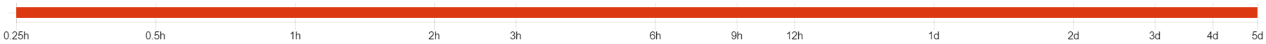
Dispersants, Helicopter application



Reduced applicability up to 2 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

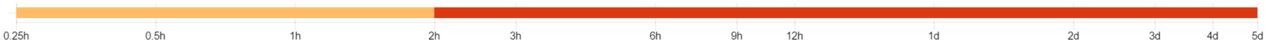
Not applicable from 2 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application



Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

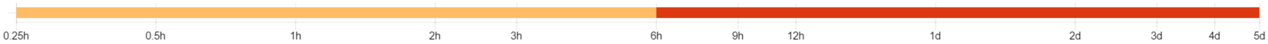
Dispersants, Vessel application



Reduced applicability up to 2 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 2 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

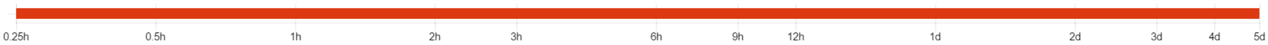
In-situ burning (ISB), Fire-resistant booms



Reduced applicability up to 6 hours due to:
- Wind speed is between 8 and 12 m/s and ignition and ISB is judged to have reduced applicability.
- Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.

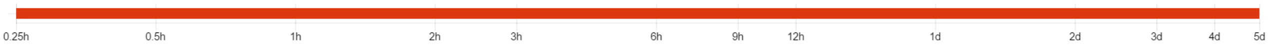
Not applicable from 6 to 120 hours due to:
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained



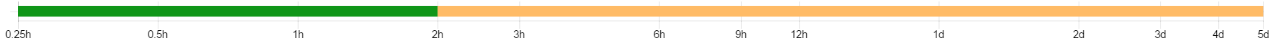
Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Use of herders



Not applicable up to 120 hours due to:
- Wind speed is above 8 m/s and use of herders is judged not to be applicable.
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

Mechanical Recovery, Booms with high visc. skimmer



Considered applicable up to 2 hours

Reduced applicability from 2 to 120 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and high viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 120 to 120 hours due to:
- Pour point is more than 25°C above ambient sea temperature and high viscosity skimmers are judged not to be applicable due to solidification

Mechanical Recovery, Booms with low visc. skimmer

Considered applicable up to 0.5 hours

Reduced applicability from 0.5 to 2 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 2 to 120 hours due to:
- Pour point is more than 15°C above ambient sea temperature and low viscosity skimmers are judged not to be applicable due to solidification.
- Viscosity is above 20.000 cP and low viscosity skimmers are judged not to be applicable.

Mechanical Recovery, Flexible one vessel system

Considered applicable up to 0.5 hours

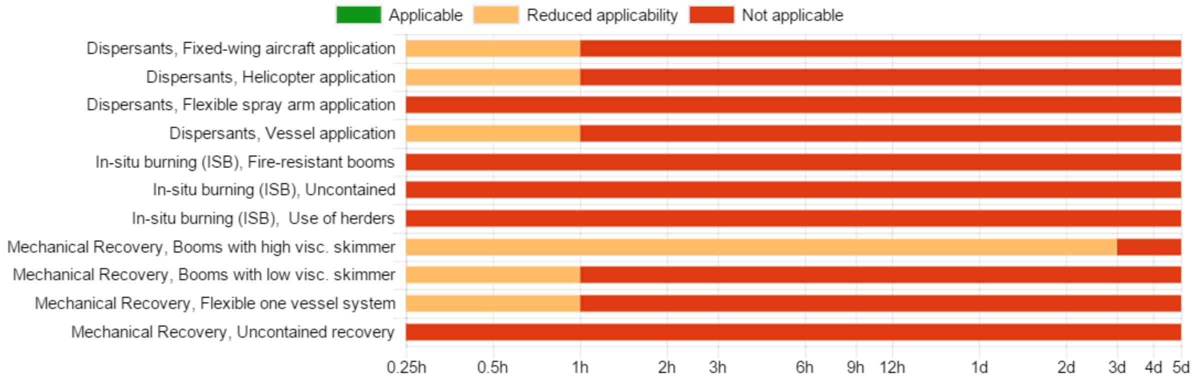
Reduced applicability from 0.5 to 2 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

Not applicable from 2 to 120 hours due to:
- Pour point more than 15°C above ambient sea water temperature and such systems are judged not to be applicable due to solidification.

Mechanical Recovery, Uncontained recovery

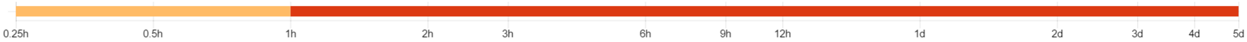
Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and uncontained recovery is judged not to be applicable due to solidification.

Decision parameter	Value
Oil type	NORD BRENT
Wind speed	15m/s
Sea temperature	5℃
Ice coverage	0%
Dispersants effective below viscosity	2500 cP
Dispersants ineffective above viscosity	7000 cP



Details

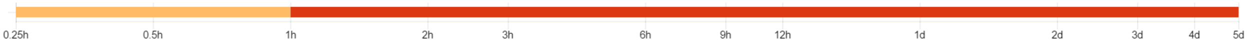
Dispersants, Fixed-wing aircraft application



Reduced applicability up to 1 hours due to:
- Wind speed is between 12 - 15 m/s and use of dispersants is judged to have reduced applicability.
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 1 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

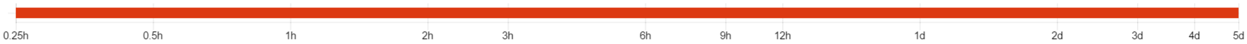
Dispersants, Helicopter application



Reduced applicability up to 1 hours due to:
- Wind speed is between 12 - 15 m/s and use of dispersants is judged to have reduced applicability.
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

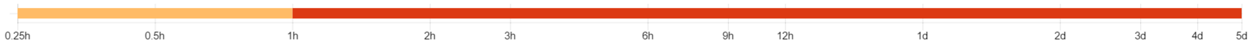
Not applicable from 1 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application



Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

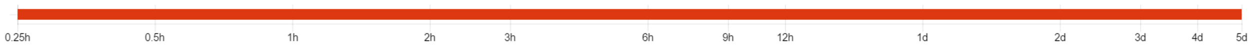
Dispersants, Vessel application



Reduced applicability up to 1 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

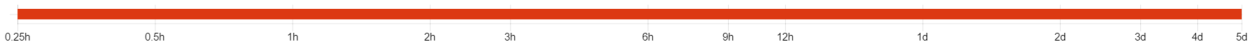
Not applicable from 1 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

In-situ burning (ISB), Fire-resistant booms



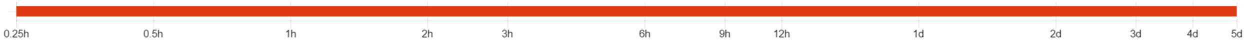
Not applicable up to 120 hours due to:
- Wind speed is above 12 m/s and ignition and ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained



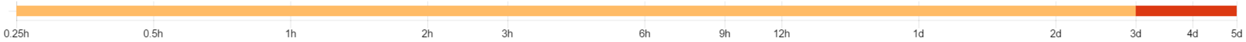
Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Wind speed is above 12 m/s and ignition and ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Use of herders



Not applicable up to 120 hours due to:
- Wind speed is above 8 m/s and use of herders is judged not to be applicable.
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

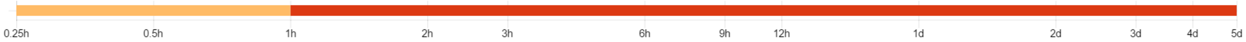
Mechanical Recovery, Booms with high visc. skimmer



Reduced applicability up to 72 hours due to:
- Wind speed is between 10 - 15 m/s and confinement by boom is judged to have reduced applicability.
- Pour point is between 10 to 15°C above the ambient sea temperature and high viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 72 to 120 hours due to:
- Pour point is more than 25°C above ambient sea temperature and high viscosity skimmers are judged not to be applicable due to solidification

Mechanical Recovery, Booms with low visc. skimmer



Reduced applicability up to 1 hours due to:
- Wind speed is between 10 - 15 m/s and confinement by boom is judged to have reduced applicability.
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 1 to 120 hours due to:
- Pour point is more than 15°C above ambient sea temperature and low viscosity skimmers are judged not to be applicable due to solidification.
- Viscosity is above 20.000 cP and low viscosity skimmers are judged not to be applicable.

Mechanical Recovery, Flexible one vessel system

Reduced applicability up to 1 hours due to:
- Wind speed is between 10 - 15 m/s and confinement is judged to have reduced applicability.
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

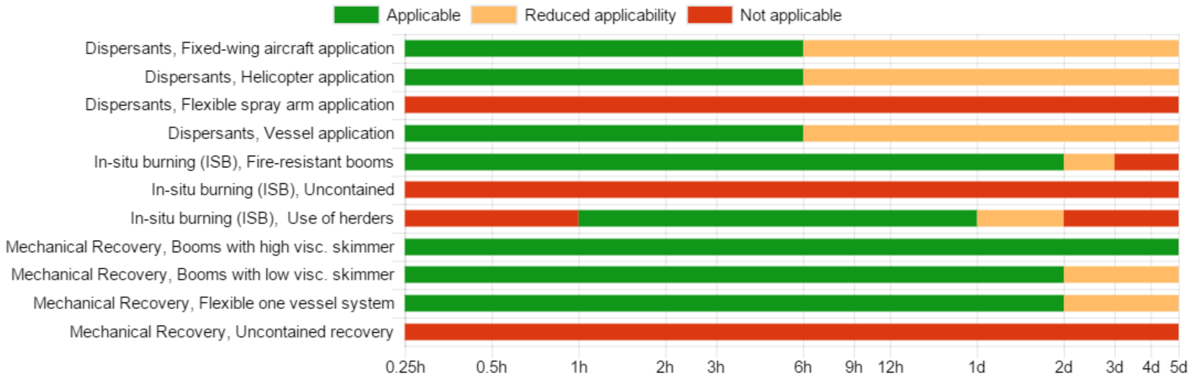
Not applicable from 1 to 120 hours due to:
- Pour point more than 15°C above ambient sea water temperature and such systems are judged not to be applicable due to solidification.

Mechanical Recovery, Uncontained recovery

Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and uncontained recovery is judged not to be applicable due to solidification.

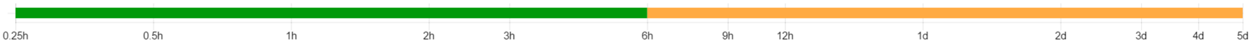
F.3 Sygna Brent (E-2&E-3), 15°

Decision parameter	Value
Oil type	SYGNA BRENT
Wind speed	2m/s
Sea temperature	15℃
Ice coverage	0%
Dispersants effective below viscosity	1700 cP
Dispersants ineffective above viscosity	8000 cP



Details

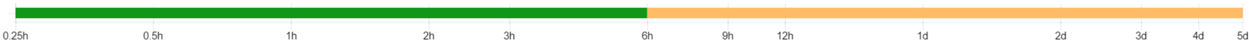
Dispersants, Fixed-wing aircraft application



Considered applicable up to 6 hours

Reduced applicability from 6 to 120 hours due to:
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

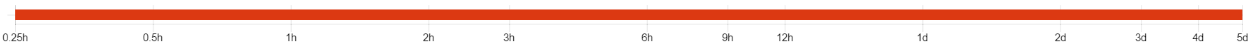
Dispersants, Helicopter application



Considered applicable up to 6 hours

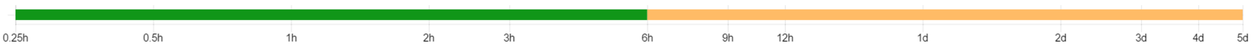
Reduced applicability from 6 to 120 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

Dispersants, Flexible spray arm application



Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.

Dispersants, Vessel application



Considered applicable up to 6 hours

Reduced applicability from 6 to 120 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

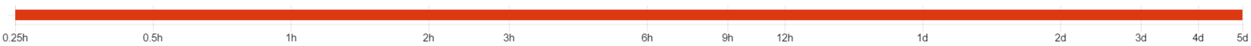
In-situ burning (ISB), Fire-resistant booms

Considered applicable up to 48 hours

Reduced applicability from 48 to 72 hours due to:
- Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.

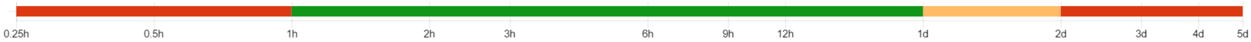
Not applicable from 72 to 120 hours due to:
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained



Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Use of herders



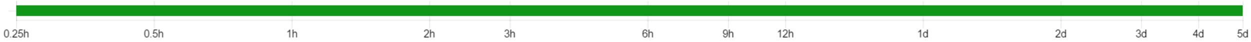
Not applicable up to 1 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.

Considered applicable from 1 to 24 hours

Reduced applicability from 24 to 48 hours due to:
- Pour point is between 8 - 10°C above the ambient sea temperature and use of herders is judged to have reduced applicability.

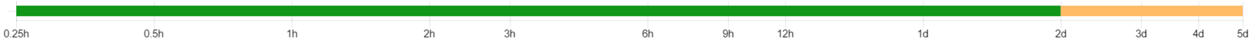
Not applicable from 48 to 120 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

Mechanical Recovery, Booms with high visc. skimmer



Considered applicable up to 120 hours

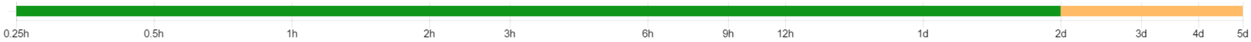
Mechanical Recovery, Booms with low visc. skimmer



Considered applicable up to 48 hours

Reduced applicability from 48 to 120 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.

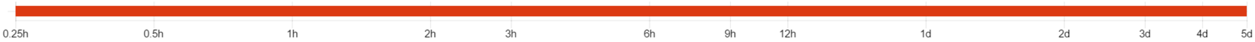
Mechanical Recovery, Flexible one vessel system



Considered applicable up to 48 hours

Reduced applicability from 48 to 120 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

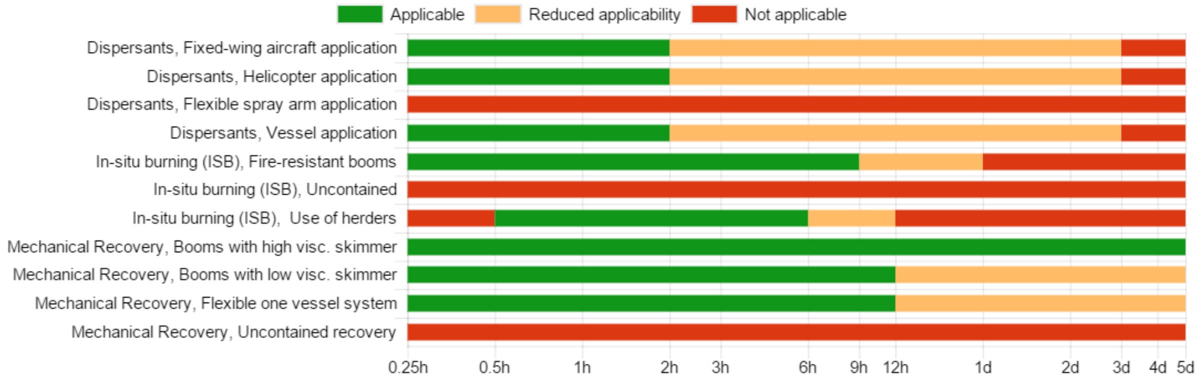
Mechanical Recovery, Uncontained recovery



Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.

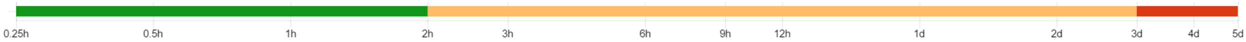
SINTEF

Decision parameter	Value
Oil type	SYGNA BRENT
Wind speed	5m/s
Sea temperature	15˚C
Ice coverage	0%
Dispersants effective below viscosity	1700 cP
Dispersants ineffective above viscosity	8000 cP



Details

Dispersants, Fixed-wing aircraft application

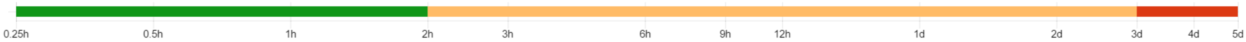


Considered applicable up to 2 hours

Reduced applicability from 2 to 72 hours due to:
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscosity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

Not applicable from 72 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Helicopter application

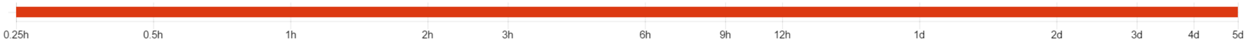


Considered applicable up to 2 hours

Reduced applicability from 2 to 72 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscosity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

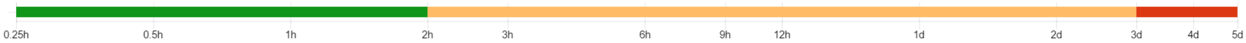
Not applicable from 72 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application



Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Vessel application

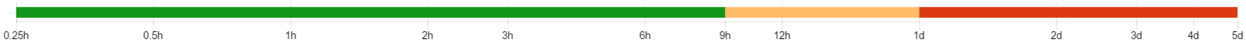


Considered applicable up to 2 hours

Reduced applicability from 2 to 72 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscosity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

Not applicable from 72 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

In-situ burning (ISB), Fire-resistant booms

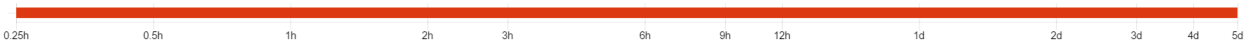


Considered applicable up to 9 hours

Reduced applicability from 9 to 24 hours due to:
- Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.

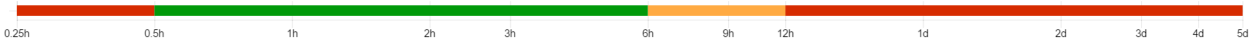
Not applicable from 24 to 120 hours due to:
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained



Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Use of herders



Not applicable up to 0.5 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.

Considered applicable from 0.5 to 6 hours

Reduced applicability from 6 to 12 hours due to:
- Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.
- Pour point is between 8 - 10°C above the ambient sea temperature and use of herders is judged to have reduced applicability.

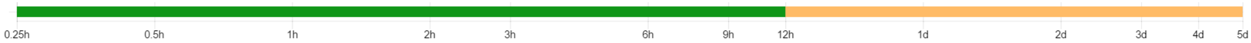
Not applicable from 12 to 120 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

Mechanical Recovery, Booms with high visc. skimmer

Considered applicable up to 120 hours

Reduced applicability from 120 to 120 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and high viscosity skimmers are judged to have reduced applicability due to solidification.

Mechanical Recovery, Booms with low visc. skimmer

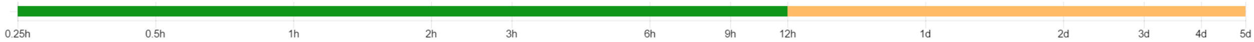


Considered applicable up to 12 hours

Reduced applicability from 12 to 120 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 120 to 120 hours due to:
- Pour point is more than 15°C above ambient sea temperature and low viscosity skimmers are judged not to be applicable due to solidification.

Mechanical Recovery, Flexible one vessel system

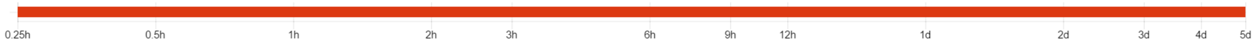


Considered applicable up to 12 hours

Reduced applicability from 12 to 120 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

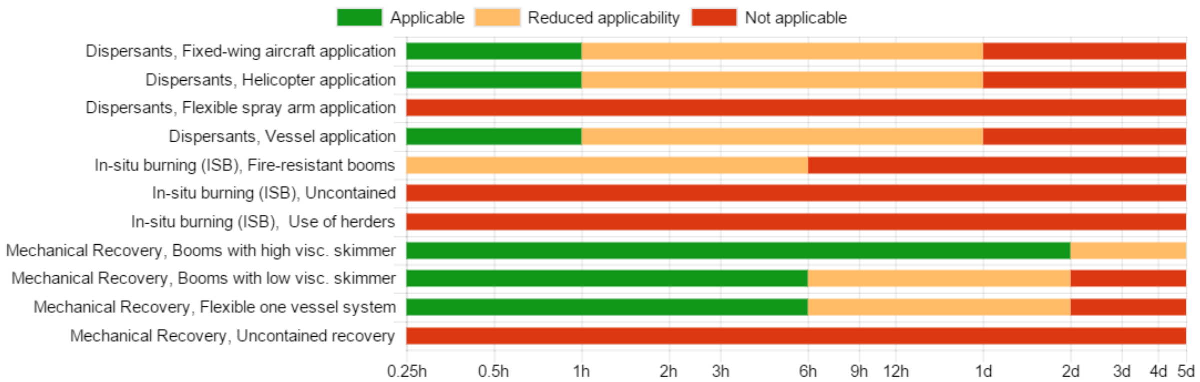
Not applicable from 120 to 120 hours due to:
- Pour point more than 15°C above ambient sea water temperature and such systems are judged not to be applicable due to solidification.

Mechanical Recovery, Uncontained recovery



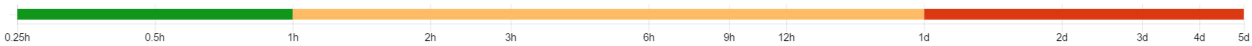
Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and uncontained recovery is judged not to be applicable due to solidification.

Decision parameter	Value
Oil type	SYGNA BRENT
Wind speed	10m/s
Sea temperature	15℃
Ice coverage	0%
Dispersants effective below viscosity	1700 cP
Dispersants ineffective above viscosity	8000 cP



Details

Dispersants, Fixed-wing aircraft application

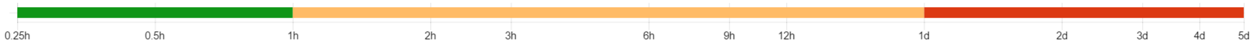


Considered applicable up to 1 hours

Reduced applicability from 1 to 24 hours due to:
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

Not applicable from 24 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Helicopter application

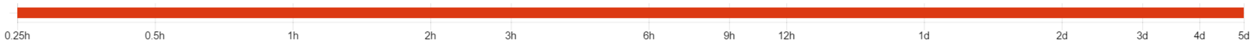


Considered applicable up to 1 hours

Reduced applicability from 1 to 24 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

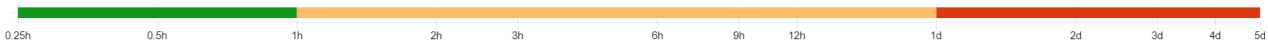
Not applicable from 24 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application



Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Vessel application

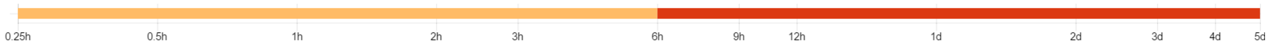


Considered applicable up to 1 hours

Reduced applicability from 1 to 24 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

Not applicable from 24 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

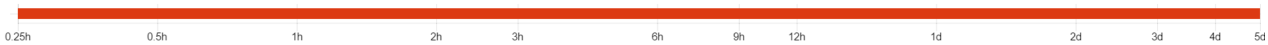
In-situ burning (ISB), Fire-resistant booms



Reduced applicability up to 6 hours due to:
- Wind speed is between 8 and 12 m/s and ignition and ISB is judged to have reduced applicability.
- Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.

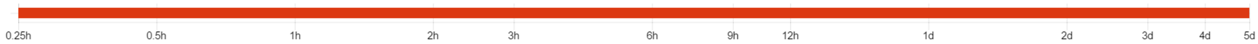
Not applicable from 6 to 120 hours due to:
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained



Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Use of herders



Not applicable up to 120 hours due to:
- Wind speed is above 8 m/s and use of herders is judged not to be applicable.
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

Mechanical Recovery, Booms with high visc. skimmer

Considered applicable up to 48 hours

Reduced applicability from 48 to 120 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and high viscosity skimmers are judged to have reduced applicability due to solidification.

Mechanical Recovery, Booms with low visc. skimmer

Considered applicable up to 6 hours

Reduced applicability from 6 to 48 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 48 to 120 hours due to:
- Pour point is more than 15°C above ambient sea temperature and low viscosity skimmers are judged not to be applicable due to solidification.

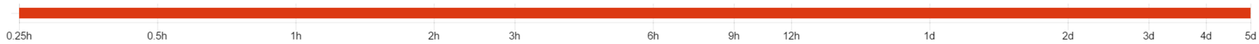
Mechanical Recovery, Flexible one vessel system

Considered applicable up to 6 hours

Reduced applicability from 6 to 48 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

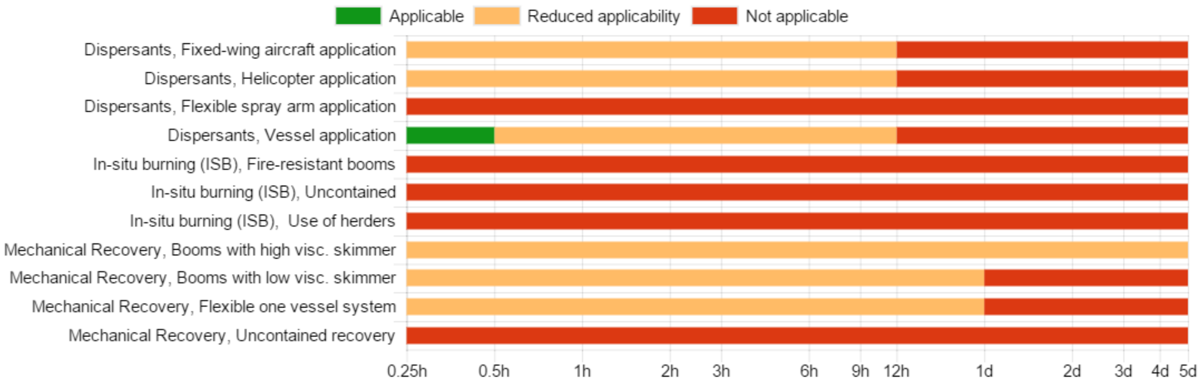
Not applicable from 48 to 120 hours due to:
- Pour point more than 15°C above ambient sea water temperature and such systems are judged not to be applicable due to solidification.

Mechanical Recovery, Uncontained recovery



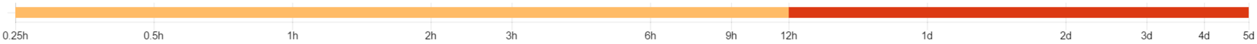
Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and uncontained recovery is judged not to be applicable due to solidification.

Decision parameter	Value
Oil type	SYGNA BRENT
Wind speed	15m/s
Sea temperature	15℃
Ice coverage	0%
Dispersants effective below viscosity	1700 cP
Dispersants ineffective above viscosity	8000 cP



Details

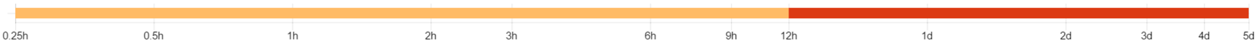
Dispersants, Fixed-wing aircraft application



Reduced applicability up to 12 hours due to:
- Wind speed is between 12 - 15 m/s and use of dispersants is judged to have reduced applicability.
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

Not applicable from 12 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

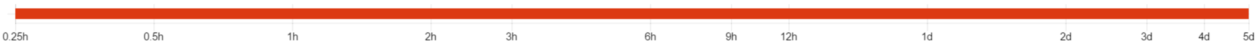
Dispersants, Helicopter application



Reduced applicability up to 12 hours due to:
- Wind speed is between 12 - 15 m/s and use of dispersants is judged to have reduced applicability.
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

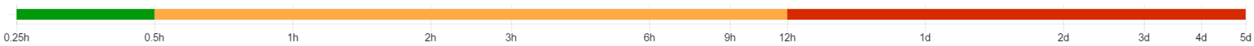
Not applicable from 12 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application



Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Vessel application

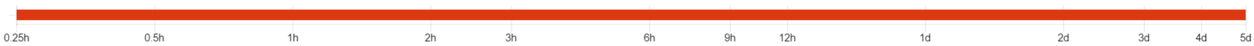


Considered applicable up to 0.5 hours

Reduced applicability from 0.5 to 12 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification
- Viscocity of the oil is above the lower viscosity limit indicating reduced effectiveness by use of dispersants.

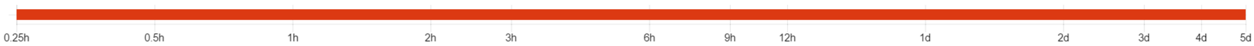
Not applicable from 12 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

In-situ burning (ISB), Fire-resistant booms



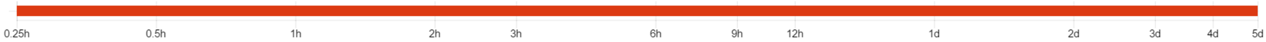
Not applicable up to 120 hours due to:
- Wind speed is above 12 m/s and ignition and ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained



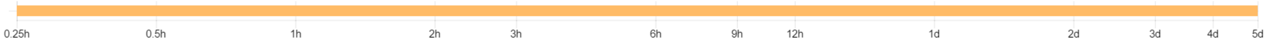
Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Wind speed is above 12 m/s and ignition and ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Use of herders



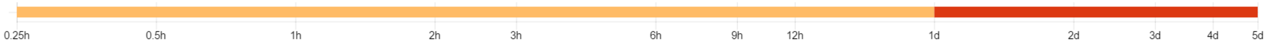
Not applicable up to 120 hours due to:
- Wind speed is above 8 m/s and use of herders is judged not to be applicable.
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

Mechanical Recovery, Booms with high visc. skimmer



Reduced applicability up to 120 hours due to:
- Wind speed is between 10 - 15 m/s and confinement by boom is judged to have reduced applicability.
- Pour point is between 10 to 15°C above the ambient sea temperature and high viscosity skimmers are judged to have reduced applicability due to solidification.

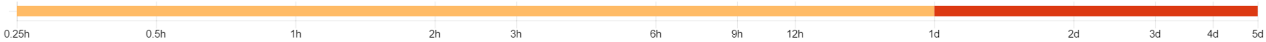
Mechanical Recovery, Booms with low visc. skimmer



Reduced applicability up to 24 hours due to:
- Wind speed is between 10 - 15 m/s and confinement by boom is judged to have reduced applicability.
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 24 to 120 hours due to:
- Pour point is more than 15°C above ambient sea temperature and low viscosity skimmers are judged not to be applicable due to solidification.
- Viscosity is above 20.000 cP and low viscosity skimmers are judged not to be applicable.

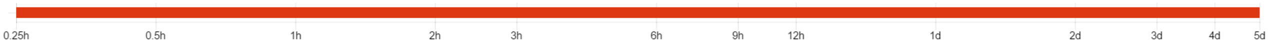
Mechanical Recovery, Flexible one vessel system



Reduced applicability up to 24 hours due to:
- Wind speed is between 10 - 15 m/s and confinement is judged to have reduced applicability.
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

Not applicable from 24 to 120 hours due to:
- Pour point more than 15°C above ambient sea water temperature and such systems are judged not to be applicable due to solidification.

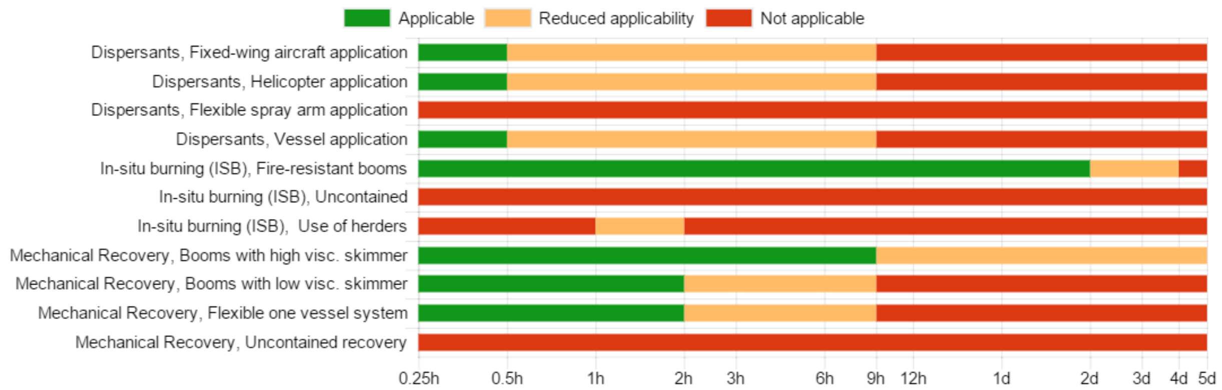
Mechanical Recovery, Uncontained recovery



Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and uncontained recovery is judged not to be applicable due to solidification.

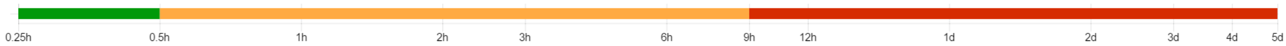
F.4 Sygna Brent (E-2&E-3), 5°C

Decision parameter	Value
Oil type	SYGNA BRENT
Wind speed	2m/s
Sea temperature	5°C
Ice coverage	0%
Dispersants effective below viscosity	1700 cP
Dispersants ineffective above viscosity	8000 cP



Details

Dispersants, Fixed-wing aircraft application

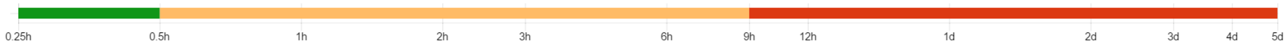


Considered applicable up to 0.5 hours

Reduced applicability from 0.5 to 9 hours due to:
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 9 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.

Dispersants, Helicopter application

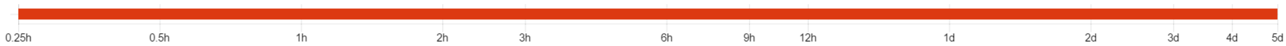


Considered applicable up to 0.5 hours

Reduced applicability from 0.5 to 9 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

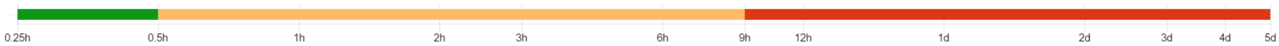
Not applicable from 9 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.

Dispersants, Flexible spray arm application



Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.

Dispersants, Vessel application

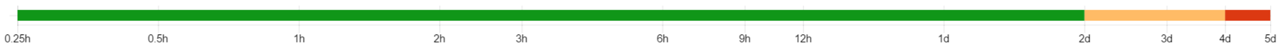


Considered applicable up to 0.5 hours

Reduced applicability from 0.5 to 9 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 9 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.

In-situ burning (ISB), Fire-resistant booms

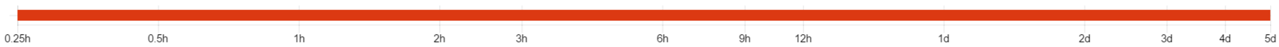


Considered applicable up to 48 hours

Reduced applicability from 48 to 96 hours due to:
- Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.

Not applicable from 96 to 120 hours due to:
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained



Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

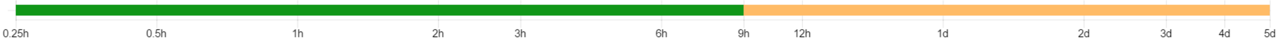
In-situ burning (ISB), Use of herders

Not applicable up to 1 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.

Reduced applicability from 1 to 2 hours due to:
- Pour point is between 8 - 10°C above the ambient sea temperature and use of herders is judged to have reduced applicability.

Not applicable from 2 to 120 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

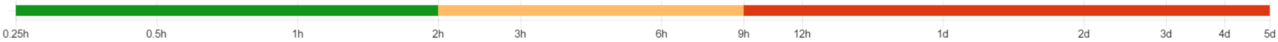
Mechanical Recovery, Booms with high visc. skimmer



Considered applicable up to 9 hours

Reduced applicability from 9 to 120 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and high viscosity skimmers are judged to have reduced applicability due to solidification.

Mechanical Recovery, Booms with low visc. skimmer

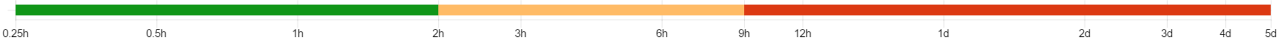


Considered applicable up to 2 hours

Reduced applicability from 2 to 9 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 9 to 120 hours due to:
- Pour point is more than 15°C above ambient sea temperature and low viscosity skimmers are judged not to be applicable due to solidification.

Mechanical Recovery, Flexible one vessel system

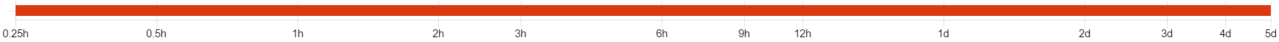


Considered applicable up to 2 hours

Reduced applicability from 2 to 9 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

Not applicable from 9 to 120 hours due to:
- Pour point more than 15°C above ambient sea water temperature and such systems are judged not to be applicable due to solidification.

Mechanical Recovery, Uncontained recovery



Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and uncontained recovery is judged not to be applicable due to solidification.

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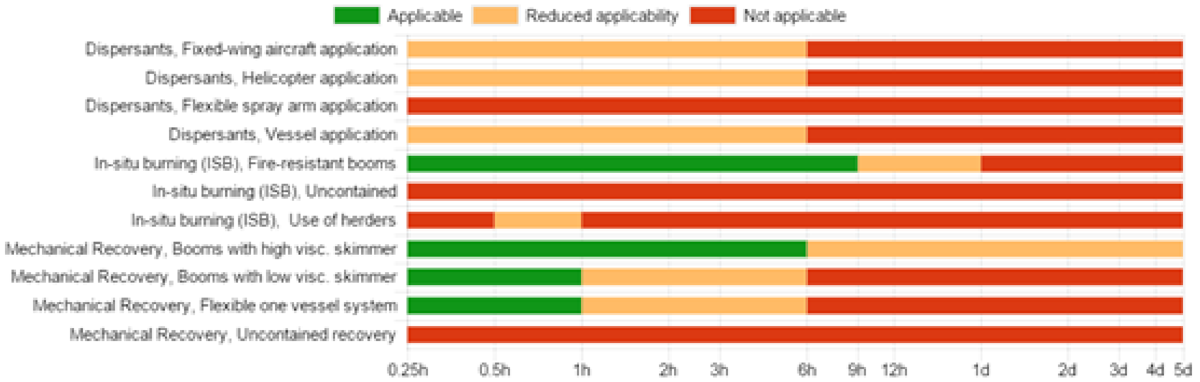
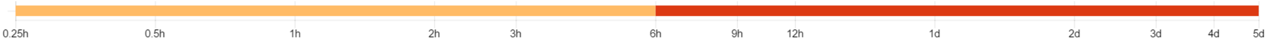
Decision parameter	Value
Oil type	SYGNA BRENT
Wind speed	5m/s
Sea temperature	5℃
Ice coverage	0%
Dispersants effective below viscosity	1700 cP
Dispersants ineffective above viscosity	8000 cP



Details

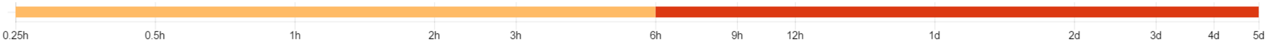
Dispersants, Fixed-wing aircraft application



Reduced applicability up to 6 hours due to:
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 6 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

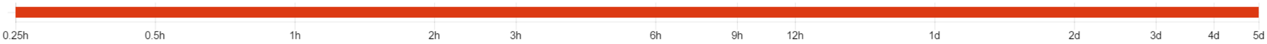
Dispersants, Helicopter application



Reduced applicability up to 6 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

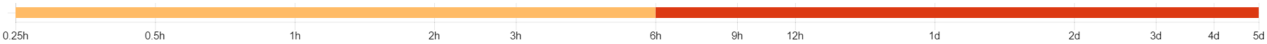
Not applicable from 6 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application



Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

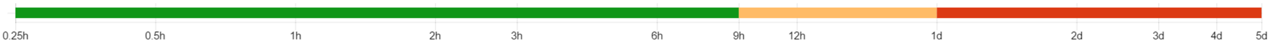
Dispersants, Vessel application



Reduced applicability up to 6 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 6 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

In-situ burning (ISB), Fire-resistant booms

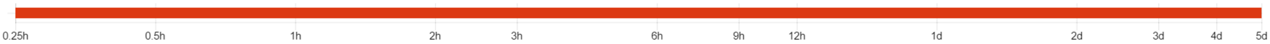


Considered applicable up to 9 hours

Reduced applicability from 9 to 24 hours due to:
- Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.

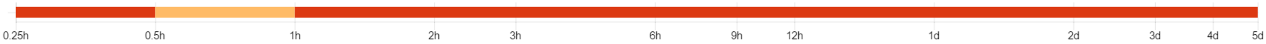
Not applicable from 24 to 120 hours due to:
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained



Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Use of herders

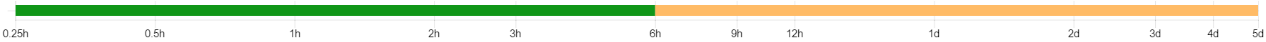


Not applicable up to 0.5 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.

Reduced applicability from 0.5 to 1 hours due to:
- Pour point is between 8 - 10°C above the ambient sea temperature and use of herders is judged to have reduced applicability.

Not applicable from 1 to 120 hours due to:
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

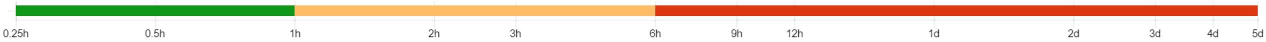
Mechanical Recovery, Booms with high visc. skimmer



Considered applicable up to 6 hours

Reduced applicability from 6 to 120 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and high viscosity skimmers are judged to have reduced applicability due to solidification.

Mechanical Recovery, Booms with low visc. skimmer

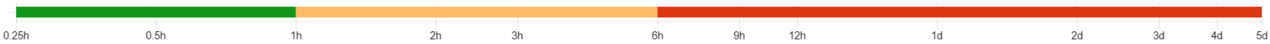


Considered applicable up to 1 hours

Reduced applicability from 1 to 6 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 6 to 120 hours due to:
- Pour point is more than 15°C above ambient sea temperature and low viscosity skimmers are judged not to be applicable due to solidification.

Mechanical Recovery, Flexible one vessel system

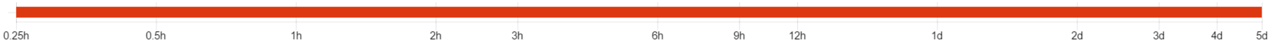


Considered applicable up to 1 hours

Reduced applicability from 1 to 6 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

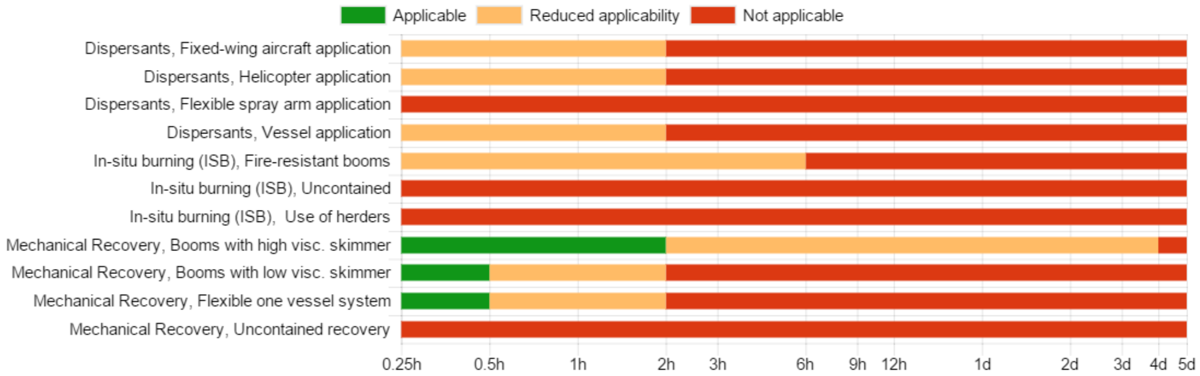
Not applicable from 6 to 120 hours due to:
- Pour point more than 15°C above ambient sea water temperature and such systems are judged not to be applicable due to solidification.

Mechanical Recovery, Uncontained recovery



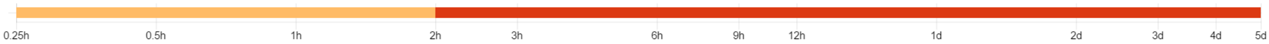
Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and uncontained recovery is judged not to be applicable due to solidification.

Decision parameter	Value
Oil type	SYGNA BRENT
Wind speed	10m/s
Sea temperature	5℃
Ice coverage	0%
Dispersants effective below viscosity	1700 cP
Dispersants ineffective above viscosity	8000 cP



Details

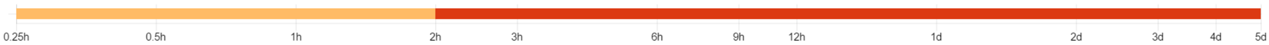
Dispersants, Fixed-wing aircraft application



Reduced applicability up to 2 hours due to:
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 2 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

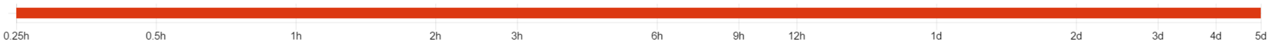
Dispersants, Helicopter application



Reduced applicability up to 2 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

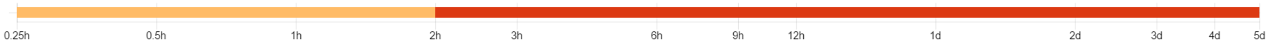
Not applicable from 2 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application



Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

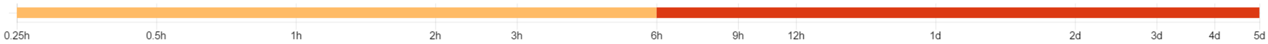
Dispersants, Vessel application



Reduced applicability up to 2 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 2 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

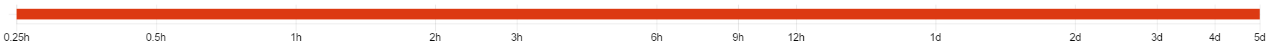
In-situ burning (ISB), Fire-resistant booms



Reduced applicability up to 6 hours due to:
- Wind speed is between 8 and 12 m/s and ignition and ISB is judged to have reduced applicability.
- Water content is between 30 - 50% and ignition and ISB is judged to have reduced applicability.

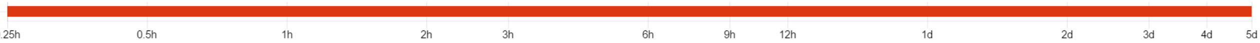
Not applicable from 6 to 120 hours due to:
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained



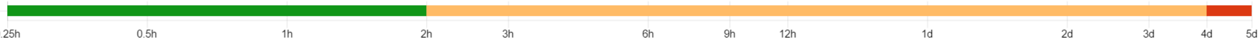
Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Use of herders



Not applicable up to 120 hours due to:
- Wind speed is above 8 m/s and use of herders is judged not to be applicable.
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

Mechanical Recovery, Booms with high visc. skimmer

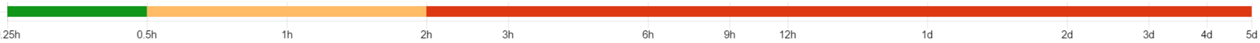


Considered applicable up to 2 hours

Reduced applicability from 2 to 96 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and high viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 96 to 120 hours due to:
- Pour point is more than 25°C above ambient sea temperature and high viscosity skimmers are judged not to be applicable due to solidification

Mechanical Recovery, Booms with low visc. skimmer

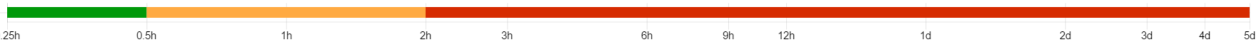


Considered applicable up to 0.5 hours

Reduced applicability from 0.5 to 2 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 2 to 120 hours due to:
- Pour point is more than 15°C above ambient sea temperature and low viscosity skimmers are judged not to be applicable due to solidification.
- Viscosity is above 20.000 cP and low viscosity skimmers are judged not to be applicable.

Mechanical Recovery, Flexible one vessel system

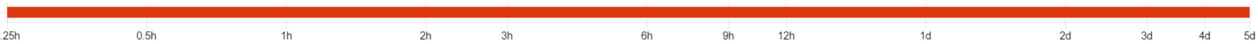


Considered applicable up to 0.5 hours

Reduced applicability from 0.5 to 2 hours due to:
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

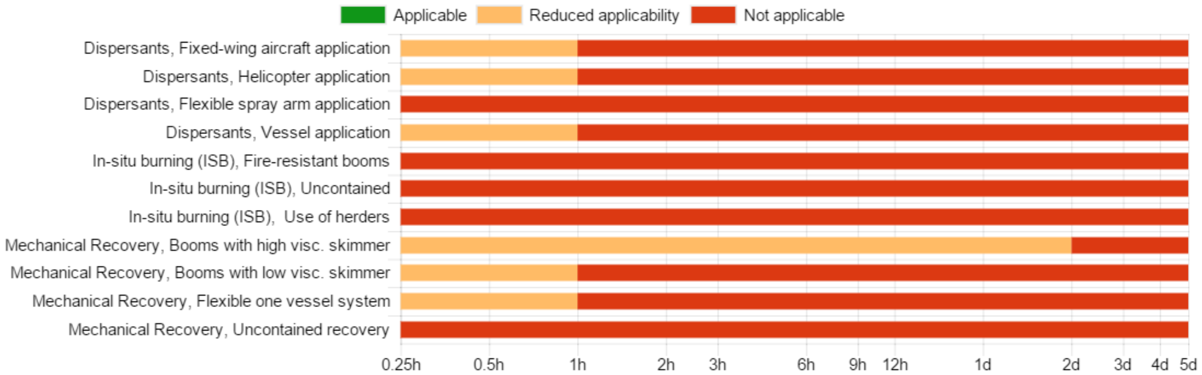
Not applicable from 2 to 120 hours due to:
- Pour point more than 15°C above ambient sea water temperature and such systems are judged not to be applicable due to solidification.

Mechanical Recovery, Uncontained recovery



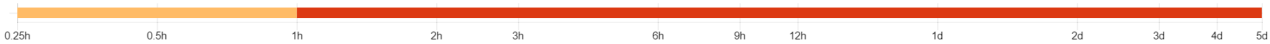
Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and uncontained recovery is judged not to be applicable due to solidification.

Decision parameter	Value
Oil type	SYGNA BRENT
Wind speed	15m/s
Sea temperature	5°C
Ice coverage	0%
Dispersants effective below viscosity	1700 cP
Dispersants ineffective above viscosity	8000 cP



Details

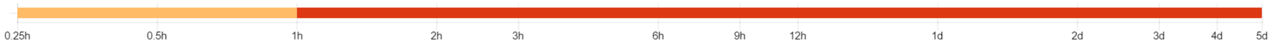
Dispersants, Fixed-wing aircraft application



Reduced applicability up to 1 hours due to:
- Wind speed is between 12 - 15 m/s and use of dispersants is judged to have reduced applicability.
- Pour point between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

Not applicable from 1 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

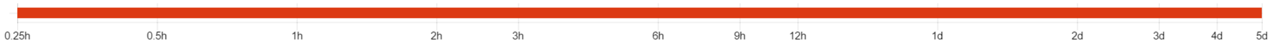
Dispersants, Helicopter application



Reduced applicability up to 1 hours due to:
- Wind speed is between 12 - 15 m/s and use of dispersants is judged to have reduced applicability.
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

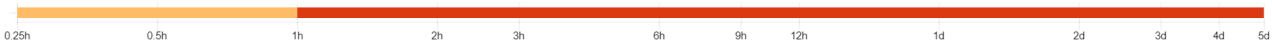
Not applicable from 1 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

Dispersants, Flexible spray arm application



Not applicable up to 120 hours due to:
- Ice coverage is below 50% and application by flexible spray arm is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

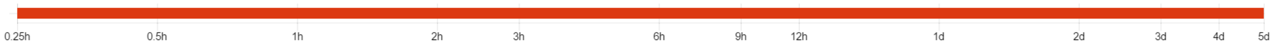
Dispersants, Vessel application



Reduced applicability up to 1 hours due to:
- Pour point is between 5 to 15°C above the ambient sea temperature and use of dispersants is judged to have reduced applicability due to solidification

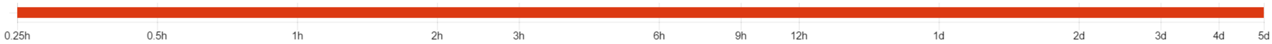
Not applicable from 1 to 120 hours due to:
- Pour point is more than 15°C above ambient sea water temperature and use of dispersants is judged not to be applicable due to solidification.
- Viscosity of the oil is above the higher viscosity limit indicating poor or slow dispersibility by use of dispersants.

In-situ burning (ISB), Fire-resistant booms



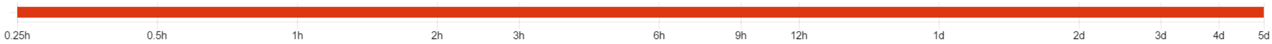
Not applicable up to 120 hours due to:
- Wind speed is above 12 m/s and ignition and ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Uncontained



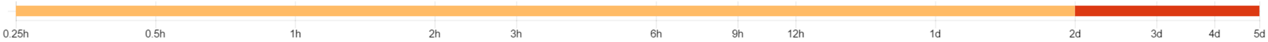
Not applicable up to 120 hours due to:
- Ice coverages is below 40% and uncontained ISB is judged not to be applicable.
- Wind speed is above 12 m/s and ignition and ISB is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.

In-situ burning (ISB), Use of herders



Not applicable up to 120 hours due to:
- Wind speed is above 8 m/s and use of herders is judged not to be applicable.
- Oil/emulsion thickness is below 0,5 mm or above 2 mm and use of herders is judged not to be applicable.
- Water content is above 50% and ignition and ISB is judged not to be applicable.
- Pour point is 10°C or more above the ambient sea temperature and use of herders is judged not to be applicable.

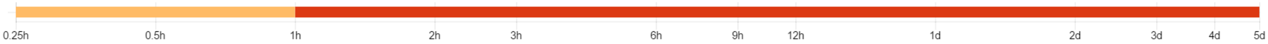
Mechanical Recovery, Booms with high visc. skimmer



Reduced applicability up to 48 hours due to:
- Wind speed is between 10 - 15 m/s and confinement by boom is judged to have reduced applicability.
- Pour point is between 10 to 15°C above the ambient sea temperature and high viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 48 to 120 hours due to:
- Pour point is more than 25°C above ambient sea temperature and high viscosity skimmers are judged not to be applicable due to solidification

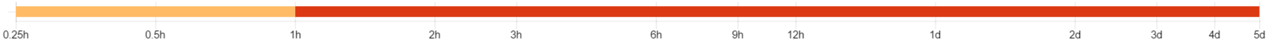
Mechanical Recovery, Booms with low visc. skimmer



Reduced applicability up to 1 hours due to:
- Wind speed is between 10 - 15 m/s and confinement by boom is judged to have reduced applicability.
- Pour point is between 10 to 15°C above the ambient sea temperature and low viscosity skimmers are judged to have reduced applicability due to solidification.

Not applicable from 1 to 120 hours due to:
- Pour point is more than 15°C above ambient sea temperature and low viscosity skimmers are judged not to be applicable due to solidification.
- Viscosity is above 20.000 cP and low viscosity skimmers are judged not to be applicable.

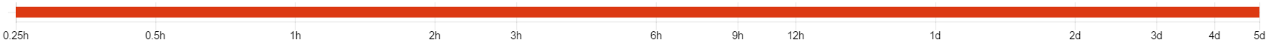
Mechanical Recovery, Flexible one vessel system



Reduced applicability up to 1 hours due to:
- Wind speed is between 10 - 15 m/s and confinement is judged to have reduced applicability.
- Pour point is between 10 to 15°C above the ambient sea temperature and such systems are judged to have reduced applicability due to solidification.

Not applicable from 1 to 120 hours due to:
- Pour point more than 15°C above ambient sea water temperature and such systems are judged not to be applicable due to solidification.

Mechanical Recovery, Uncontained recovery



Not applicable up to 120 hours due to:
- Ice coverage is below 30% and uncontained recovery is judged not to be applicable.
- Pour point is more than 15°C above ambient sea water temperature and uncontained recovery is judged not to be applicable due to solidification.

G Summary tabulated weathering predictions

Note: "Ikke dispergerbar" is related to the viscosity limits for OWM predictions " Poorly /slowly dispersible"

G.1 SF Nord Brent (E-2&E-3)

Table G-1 Summary weathering predictions for SF Nord Brent (E-2&E-3) at 5 °C

Oil_type	Season	Temp. °C	Wind m/s	Hour	Water cont.	Emulsion viscosity	Dispersibility	Evap. %	Surface oil %	Naturally disp. %	Flash Point °C	Explosion hazard	Pour point
Nord Brent	Vinter	5	2	1	1	172	Kjemisk dispergerbar	11	89	0	27	Eksplosjonsfare ved tanking	12
Nord Brent	Vinter	5	2	2	2	263	Kjemisk dispergerbar	15	85	0	41	Eksplosjonsfare ved tanking	15
Nord Brent	Vinter	5	2	3	3	332	Kjemisk dispergerbar	18	83	0	48	Eksplosjonsfare ved tanking	16
Nord Brent	Vinter	5	2	6	7	492	Kjemisk dispergerbar	21	79	0	59	Eksplosjonsfare ved tanking	18
Nord Brent	Vinter	5	2	9	10	633	Kjemisk dispergerbar	22	78	0	64	Ingen eksplosjonsfare	19
Nord Brent	Vinter	5	2	12	13	773	Kjemisk dispergerbar	23	77	0	68	Ingen eksplosjonsfare	20
Nord Brent	Vinter	5	2	24	23	1386	Kjemisk dispergerbar	26	74	0	78	Ingen eksplosjonsfare	22
Nord Brent	Vinter	5	2	48	39	2850	Redusert kjemisk disp.	28	72	0	87	Ingen eksplosjonsfare	24
Nord Brent	Vinter	5	2	72	49	4590	Redusert kjemisk disp.	30	70	0	93	Ingen eksplosjonsfare	25
Nord Brent	Vinter	5	2	96	57	6392	Redusert kjemisk disp.	31	69	0	97	Ingen eksplosjonsfare	25
Nord Brent	Vinter	5	2	120	62	8095	Ikke dispergerbar	32	68	0	100	Ingen eksplosjonsfare	26
Nord Brent	Vinter	5	5	1	5	286	Kjemisk dispergerbar	16	84	0	41	Eksplosjonsfare ved tanking	15
Nord Brent	Vinter	5	5	2	9	469	Kjemisk dispergerbar	19	80	0	54	Eksplosjonsfare ved tanking	18
Nord Brent	Vinter	5	5	3	13	634	Kjemisk dispergerbar	21	78	1	61	Ingen eksplosjonsfare	19
Nord Brent	Vinter	5	5	6	23	1164	Kjemisk dispergerbar	24	75	1	71	Ingen eksplosjonsfare	21
Nord Brent	Vinter	5	5	9	32	1794	Kjemisk dispergerbar	26	73	1	77	Ingen eksplosjonsfare	22
Nord Brent	Vinter	5	5	12	40	2493	Kjemisk dispergerbar	27	72	2	81	Ingen eksplosjonsfare	22
Nord Brent	Vinter	5	5	24	58	5679	Redusert kjemisk disp.	29	69	3	90	Ingen eksplosjonsfare	24
Nord Brent	Vinter	5	5	48	70	10710	Ikke dispergerbar	31	65	4	100	Ingen eksplosjonsfare	26
Nord Brent	Vinter	5	5	72	73	13135	Ikke dispergerbar	33	62	5	106	Ingen eksplosjonsfare	27
Nord Brent	Vinter	5	5	96	73	14454	Ikke dispergerbar	34	60	6	110	Ingen eksplosjonsfare	27
Nord Brent	Vinter	5	5	120	73	15527	Ikke dispergerbar	34	59	7	113	Ingen eksplosjonsfare	28
Nord Brent	Vinter	5	10	1	14	630	Kjemisk dispergerbar	21	77	3	59	Eksplosjonsfare ved tanking	18
Nord Brent	Vinter	5	10	2	26	1221	Kjemisk dispergerbar	24	71	5	70	Ingen eksplosjonsfare	21
Nord Brent	Vinter	5	10	3	35	1933	Kjemisk dispergerbar	25	68	7	76	Ingen eksplosjonsfare	22
Nord Brent	Vinter	5	10	6	54	4466	Redusert kjemisk disp.	28	61	12	86	Ingen eksplosjonsfare	23
Nord Brent	Vinter	5	10	9	64	7035	Ikke dispergerbar	29	56	15	92	Ingen eksplosjonsfare	24
Nord Brent	Vinter	5	10	12	69	9149	Ikke dispergerbar	30	53	18	96	Ingen eksplosjonsfare	25
Nord Brent	Vinter	5	10	24	73	13268	Ikke dispergerbar	32	43	26	105	Ingen eksplosjonsfare	27
Nord Brent	Vinter	5	10	48	73	16612	Ikke dispergerbar	33	30	37	115	Ingen eksplosjonsfare	28
Nord Brent	Vinter	5	10	72	73	18935	Ikke dispergerbar	34	21	45	121	Ingen eksplosjonsfare	29
Nord Brent	Vinter	5	10	96	73	20786	Ikke dispergerbar	35	15	50	125	Ingen eksplosjonsfare	30
Nord Brent	Vinter	5	10	120	73	22355	Ikke dispergerbar	35	11	54	128	Ingen eksplosjonsfare	30
Nord Brent	Vinter	5	15	1	27	1241	Kjemisk dispergerbar	23	64	13	69	Ingen eksplosjonsfare	20
Nord Brent	Vinter	5	15	2	45	2836	Redusert kjemisk disp.	26	53	22	79	Ingen eksplosjonsfare	22
Nord Brent	Vinter	5	15	3	56	4654	Redusert kjemisk disp.	27	46	28	85	Ingen eksplosjonsfare	23
Nord Brent	Vinter	5	15	6	70	9370	Ikke dispergerbar	29	33	39	95	Ingen eksplosjonsfare	25
Nord Brent	Vinter	5	15	9	73	11924	Ikke dispergerbar	29	25	46	101	Ingen eksplosjonsfare	26
Nord Brent	Vinter	5	15	12	73	13267	Ikke dispergerbar	30	19	51	105	Ingen eksplosjonsfare	27
Nord Brent	Vinter	5	15	24	73	16625	Ikke dispergerbar	31	7	62	115	Ingen eksplosjonsfare	28
Nord Brent	Vinter	5	15	48	73	20807	Ikke dispergerbar	31	1	67	125	Ingen eksplosjonsfare	30
Nord Brent	Vinter	5	15	72	73	23778	Ikke dispergerbar	31	0	69	131	Ingen eksplosjonsfare	31
Nord Brent	Vinter	5	15	96	73	26334	Ikke dispergerbar	31	0	69	135	Ingen eksplosjonsfare	31
Nord Brent	Vinter	5	15	120	73	28733	Ikke dispergerbar	31	0	69	139	Ingen eksplosjonsfare	32

Table G-2 Summary weathering predictions for SF Nord Brent (E-2&E-3) at 15 °C

Oil_type	Season	Temp. °C	Wind m/s	Hour	Water cont.	Emulsion viscosity	Dispersibility	Evap. %	Surface oil %	Naturally disp. %	Flash Point °C	Explosion hazard	Pour point
Nord Brent	Sommer	15	2	1	1	126	Kjemisk dispergerbar	14	87	0	35	Eksplosjonsfare ved tanking	14
Nord Brent	Sommer	15	2	2	2	189	Kjemisk dispergerbar	18	82	0	49	Eksplosjonsfare ved tanking	17
Nord Brent	Sommer	15	2	3	3	235	Kjemisk dispergerbar	20	80	0	57	Eksplosjonsfare ved tanking	18
Nord Brent	Sommer	15	2	6	7	340	Kjemisk dispergerbar	23	77	0	68	Ingen eksplosjonsfare	20
Nord Brent	Sommer	15	2	9	10	434	Kjemisk dispergerbar	25	75	0	74	Ingen eksplosjonsfare	21
Nord Brent	Sommer	15	2	12	13	526	Kjemisk dispergerbar	26	74	0	78	Ingen eksplosjonsfare	22
Nord Brent	Sommer	15	2	24	23	931	Kjemisk dispergerbar	29	71	0	89	Ingen eksplosjonsfare	24
Nord Brent	Sommer	15	2	48	40	1975	Kjemisk dispergerbar	31	69	0	99	Ingen eksplosjonsfare	26
Nord Brent	Sommer	15	2	72	52	3268	Redusert kjemisk disp.	33	67	0	105	Ingen eksplosjonsfare	27
Nord Brent	Sommer	15	2	96	60	4610	Redusert kjemisk disp.	34	66	0	109	Ingen eksplosjonsfare	27
Nord Brent	Sommer	15	2	120	65	5885	Redusert kjemisk disp.	35	65	0	112	Ingen eksplosjonsfare	28
Nord Brent	Sommer	15	5	1	5	206	Kjemisk dispergerbar	18	82	0	50	Eksplosjonsfare ved tanking	17
Nord Brent	Sommer	15	5	2	9	328	Kjemisk dispergerbar	22	78	0	63	Ingen eksplosjonsfare	19
Nord Brent	Sommer	15	5	3	13	437	Kjemisk dispergerbar	24	76	1	70	Ingen eksplosjonsfare	21
Nord Brent	Sommer	15	5	6	23	788	Kjemisk dispergerbar	27	72	1	81	Ingen eksplosjonsfare	22
Nord Brent	Sommer	15	5	9	32	1206	Kjemisk dispergerbar	28	70	2	87	Ingen eksplosjonsfare	24
Nord Brent	Sommer	15	5	12	40	1690	Kjemisk dispergerbar	29	69	2	92	Ingen eksplosjonsfare	24
Nord Brent	Sommer	15	5	24	60	4009	Redusert kjemisk disp.	32	65	3	102	Ingen eksplosjonsfare	26
Nord Brent	Sommer	15	5	48	74	7867	Ikke dispergerbar	34	61	4	112	Ingen eksplosjonsfare	28
Nord Brent	Sommer	15	5	72	77	9749	Ikke dispergerbar	36	59	6	118	Ingen eksplosjonsfare	29
Nord Brent	Sommer	15	5	96	77	10737	Ikke dispergerbar	37	56	7	123	Ingen eksplosjonsfare	29
Nord Brent	Sommer	15	5	120	77	11514	Ikke dispergerbar	38	54	8	126	Ingen eksplosjonsfare	30
Nord Brent	Sommer	15	10	1	14	437	Kjemisk dispergerbar	23	74	3	68	Ingen eksplosjonsfare	20
Nord Brent	Sommer	15	10	2	26	830	Kjemisk dispergerbar	26	68	6	80	Ingen eksplosjonsfare	22
Nord Brent	Sommer	15	10	3	35	1300	Kjemisk dispergerbar	28	64	8	87	Ingen eksplosjonsfare	23
Nord Brent	Sommer	15	10	6	55	3085	Redusert kjemisk disp.	30	56	13	97	Ingen eksplosjonsfare	25
Nord Brent	Sommer	15	10	9	66	5010	Redusert kjemisk disp.	32	51	17	103	Ingen eksplosjonsfare	26
Nord Brent	Sommer	15	10	12	72	6647	Redusert kjemisk disp.	33	48	20	108	Ingen eksplosjonsfare	27
Nord Brent	Sommer	15	10	24	78	9856	Ikke dispergerbar	35	37	28	118	Ingen eksplosjonsfare	29
Nord Brent	Sommer	15	10	48	78	12262	Ikke dispergerbar	36	24	40	129	Ingen eksplosjonsfare	30
Nord Brent	Sommer	15	10	72	78	14034	Ikke dispergerbar	37	16	47	136	Ingen eksplosjonsfare	32
Nord Brent	Sommer	15	10	96	78	15611	Ikke dispergerbar	38	11	51	141	Ingen eksplosjonsfare	32
Nord Brent	Sommer	15	10	120	78	17072	Ikke dispergerbar	38	8	54	146	Ingen eksplosjonsfare	33
Nord Brent	Sommer	15	15	1	27	844	Kjemisk dispergerbar	26	59	15	79	Ingen eksplosjonsfare	22
Nord Brent	Sommer	15	15	2	45	1915	Kjemisk dispergerbar	28	47	25	90	Ingen eksplosjonsfare	24
Nord Brent	Sommer	15	15	3	57	3207	Redusert kjemisk disp.	29	40	31	97	Ingen eksplosjonsfare	25
Nord Brent	Sommer	15	15	6	73	6793	Redusert kjemisk disp.	31	27	42	107	Ingen eksplosjonsfare	27
Nord Brent	Sommer	15	15	9	77	8807	Ikke dispergerbar	32	20	49	113	Ingen eksplosjonsfare	28
Nord Brent	Sommer	15	15	12	78	9843	Ikke dispergerbar	32	14	53	118	Ingen eksplosjonsfare	29
Nord Brent	Sommer	15	15	24	78	12234	Ikke dispergerbar	33	4	62	128	Ingen eksplosjonsfare	30
Nord Brent	Sommer	15	15	48	78	15546	Ikke dispergerbar	34	1	66	141	Ingen eksplosjonsfare	32
Nord Brent	Sommer	15	15	72	78	18323	Ikke dispergerbar	34	0	66	149	Ingen eksplosjonsfare	34
Nord Brent	Sommer	15	15	96	78	20613	Ikke dispergerbar	34	0	66	156	Ingen eksplosjonsfare	35
Nord Brent	Sommer	15	15	120	78	22399	Ikke dispergerbar	34	0	66	160	Ingen eksplosjonsfare	35

G.2 Sygna Brent (N-1&N-2)

Table G-3 Summary weathering predictions for Sygna Brent (N-1&N-2) at 5 °C

Oil_type	Season	Temp. °C	Wind m/s	Hour	Water cont.	Emulsion viscosity	Dispersibility	Evap. %	Surface oil %	Naturally disp. %	Flash Point °C	Explosion hazard	Pour point
Sygna Brent	Vinter	5	2	1	1	164	Kjemisk dispergerbar	12	88	0	28	Eksplosjonsfare ved tanking	13
Sygna Brent	Vinter	5	2	2	2	261	Kjemisk dispergerbar	16	84	0	41	Eksplosjonsfare ved tanking	16
Sygna Brent	Vinter	5	2	3	3	336	Kjemisk dispergerbar	18	82	0	49	Eksplosjonsfare ved tanking	17
Sygna Brent	Vinter	5	2	6	6	514	Kjemisk dispergerbar	22	79	0	59	Eksplosjonsfare ved tanking	19
Sygna Brent	Vinter	5	2	9	10	673	Kjemisk dispergerbar	23	77	0	65	Ingen eksplosjonsfare	20
Sygna Brent	Vinter	5	2	12	12	829	Kjemisk dispergerbar	24	76	0	69	Ingen eksplosjonsfare	21
Sygna Brent	Vinter	5	2	24	23	1501	Kjemisk dispergerbar	27	73	0	79	Ingen eksplosjonsfare	23
Sygna Brent	Vinter	5	2	48	38	3022	Redusert kjemisk disp.	29	71	0	89	Ingen eksplosjonsfare	24
Sygna Brent	Vinter	5	2	72	48	4713	Redusert kjemisk disp.	31	69	0	94	Ingen eksplosjonsfare	25
Sygna Brent	Vinter	5	2	96	56	6384	Redusert kjemisk disp.	32	68	0	98	Ingen eksplosjonsfare	26
Sygna Brent	Vinter	5	2	120	61	7921	Redusert kjemisk disp.	33	67	0	101	Ingen eksplosjonsfare	27
Sygna Brent	Vinter	5	5	1	4	285	Kjemisk dispergerbar	16	83	0	42	Eksplosjonsfare ved tanking	16
Sygna Brent	Vinter	5	5	2	9	482	Kjemisk dispergerbar	20	80	0	55	Eksplosjonsfare ved tanking	19
Sygna Brent	Vinter	5	5	3	12	663	Kjemisk dispergerbar	22	77	1	62	Ingen eksplosjonsfare	20
Sygna Brent	Vinter	5	5	6	23	1235	Kjemisk dispergerbar	25	74	1	72	Ingen eksplosjonsfare	22
Sygna Brent	Vinter	5	5	9	32	1892	Redusert kjemisk disp.	27	72	1	78	Ingen eksplosjonsfare	23
Sygna Brent	Vinter	5	5	12	39	2589	Redusert kjemisk disp.	28	71	2	82	Ingen eksplosjonsfare	23
Sygna Brent	Vinter	5	5	24	57	5561	Redusert kjemisk disp.	30	67	3	91	Ingen eksplosjonsfare	25
Sygna Brent	Vinter	5	5	48	70	9994	Ikke dispergerbar	33	64	4	101	Ingen eksplosjonsfare	27
Sygna Brent	Vinter	5	5	72	72	12255	Ikke dispergerbar	34	61	5	106	Ingen eksplosjonsfare	27
Sygna Brent	Vinter	5	5	96	72	13551	Ikke dispergerbar	35	59	6	110	Ingen eksplosjonsfare	28
Sygna Brent	Vinter	5	5	120	72	14593	Ikke dispergerbar	35	57	7	113	Ingen eksplosjonsfare	29
Sygna Brent	Vinter	5	10	1	14	654	Kjemisk dispergerbar	22	76	3	60	Ingen eksplosjonsfare	19
Sygna Brent	Vinter	5	10	2	25	1286	Kjemisk dispergerbar	25	70	5	71	Ingen eksplosjonsfare	21
Sygna Brent	Vinter	5	10	3	35	2014	Redusert kjemisk disp.	26	67	7	77	Ingen eksplosjonsfare	23
Sygna Brent	Vinter	5	10	6	53	4417	Redusert kjemisk disp.	29	60	12	87	Ingen eksplosjonsfare	24
Sygna Brent	Vinter	5	10	9	63	6700	Redusert kjemisk disp.	30	55	15	93	Ingen eksplosjonsfare	25
Sygna Brent	Vinter	5	10	12	68	8540	Ikke dispergerbar	31	52	18	97	Ingen eksplosjonsfare	26
Sygna Brent	Vinter	5	10	24	73	12340	Ikke dispergerbar	33	41	26	106	Ingen eksplosjonsfare	27
Sygna Brent	Vinter	5	10	48	73	15577	Ikke dispergerbar	34	28	37	115	Ingen eksplosjonsfare	29
Sygna Brent	Vinter	5	10	72	73	17829	Ikke dispergerbar	35	20	45	121	Ingen eksplosjonsfare	30
Sygna Brent	Vinter	5	10	96	73	19635	Ikke dispergerbar	36	14	50	125	Ingen eksplosjonsfare	30
Sygna Brent	Vinter	5	10	120	73	21180	Ikke dispergerbar	36	10	54	128	Ingen eksplosjonsfare	31
Sygna Brent	Vinter	5	15	1	26	1298	Kjemisk dispergerbar	24	63	13	70	Ingen eksplosjonsfare	21
Sygna Brent	Vinter	5	15	2	44	2877	Redusert kjemisk disp.	27	52	22	81	Ingen eksplosjonsfare	23
Sygna Brent	Vinter	5	15	3	55	4557	Redusert kjemisk disp.	28	45	28	86	Ingen eksplosjonsfare	24
Sygna Brent	Vinter	5	15	6	69	8682	Ikke dispergerbar	30	32	39	96	Ingen eksplosjonsfare	26
Sygna Brent	Vinter	5	15	9	73	10987	Ikke dispergerbar	30	24	46	102	Ingen eksplosjonsfare	27
Sygna Brent	Vinter	5	15	12	73	12300	Ikke dispergerbar	31	18	51	106	Ingen eksplosjonsfare	27
Sygna Brent	Vinter	5	15	24	73	15543	Ikke dispergerbar	32	7	62	115	Ingen eksplosjonsfare	29
Sygna Brent	Vinter	5	15	48	73	19595	Ikke dispergerbar	32	1	67	124	Ingen eksplosjonsfare	30
Sygna Brent	Vinter	5	15	72	73	22523	Ikke dispergerbar	32	0	68	130	Ingen eksplosjonsfare	31
Sygna Brent	Vinter	5	15	96	73	25077	Ikke dispergerbar	32	0	68	134	Ingen eksplosjonsfare	32
Sygna Brent	Vinter	5	15	120	73	27493	Ikke dispergerbar	32	0	68	138	Ingen eksplosjonsfare	32

Table G-4 Summary weathering predictions for Sygna Brent (N-1&N-2) at 15 °C

Oil_type	Season	Temp. °C	Wind m/s	Hour	Water cont.	Emulsion viscosity	Dispersibility	Evap. %	Surface oil %	Naturally disp. %	Flash Point °C	Explosion hazard	Pour point
Sygna Brent	Sommer	15	2	1	1	123	Kjemisk dispergerbar	14	86	0	35	Eksplosjonsfare ved tanking	15
Sygna Brent	Sommer	15	2	2	2	192	Kjemisk dispergerbar	19	81	0	50	Eksplosjonsfare ved tanking	18
Sygna Brent	Sommer	15	2	3	3	243	Kjemisk dispergerbar	21	79	0	57	Eksplosjonsfare ved tanking	19
Sygna Brent	Sommer	15	2	6	6	364	Kjemisk dispergerbar	24	76	0	69	Ingen eksplosjonsfare	21
Sygna Brent	Sommer	15	2	9	10	471	Kjemisk dispergerbar	26	74	0	75	Ingen eksplosjonsfare	22
Sygna Brent	Sommer	15	2	12	12	576	Kjemisk dispergerbar	27	73	0	79	Ingen eksplosjonsfare	23
Sygna Brent	Sommer	15	2	24	23	1025	Kjemisk dispergerbar	30	70	0	90	Ingen eksplosjonsfare	25
Sygna Brent	Sommer	15	2	48	39	2103	Redusert kjemisk disp.	32	68	0	100	Ingen eksplosjonsfare	26
Sygna Brent	Sommer	15	2	72	51	3333	Redusert kjemisk disp.	34	66	0	106	Ingen eksplosjonsfare	27
Sygna Brent	Sommer	15	2	96	59	4568	Redusert kjemisk disp.	35	65	0	110	Ingen eksplosjonsfare	28
Sygna Brent	Sommer	15	2	120	65	5686	Redusert kjemisk disp.	36	64	0	113	Ingen eksplosjonsfare	28
Sygna Brent	Sommer	15	5	1	4	209	Kjemisk dispergerbar	19	81	0	50	Eksplosjonsfare ved tanking	18
Sygna Brent	Sommer	15	5	2	9	345	Kjemisk dispergerbar	23	77	0	64	Ingen eksplosjonsfare	20
Sygna Brent	Sommer	15	5	3	12	468	Kjemisk dispergerbar	25	75	1	71	Ingen eksplosjonsfare	21
Sygna Brent	Sommer	15	5	6	23	854	Kjemisk dispergerbar	28	71	1	82	Ingen eksplosjonsfare	23
Sygna Brent	Sommer	15	5	9	32	1292	Kjemisk dispergerbar	29	69	1	88	Ingen eksplosjonsfare	24
Sygna Brent	Sommer	15	5	12	39	1778	Redusert kjemisk disp.	31	68	2	93	Ingen eksplosjonsfare	25
Sygna Brent	Sommer	15	5	24	59	3907	Redusert kjemisk disp.	33	64	3	103	Ingen eksplosjonsfare	27
Sygna Brent	Sommer	15	5	48	74	7219	Redusert kjemisk disp.	35	60	4	113	Ingen eksplosjonsfare	28
Sygna Brent	Sommer	15	5	72	77	8889	Ikke dispergerbar	37	58	6	118	Ingen eksplosjonsfare	29
Sygna Brent	Sommer	15	5	96	78	9837	Ikke dispergerbar	38	55	7	123	Ingen eksplosjonsfare	30
Sygna Brent	Sommer	15	5	120	78	10576	Ikke dispergerbar	38	54	8	126	Ingen eksplosjonsfare	31
Sygna Brent	Sommer	15	10	1	14	465	Kjemisk dispergerbar	24	73	3	69	Ingen eksplosjonsfare	21
Sygna Brent	Sommer	15	10	2	25	891	Kjemisk dispergerbar	27	67	6	81	Ingen eksplosjonsfare	23
Sygna Brent	Sommer	15	10	3	35	1378	Kjemisk dispergerbar	29	63	8	88	Ingen eksplosjonsfare	24
Sygna Brent	Sommer	15	10	6	54	3065	Redusert kjemisk disp.	31	55	13	98	Ingen eksplosjonsfare	26
Sygna Brent	Sommer	15	10	9	65	4730	Redusert kjemisk disp.	33	51	17	104	Ingen eksplosjonsfare	27
Sygna Brent	Sommer	15	10	12	72	6127	Redusert kjemisk disp.	34	47	20	108	Ingen eksplosjonsfare	28
Sygna Brent	Sommer	15	10	24	78	8960	Ikke dispergerbar	35	36	29	118	Ingen eksplosjonsfare	29
Sygna Brent	Sommer	15	10	48	78	11250	Ikke dispergerbar	37	23	40	128	Ingen eksplosjonsfare	31
Sygna Brent	Sommer	15	10	72	78	12961	Ikke dispergerbar	38	15	47	135	Ingen eksplosjonsfare	32
Sygna Brent	Sommer	15	10	96	78	14500	Ikke dispergerbar	39	10	51	140	Ingen eksplosjonsfare	33
Sygna Brent	Sommer	15	10	120	78	15930	Ikke dispergerbar	39	7	54	144	Ingen eksplosjonsfare	33
Sygna Brent	Sommer	15	15	1	26	902	Kjemisk dispergerbar	27	58	15	80	Ingen eksplosjonsfare	23
Sygna Brent	Sommer	15	15	2	44	1972	Redusert kjemisk disp.	29	47	24	91	Ingen eksplosjonsfare	25
Sygna Brent	Sommer	15	15	3	56	3157	Redusert kjemisk disp.	30	39	31	98	Ingen eksplosjonsfare	26
Sygna Brent	Sommer	15	15	6	73	6211	Redusert kjemisk disp.	32	26	42	108	Ingen eksplosjonsfare	28
Sygna Brent	Sommer	15	15	9	77	7961	Redusert kjemisk disp.	33	19	49	114	Ingen eksplosjonsfare	29
Sygna Brent	Sommer	15	15	12	78	8928	Ikke dispergerbar	33	14	53	118	Ingen eksplosjonsfare	29
Sygna Brent	Sommer	15	15	24	78	11187	Ikke dispergerbar	34	4	62	128	Ingen eksplosjonsfare	31
Sygna Brent	Sommer	15	15	48	78	14389	Ikke dispergerbar	34	0	65	139	Ingen eksplosjonsfare	33
Sygna Brent	Sommer	15	15	72	78	17102	Ikke dispergerbar	34	0	66	148	Ingen eksplosjonsfare	34
Sygna Brent	Sommer	15	15	96	78	19339	Ikke dispergerbar	34	0	66	153	Ingen eksplosjonsfare	35
Sygna Brent	Sommer	15	15	120	78	21080	Ikke dispergerbar	34	0	66	158	Ingen eksplosjonsfare	35

G.3 Statfjord C Blend

Table G-5 Summary weathering predictions for Statfjord C Blend 100 s^{-1}, 5 °C (updated)

Oil_type	Season	Temp. °C	Wind m/s	Hour	Water cont.	Emulsion viscosity	Dispersibility	Evap. %	Surface oil %	Naturally disp. %	Flash Point °C	Explosion hazard	Pour point
Statfjord C Blend 100s-1	Vinter	5	2	1	1	77	Kjemisk dispergerbar	13	87	0	0	-	6
Statfjord C Blend 100s-1	Vinter	5	2	2	2	138	Kjemisk dispergerbar	18	82	0	0	-	9
Statfjord C Blend 100s-1	Vinter	5	2	3	4	188	Kjemisk dispergerbar	20	80	0	0	-	11
Statfjord C Blend 100s-1	Vinter	5	2	6	7	315	Kjemisk dispergerbar	24	77	0	0	-	13
Statfjord C Blend 100s-1	Vinter	5	2	9	10	435	Kjemisk dispergerbar	25	75	0	0	-	15
Statfjord C Blend 100s-1	Vinter	5	2	12	13	558	Kjemisk dispergerbar	27	73	0	0	-	15
Statfjord C Blend 100s-1	Vinter	5	2	24	24	1127	Kjemisk dispergerbar	29	71	0	0	-	17
Statfjord C Blend 100s-1	Vinter	5	2	48	40	2639	Redusert kjemisk disp.	32	68	0	0	-	19
Statfjord C Blend 100s-1	Vinter	5	2	72	51	4440	Redusert kjemisk disp.	33	67	0	0	-	20
Statfjord C Blend 100s-1	Vinter	5	2	96	57	6255	Redusert kjemisk disp.	34	66	0	0	-	21
Statfjord C Blend 100s-1	Vinter	5	2	120	62	7921	Redusert kjemisk disp.	35	65	0	0	-	22
Statfjord C Blend 100s-1	Vinter	5	5	1	5	154	Kjemisk dispergerbar	18	82	0	0	-	9
Statfjord C Blend 100s-1	Vinter	5	5	2	9	293	Kjemisk dispergerbar	22	77	1	0	-	12
Statfjord C Blend 100s-1	Vinter	5	5	3	13	430	Kjemisk dispergerbar	24	75	1	0	-	14
Statfjord C Blend 100s-1	Vinter	5	5	6	24	898	Kjemisk dispergerbar	27	72	1	0	-	16
Statfjord C Blend 100s-1	Vinter	5	5	9	33	1473	Kjemisk dispergerbar	29	70	2	0	-	17
Statfjord C Blend 100s-1	Vinter	5	5	12	40	2139	Redusert kjemisk disp.	30	68	2	0	-	18
Statfjord C Blend 100s-1	Vinter	5	5	24	57	5137	Redusert kjemisk disp.	32	65	3	0	-	20
Statfjord C Blend 100s-1	Vinter	5	5	48	68	9609	Redusert kjemisk disp.	35	61	4	0	-	22
Statfjord C Blend 100s-1	Vinter	5	5	72	70	12023	Redusert kjemisk disp.	36	58	6	0	-	23
Statfjord C Blend 100s-1	Vinter	5	5	96	70	13592	Redusert kjemisk disp.	37	56	7	0	-	23
Statfjord C Blend 100s-1	Vinter	5	5	120	70	14824	Ikke dispergerbar	38	55	8	0	-	24
Statfjord C Blend 100s-1	Vinter	5	10	1	15	425	Kjemisk dispergerbar	24	73	4	0	-	13
Statfjord C Blend 100s-1	Vinter	5	10	2	27	943	Kjemisk dispergerbar	27	67	7	0	-	16
Statfjord C Blend 100s-1	Vinter	5	10	3	36	1584	Kjemisk dispergerbar	28	63	9	0	-	17
Statfjord C Blend 100s-1	Vinter	5	10	6	53	3923	Redusert kjemisk disp.	31	56	14	0	-	19
Statfjord C Blend 100s-1	Vinter	5	10	9	62	6199	Redusert kjemisk disp.	32	51	17	0	-	20
Statfjord C Blend 100s-1	Vinter	5	10	12	66	8008	Redusert kjemisk disp.	33	48	19	0	-	21
Statfjord C Blend 100s-1	Vinter	5	10	24	70	11996	Redusert kjemisk disp.	35	38	28	0	-	23
Statfjord C Blend 100s-1	Vinter	5	10	48	70	15774	Ikke dispergerbar	36	25	38	0	-	24
Statfjord C Blend 100s-1	Vinter	5	10	72	70	18402	Ikke dispergerbar	37	18	45	0	-	25
Statfjord C Blend 100s-1	Vinter	5	10	96	70	20527	Ikke dispergerbar	38	13	50	0	-	26
Statfjord C Blend 100s-1	Vinter	5	10	120	70	22362	Ikke dispergerbar	38	9	53	0	-	27
Statfjord C Blend 100s-1	Vinter	5	15	1	28	955	Kjemisk dispergerbar	26	57	17	0	-	16
Statfjord C Blend 100s-1	Vinter	5	15	2	45	2387	Redusert kjemisk disp.	29	46	26	0	-	18
Statfjord C Blend 100s-1	Vinter	5	15	3	55	4028	Redusert kjemisk disp.	30	39	31	0	-	19
Statfjord C Blend 100s-1	Vinter	5	15	6	67	8046	Redusert kjemisk disp.	31	27	41	0	-	21
Statfjord C Blend 100s-1	Vinter	5	15	9	69	10356	Redusert kjemisk disp.	32	20	48	0	-	22
Statfjord C Blend 100s-1	Vinter	5	15	12	70	11857	Redusert kjemisk disp.	33	15	52	0	-	23
Statfjord C Blend 100s-1	Vinter	5	15	24	70	15577	Ikke dispergerbar	33	5	61	0	-	24
Statfjord C Blend 100s-1	Vinter	5	15	48	70	20279	Ikke dispergerbar	34	1	66	0	-	26
Statfjord C Blend 100s-1	Vinter	5	15	72	70	23739	Ikke dispergerbar	34	0	66	0	-	27
Statfjord C Blend 100s-1	Vinter	5	15	96	70	26825	Ikke dispergerbar	34	0	66	0	-	28
Statfjord C Blend 100s-1	Vinter	5	15	120	70	29785	Ikke dispergerbar	34	0	66	0	-	28

Table G-6 Summary weathering predictions for Statfjord C Blend 100s-1 , 15 °C (updated)

Oil_type	Season	Temp. °C	Wind m/s	Hour	Water cont.	Emulsion viscosity	Dispersibility	Evap. %	Surface oil %	Naturally disp. %	Flash Point °C	Explosion hazard	Pour point
Statfjord C Blend 100s-1	Sommer	15	2	1	1	66	Kjemisk dispergerbar	16	84	0	0	-	8
Statfjord C Blend 100s-1	Sommer	15	2	2	2	114	Kjemisk dispergerbar	21	79	0	0	-	11
Statfjord C Blend 100s-1	Sommer	15	2	3	4	152	Kjemisk dispergerbar	23	77	0	0	-	13
Statfjord C Blend 100s-1	Sommer	15	2	6	7	246	Kjemisk dispergerbar	26	74	0	0	-	15
Statfjord C Blend 100s-1	Sommer	15	2	9	10	334	Kjemisk dispergerbar	28	72	0	0	-	17
Statfjord C Blend 100s-1	Sommer	15	2	12	13	424	Kjemisk dispergerbar	29	71	0	0	-	17
Statfjord C Blend 100s-1	Sommer	15	2	24	24	834	Kjemisk dispergerbar	32	68	0	0	-	19
Statfjord C Blend 100s-1	Sommer	15	2	48	40	1906	Redusert kjemisk disp.	35	65	0	0	-	21
Statfjord C Blend 100s-1	Sommer	15	2	72	51	3164	Redusert kjemisk disp.	36	64	0	0	-	23
Statfjord C Blend 100s-1	Sommer	15	2	96	57	4416	Redusert kjemisk disp.	37	63	0	0	-	23
Statfjord C Blend 100s-1	Sommer	15	2	120	62	5542	Redusert kjemisk disp.	38	62	0	0	-	24
Statfjord C Blend 100s-1	Sommer	15	5	1	5	127	Kjemisk dispergerbar	21	79	0	0	-	11
Statfjord C Blend 100s-1	Sommer	15	5	2	9	233	Kjemisk dispergerbar	25	75	1	0	-	14
Statfjord C Blend 100s-1	Sommer	15	5	3	13	334	Kjemisk dispergerbar	27	72	1	0	-	16
Statfjord C Blend 100s-1	Sommer	15	5	6	24	677	Kjemisk dispergerbar	30	69	1	0	-	18
Statfjord C Blend 100s-1	Sommer	15	5	9	33	1094	Kjemisk dispergerbar	32	67	2	0	-	19
Statfjord C Blend 100s-1	Sommer	15	5	12	40	1574	Kjemisk dispergerbar	33	65	2	0	-	20
Statfjord C Blend 100s-1	Sommer	15	5	24	57	3683	Redusert kjemisk disp.	35	62	3	0	-	22
Statfjord C Blend 100s-1	Sommer	15	5	48	68	6725	Redusert kjemisk disp.	38	58	5	0	-	24
Statfjord C Blend 100s-1	Sommer	15	5	72	70	8287	Redusert kjemisk disp.	39	55	6	0	-	25
Statfjord C Blend 100s-1	Sommer	15	5	96	70	9308	Redusert kjemisk disp.	40	53	7	0	-	26
Statfjord C Blend 100s-1	Sommer	15	5	120	70	10124	Redusert kjemisk disp.	41	51	9	0	-	26
Statfjord C Blend 100s-1	Sommer	15	10	1	15	333	Kjemisk dispergerbar	26	70	4	0	-	15
Statfjord C Blend 100s-1	Sommer	15	10	2	27	713	Kjemisk dispergerbar	30	63	7	0	-	18
Statfjord C Blend 100s-1	Sommer	15	10	3	36	1179	Kjemisk dispergerbar	31	59	10	0	-	19
Statfjord C Blend 100s-1	Sommer	15	10	6	53	2846	Redusert kjemisk disp.	34	52	15	0	-	21
Statfjord C Blend 100s-1	Sommer	15	10	9	62	4432	Redusert kjemisk disp.	35	47	18	0	-	22
Statfjord C Blend 100s-1	Sommer	15	10	12	66	5674	Redusert kjemisk disp.	36	43	21	0	-	23
Statfjord C Blend 100s-1	Sommer	15	10	24	70	8273	Redusert kjemisk disp.	38	33	30	0	-	25
Statfjord C Blend 100s-1	Sommer	15	10	48	70	10762	Redusert kjemisk disp.	39	20	41	0	-	27
Statfjord C Blend 100s-1	Sommer	15	10	72	70	12637	Redusert kjemisk disp.	40	13	47	0	-	28
Statfjord C Blend 100s-1	Sommer	15	10	96	70	14354	Redusert kjemisk disp.	41	8	51	0	-	29
Statfjord C Blend 100s-1	Sommer	15	10	120	70	15960	Ikke dispergerbar	41	6	54	0	-	30
Statfjord C Blend 100s-1	Sommer	15	15	1	28	724	Kjemisk dispergerbar	29	53	18	0	-	18
Statfjord C Blend 100s-1	Sommer	15	15	2	45	1762	Redusert kjemisk disp.	31	42	27	0	-	20
Statfjord C Blend 100s-1	Sommer	15	15	3	55	2928	Redusert kjemisk disp.	32	35	33	0	-	21
Statfjord C Blend 100s-1	Sommer	15	15	6	67	5708	Redusert kjemisk disp.	34	22	44	0	-	23
Statfjord C Blend 100s-1	Sommer	15	15	9	69	7233	Redusert kjemisk disp.	35	16	50	0	-	24
Statfjord C Blend 100s-1	Sommer	15	15	12	70	8186	Redusert kjemisk disp.	35	11	54	0	-	25
Statfjord C Blend 100s-1	Sommer	15	15	24	70	10628	Redusert kjemisk disp.	36	3	61	0	-	27
Statfjord C Blend 100s-1	Sommer	15	15	48	70	14141	Redusert kjemisk disp.	36	0	64	0	-	29
Statfjord C Blend 100s-1	Sommer	15	15	72	70	17168	Ikke dispergerbar	36	0	64	0	-	30
Statfjord C Blend 100s-1	Sommer	15	15	96	70	19648	Ikke dispergerbar	36	0	64	0	-	31
Statfjord C Blend 100s-1	Sommer	15	15	120	70	21552	Ikke dispergerbar	36	0	64	0	-	32