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DRILL CUTTINGS PILES MANAGEMENT

Drill cuttings piles management and environmental experiences

BRANSJEFORENINGEN NORSK OLJE OG GASS

Report No.: 2017-4056, Rev. 01,
Document No.: 113J708G-3
Date: 2017-12-19

Project name:	Drill cuttings piles management	DNV GL AS Oil & Gas
Report title:	Drill cuttings piles management and environmental experiences	Environmental Risk Management P.O. Box 300
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Date of issue:	2017-12-19	
Project No.:	PP174610	
Organisation unit:	Environmental Risk Management	
Report No.:	2017-4056, Rev. 01,	
Document No.:	113J708G-3	

Applicable contract(s) governing the provision of this Report:

Objective:Discuss and suggest alternatives for drill cuttings piles management

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Keywords:Drill cuttings piles
[Keywords]

Front cover image: Image of a drill cuttings pile grab sample, viewed from the side, with some 'healthy' brownish surface at the top (photo by DNV GL).

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
A, Draft	18-05-2017	For client comments	Ø. Tvedten	S. Nesse	
01,	19-12-2017	Final version	Ø. Tvedten	S. Nesse	M. Myhre

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EXECUTIVE SUMMARY

The purpose of the current report is to provide guidance in drill cuttings pile management as part of planning for offshore field decommissioning.

Drill cutting piles at offshore oil and gas fields have developed over many years of drilling activity on the fields. The complexity of the decommissioning planning and execution of these piles may imply substation costs and environmental issues. Hence, it is important as part of the decommissioning planning to have sufficient knowledge about the piles and management options to be able to make the best decision.

In 2016 the Norwegian Oil & Gas Association issued an updated guidance document for the mapping and characterisation of drill cuttings piles, including sampling and analyses. OSPAR has recently issued a guideline for drill cuttings sampling and analyses (OSPAR 2017a). This current report discusses how knowledge gained from such characterisation can be applied during decommissioning planning. It discusses the experiences from drill cuttings sampling, dredging operations and applied drill cuttings pile management solutions.

Management of drill cuttings piles forms an integral part of the decommissioning programme for redundant fields/platforms, and relevant solutions should normally be identified and assessed. The framework for management of drill cuttings in the NE Atlantic is provided by OSPAR, as per Recommendation 2006/5 On a Management Regime for Offshore Cuttings Piles. Based on a high-level screening exercise, OSPAR (2009b) in 2009 generally accepted that drill cuttings piles in the North Sea that are within certain thresholds (OSPAR 2006/5), can be left undisturbed for natural degradation. However, this solution often comes in conflict with the OSPAR Decision 98/3 requirement for disposal of redundant installations, calling for additional management solutions to be considered.

Two key issues of importance with regards to drill cuttings management as part of the decommissioning planning are:

1. Will the OSPAR criteria for leaving the drill cuttings piles in situ be met?
2. Is it technically feasible to leave the drill cuttings piles in place considering the overall field decommissioning and disposal?

For the individual field/installation, it is important to document the cuttings pile status versus the OSPAR thresholds (persistence and loss of oil), and likely verify whether it is within the criteria for leaving in situ for natural degradation. This documentation will normally be part of the decommission plan to the authorities. The assessment should be based on updated and relevant information about the pile (cf. OSPAR 2017a and NOROG 2016). The persistence of the pile can be estimated from mapping at time intervals and/or calculations/modelling of degradation and erosion. The leaching/loss of oil can be measured or tested by various techniques and modelled to support the evaluation. However, reliable figures on loss of oil for the actual conditions at the site offshore are generally difficult to obtain.

If the cuttings pile does not meet the criteria to be left in situ for natural degradation, OSPAR 2006/5 recommends the following solutions to be assessed:

a) Leave in situ (possibly with environmental monitoring)

b) Leave in situ with measures (covering, bioremediation)

c) Relocation (locally) or injection offshore

d) Removal to shore (reuse, treatment, disposal)

To be able to physically remove redundant installations, steel jacket foundation piles are normally being cut externally 1-2m below the seabed (3m in the UK (DECC 2011)). Therefore, removal of sediments and possible overlying drill cuttings is often necessary to enable space for rigging of equipment and for performing the cuts. This contradicts with the primary objective of leaving the drill cuttings material in situ for natural degradation, and calls for management solutions c) or d) for the parts of the pile which are affected by dredging, as per above list. Any part of the pile which is not influenced by jacket removal can be left undisturbed for natural degradation.

The solution for the management of drill cuttings piles during decommissioning has in the past been to relocate the material locally on the seabed to allow the removal of the steel jacket foundation. Suction dredging has been the dominating technique for the relocation. The operation generates a turbidity plume with dispersion of solids and associated contaminants. The main parts of the contaminants are found to be attached to the particles and will sink to the seabed close to the disposal area. Through environmental monitoring it is documented that effects on the seabed are mainly found within 100-200m distance from the cuttings disposal area, while small particles (e.g. barite) can drift for a couple of kilometres or so before they settle. No severe environmental effects from such dredging activities have been documented so far (OSPAR 2009c, OSPAR 2016, DNV 2012ac, DNV GL 2014a). The regional monitoring detected an environmental gradient from dredging sites, but the chemical footprint was reduced three years after dredging campaigns at Valhall and Albuskjell 2/4 F.

OSPAR 98/3 opens for leaving the lower part of large steel jackets[1] in place if “there are significant reasons why an alternative disposal […] is preferable to reuse or recycling or final disposal on land”. This requires a derogation process among the OSPAR countries. In several past OSPAR derogation cases, the cuttings piles have been approved to be left on the seabed together with the jacket footing, allowing for natural degradation. The OSPAR derogation processes have generally not received any significant comments or objections, proving the general acceptance of this management option.

For future discharges of drill cuttings (permitted water based mud or treated oil based cuttings), it is advised not to generate a cuttings pile inside the jacket foundation area, this is to reduce the need for later dredging operations during decommissioning.

[1] For jackets with overall weight in air >10 000 tonnes

GLOSSARY

BAT	Best available techniques
BEIS	The Department for Business, Energy and Industrial Strategy (BEIS) (formerly the Department for Energy and Climate Change (DECC))
BEP	Best environmental practice
DECC	Department of Energy and Climate Change (became part of Department for Business, Energy & Industrial Strategy in July 2016)
DP	Decommissioning plan (Norway), decommissioning programme (UK)
Drill cuttings	Fragments of rock drilled from the formations down to the reservoir. Contain remnants of drilling fluids. May create piles on the seabed after discharge.
EIA	Environmental impact assessment
ES	Environmental statement
GBS	Gravity-based structure
Hazid	Hazard identification
IOGP	International Association of Oil and Gas Producers (previously OGP)
JIP	Joint industry project
LSA	Low specific activity (in this context, radiation in scale/rock from reservoir)
MBES	Multi Beam Echo Sounder
NCS	Norwegian continental shelf
NEA	Norwegian Environment Agency
NOROG/NOIA	Norwegian Oil Industry Association
OBM	Oil-based mud (oil-based drilling fluid)
OGP	former abbreviation for IOGP,
OGUK	Oil & Gas UK
OIC	Offshore Industry Committee
OLF	former name of the Norwegian Oil and Gas Association
PDO	Plan for development and operation
PPE	Personal protective equipment
ROV	Remotely operated vehicle
SPI	Sediment Profiling Images
TCC	Thermomechanical Cuttings Cleaning
THC	Total hydrocarbons (in this context Cn12–Cn35)
TOC	Total organic carbon
TOM	Total organic material
UKCS	United Kingdom Continental Shelf
UKOOA	UK Offshore Operators Association (now: Oil & Gas UK)
WBM	Water-based mud

1 INTRODUCTION

1.1 Background

In 2016, the Norwegian Oil and Gas Association issued an update on the guidance for drill cuttings pile characterisation. The document suggests methods for mapping, sampling and analyses of drill cuttings piles.

It is however evident that there is a lack of guidance with regards to drill cuttings management, how to assess and apply data, and limited experience transfer within industry. Hence, NOROG decided to undertake a study to increase the knowledge base, share experiences and increase harmonization among companies related to application of current knowledge and usage of the data for planning and execution of offshore field decommissioning and disposal. Key questions are:

1. How should the OSPAR (2006/5) criteria for drill cuttings piles vs. available data from a pile be handled in the decommissioning plan?
2. What is best practice for management of cuttings piles?
3. How have OSPAR derogation cases been managed and influenced on cuttings piles management?
4. What are the general experiences from previous drill cuttings piles sampling campaigns?
5. How should the analytical results (distribution and level of contamination) be utilized during the decommissioning of installations?
6. What are the environmental effects from dredging operations?

1.2 Approach and limitations

This document discusses the topics listed above and presents some experience cases from the management of cuttings piles, pointing at solution(s) for a sound drill cuttings pile management.

Focus in this document is on drill cuttings piles with significant contamination of pollutants and environmental concern (i.e. old cuttings piles with remnants of oil based drilling mud (OBM)) or synthetic based muds and less on recent approved discharges of water based drilling fluids (WBM) and associated cuttings. The “ban” of discharge of oil based drilling fluids attached to the cuttings[1] introduced in 1991/1993 greatly reduced the footprint of the drill cuttings discharges (Bakke *et al*. 2013, NEA 2010 and 2016b). Current industry management practice is to recycle used oil based drilling fluids. The drill cuttings with remnants of oil based mud is injected in disposal wells, transported to shore, or treated/cleaned offshore (TCC) prior to discharge.

A tabular overview of selected cuttings piles and past dredging activities at the NCS is presented in Appendix A.

The study is mainly based on experience and reporting at the NCS, but some relevant projects and documents from the UKCS are included.

[1] The requirement for oil on cuttings was lowered to <1% (in 1991 for new fields and 1993 for existing fields), in practice terminating the discharge to sea of such due to technology limitation at that point in time. New technologies with better performance are now available, however currently with limited application on the NCS.

2 THE OSPAR (REC 2006/5) THRESHOLDS FOR DRILL CUTTINGS PILES

2.1 The OSPAR criteria and implementation

OSPAR recommendation 2006/5 (OSPAR 2006) *on a management regime for offshore cuttings piles* states that piles with a loss of oil to the water column of less than 10 tonnes per annum and a persistence of oil contaminated seabed area smaller than 500km^{2}yrs [2] may be left *in situ* to degrade naturally (Figure 2-1). The criteria were developed in an UKOOA R&D JIP on cuttings piles (1999-2005). If a pile does not fulfil these requirements, comparative assessment should be initiated for further evaluation of environmental effects and possible disposal options. This stage 2 investigation calls for a BAT and/or BEP assessment (Figure 2-1). If a pile exceeds the thresholds of 100 tonnes and 2 500km^{2}yrs, the options to leave for natural degradation, cover, or recover should be considered.

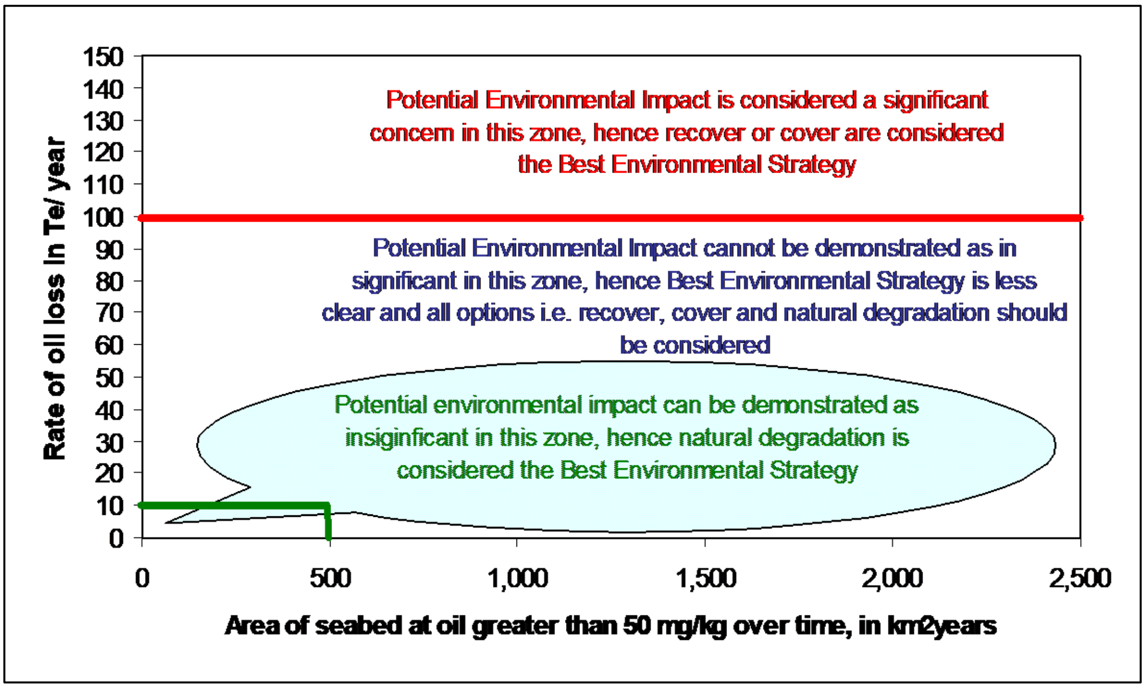

Figure 2-1. Criteria for environmental significance (UKOOA 2002 and OSPAR 2006).

Reporting on all cuttings piles in the North Sea area in 2008 (for UKCS and NCS, ERT 2008, DNV 2008a respectively) represented the initial screening phase of oil-contaminated piles as requested by OSPAR. The 2008 reporting indicated that the piles in general were within the 'green' sector (below 10 tonnes loss of oil and persistence of 500km^{2}yrs). OSPAR took the reporting into account and issued an implementation report on recommendation 2006/05 in 2009 (OSPAR 2009b). This document accepted that, based on the current data, the cuttings piles were within the thresholds and could be left *in situ* for natural degradation. Further management of drill cuttings piles should form a part of the individual decommissioning plan for the installations.

[2] A persistence of 500km^{2}yrs could mean an area of one km^2 is contaminated for 500 years or an area of 500km^2 is contaminated for one year. A concentration of 50mg THC/kg dry sediment is set as the limit for pollutant/presence of drill cuttings.

2.2 Assessment of pile conditions against the OSPAR criteria

The implementation report by OSPAR in 2009 (OSPAR, 2009b), indicates that all the present drill cuttings piles are below the criteria in the 2006/5 recommendations. Hence, the piles could be left *in situ* for natural degradation. Still, the decommissioning programmes generally addresses this issue and it should document the present site specific conditions to verify that the pile is within the OSPAR thresholds. In addition, the leave *in situ* option may come in conflict with removal of redundant installations as required in OSPAR Decision 98/3.

The OSPAR recommendation do not describe any methods for how to measure the piles against the thresholds. The NOROG guidance document for characterisation of cuttings piles (NOROG 2016), discusses and suggests some alternatives for measurements. Some issues with determining the loss of oil and persistence are briefly mentioned below.

Persistence of the pile can be investigated by studying changes in area and volume of the cuttings pile from repeated surveys over time. The definition of a fixed 'zero' level of the seabed is essential for comparison between two successive Multi Beam Echo Sounder (MBES) surveys. The contaminated area (with >50mg THC/kg) (OSPAR 2006, UKOOA 2002) should be determined by sampling and analysis. The size of the contaminated area is used to calculate for how long the pile can persist at the seabed without further actions required, according to the OSPAR threshold[3]. Modelling or estimation of natural degradation over time can be used to assess for how long time it is likely that the pile persists into the future and compare it with the threshold.

Results from leaching experiments with drill cuttings indicate that the contaminants generally have low water solubility. Several studies of this was performed in the UKOOA projects on drill cuttings (RF 2004, 2005). The tests were done at intact cuttings samples placed in seawater at the laboratory and in 'standard' bottle shaking tests (> 100 samples). The tests included variation in the original THC content, water:sediment ratio, shaking time and leaching without any shaking. The tests indicate that there is no direct relationship between the concentration of organic substances in the cuttings and the released amount into the water. Hence, UKOOA (RF 2005) concludes that leaching rates are low and difficult to determine/measure for various cuttings piles in the field.

However, leaching test results can still be relevant part of the assessment for the potential loss of contaminants from the cuttings pile and indeed from dredging or other cuttings disturbance operations. A bottle shaking test is likely to represent a worst-case scenario compared to a dredging situation, and the leaching rate is much less from an undisturbed pile.

It is possible to calculate theoretical loss of oil /kg from cuttings piles from the results from such tests (if any oil can be traced in the water phase), but the usefulness of such theoretical data versus the offshore field conditions is questionable. Results from leaching tests (standard laboratory bottle shaking tests) have been used to estimate the loss of oil for some cuttings piles (DNV 2012b, pers. com. Statoil 2016). The THC concentration measured in the water is used to calculate the loss of oil form the whole pile area. The results indicate that the loss of oil was far below the 10 tonnes threshold.

Drill cuttings piles modelling tools were developed as a part of the UKOOA JIP (BMT 2000, 2002, 2004). The models were developed to predict the persistence and loss of oil in short (initially and the first years) and long terms (e.g. in 1 000 years' time). Over time, as the natural degradation of the pile takes place, the loss of oil is reduced together with the seabed area covered with cuttings. Selected cuttings piles were analysed with respect to the OSPAR criteria (the criteria were developed in the UKOOA JIP). The

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[3] A circular pile which is 200 m in diameter has an area of 0,0314 km^2. Such a pile (with THC contamination above 50mg/kg) can persist for about 15 900 years to be within the 500km^2yr threshold.

piles were found to be by far below the 500km^{2}yrs, and all but one, had a loss of oil below10 Te/year (initially, i.e. the first years of degradation), UKOOA 2005.

In later years, modelling of several piles at the UKCS have been used to calculate the persistence and loss of oil from cuttings piles left *in situ* as a part of decommissioning programmes (e.g. for Murchison, CNR 2013, Brent cuttings piles, Shell 2017ab). The results have been compared with the OSPAR thresholds.

In addition, the dispersion of particles and sedimentation, and the environmental consequences on water living organisms and seabed fauna from disturbance has been studied for several fields (see Chapter 7). Modelled data from drill cuttings dredging campaigns (loss of oil from settled material and the persistence of the area) have been compared to the OSPAR criteria. If the modelled dredging effects exceeded the OSPAR criteria this could have influence on the selection of possible dredging options.

Generic factors were developed (based on findings in the UKOOA JIP) and formed the basis for the UKCS screening study reported to OSPAR in 2008 (ERT 2008). The factors were used to estimate distribution (size of area) and persistence of the piles as well as loss of oil. These factors do not seem to have been developed or been applied any further.

Various processes which influence on the development of a drill cuttings pile is illustrated in Figure 2-2.

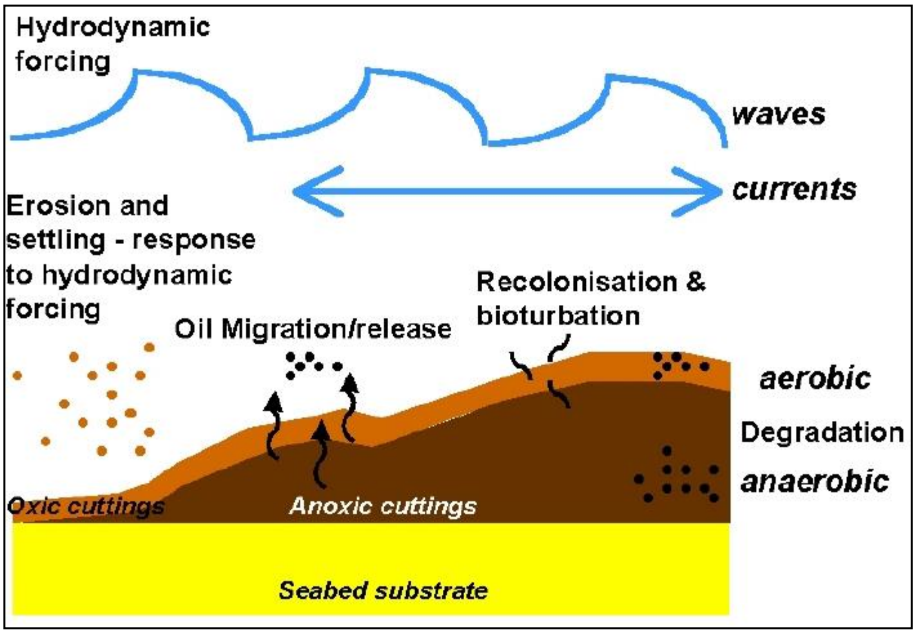


Figure 2-2. Processes influencing on the development (and reduction) of drill cuttings piles (from BMT 2002).

To sum up; The assessment of a pile against the OSPAR thresholds should be a part of a decommissioning plan and should preferably be based on updated information from drill cuttings pile characterisation survey and possible modelled data. In addition, the application of relevant data from other surveys and experiments to back up on the conclusions is recommended.

3 BEST PRACTICE FOR MANAGEMENT OF CUTTINGS PILES

3.1 Current experiences

In North Sea countries with offshore petroleum activities, field decommissioning and disposal are regulated in accordance with OSPAR decision 98/3. Installations with steel substructures below 10 000 tonnes should be removed after production from the field ceases, while the lower part ("footings") of larger substructures installed before February 1999 may be left *in situ* subject to OSPAR derogation.

Although the regulatory process varies somewhat between countries, a decommissioning plan may be considered similar in its content and purpose. It will reflect the process of evaluating and documenting disposal alternatives and recommend on a solution (Figure 3-1).

As mentioned above, a conflict will arise in many cases between the BAT strategy to leave the cuttings pile undisturbed for natural degradation (OSPAR 2006/5 and 2009b) and the removal of installations in accordance with OSPAR decision 98/3. The latter may require some parts of contaminated seabed/cuttings material to be removed/relocated. This could be to secure access for cutting tools to enable cutting of piles (steel jacket foundation) below the seabed surface, clearance of sediments to prepare for safe lifts or to remove the conductor frame. The jacket foundation piles can also be cut from the inside, if there is access for the cut tools to be positioned inside the piles. However, grout or other obstacles can block this option for platform legs. For some jackets removal operations there have been a combination of both cutting the legs from the inside (preferable option) and from the outside (dredging operation required).

In general, industry practice has been to sample the cuttings pile as part of planning for disposal of offshore facilities. The quantity of cuttings material and the contamination status of the pile are important data ahead of the dredging activity. Such information is required as part of the permit application (Pollution Regulation section 22) and to plan measures to mitigate the potential for negative environmental effects from disposal activities.

The results of characterisation, assessment of management options for cuttings piles and associated environmental impacts are to be discussed in the ES/EIA for decommissioning of the installation/field.

The UKOOA R&D JIP (UKOOA 2002 and 2005) concluded that hydrocarbons are the prime contaminant in drill cuttings piles and the decisive management factor for most piles. Environmental significance will thereby depend by large on the level of hydrocarbon contamination, on how far this leaches to the surrounding environment, and on its persistence. The value and vulnerability of the environmental conditions in the influenced area should also be considered when assessing the environmental significance of the contamination.

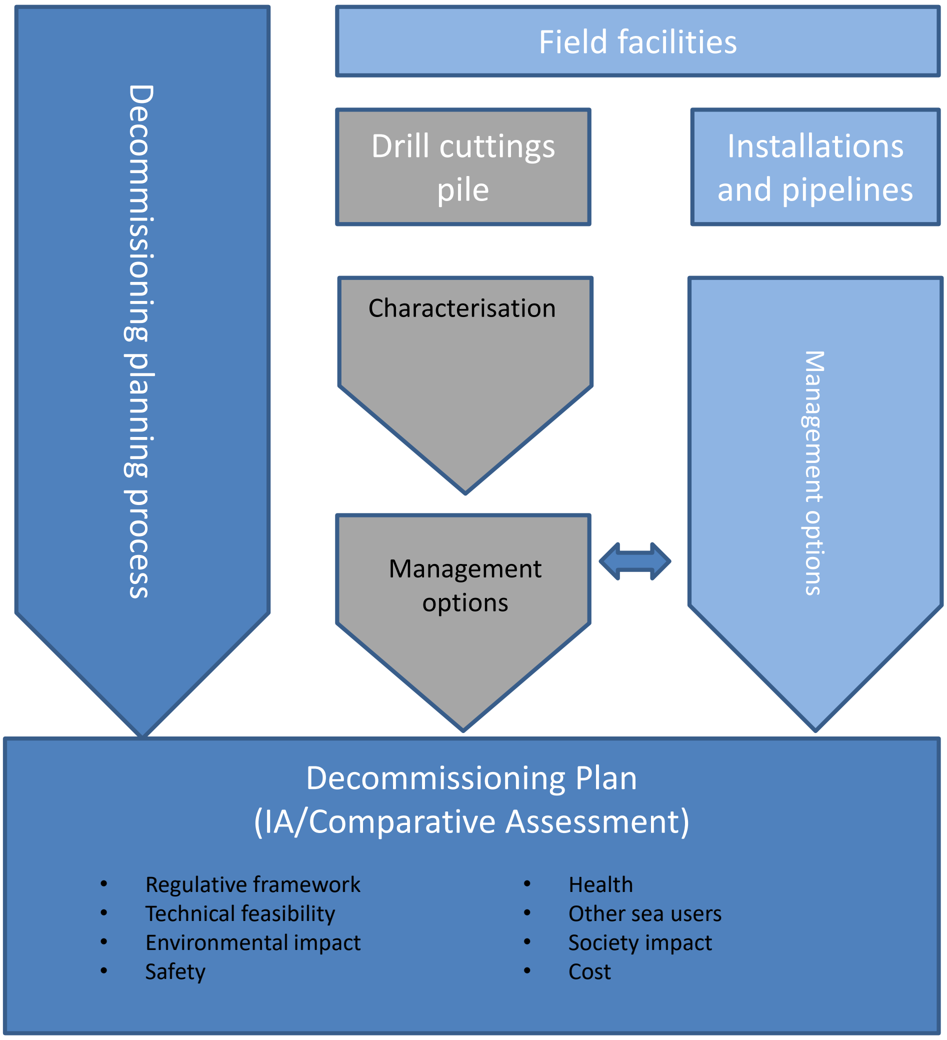


Figure 3-1. The cuttings pile management process as part of developing the overall decommissioning plan.

3.2 Disposal solutions for drill cuttings piles

Several studies have discussed various options for how to deal with the contaminated cuttings piles with environmental concerns. I.e. piles that exceeds the OSPAR criteria (or with other conditions which have significant environmental impact). Alternative disposal options were addressed in e.g. the UKOOA R&D JIP on drill cuttings piles (UKOOA 2002, RF 1998, RF 1999), by Gerrard et al. 1999, COPSAS 1999, DNV/RF 2001. Some relevant options are listed briefly below.

Alternatives;

- Leave in place and;
    - Leave as is in situ for natural degradation
    - Bioremediation (enhancement of the degradation of organic pollutants)
    - Cover
    - Dispose in an excavated pit in the seabed

    - Dispose in big bags on the seabed (or remove the big bags)
- Relocate
    - Transfer cuttings material from the jacket footprint area and dispose it at the adjacent seafloor
- Remove and;
    - Inject in disposal well
    - Treat on a vessel or platform, discharge cleaned water and cuttings to sea
    - Transport to shore (of cuttings with or without contaminated water) for treatment and disposal

The disposal alternatives for cuttings piles have been discussed in various recent decommissioning programmes and EIAs. The options for relocation at the seabed and recover to surface for various treatment/disposal alternatives are the two alternatives commonly being evaluated.

The outcome of the evaluations has been the option to leave the cuttings for natural degradation in most (all) decommissioning projects so far. However, for technical reasons before steel jacket foundation removal below sea bed level it has been necessary to relocate part of the pile.

This illustrates the importance of having a broad-based approach when recommending disposal alternatives, including criteria on technical, operational, safety and cost – in addition to environmental – in the internal decision making process. Hence, such evaluation should be applied on the principles of BAT for each project to ensure the best practicable environmental solution.

4 DEROGATION CASES

The management of cuttings piles is important as part of planning for disposal of facilities (such as jackets), related either to their removal or to leaving the footings in place pending OSPAR derogation.

There have been a few cases were the operators have applied for derogation for the OSPAR Decision 98/3 on full removal of disused offshore platforms and where there are significant drill cuttings piles at the footings (e.g. Brent A, North West Hutton, Miller and Murchison). The installed jacket weights are above 10 000 tonnes for these platforms. A few concrete structures (the Ekofisk tank and concrete installations at the Frigg field/MCP-01) are already accepted to be left offshore, but there were no issues with drill cuttings piles at these sites (Table 4-1).

It is expected that additional future application for derogation will develop where the Gravity Based Structures (GBS, Brent GBSs are under consideration by BEIS)) or steel jacket footings and the associated drill cuttings will be left in place. So far there have been little controversy (nothing publicly reported) between the OSPAR parties about the derogations.

The solution to leave the jacket footings or GBS in place allows for the cuttings to degrade naturally over time. The persistence of these cuttings piles is several decades or hundreds of years, but erosion, leakage and degradation of the organic contaminants will likely reduce the volume and distribution area.

Leaving the cuttings pile undisturbed is recognised as advantageous for the environment compared to the impacts from dredging of the material which is required for removal operations. In the decommissioning programmes the arguments for derogations are both of technical and safety reasons and evaluation of environmental impacts from disturbance of the cuttings and emissions to air from vessels during marine operations.

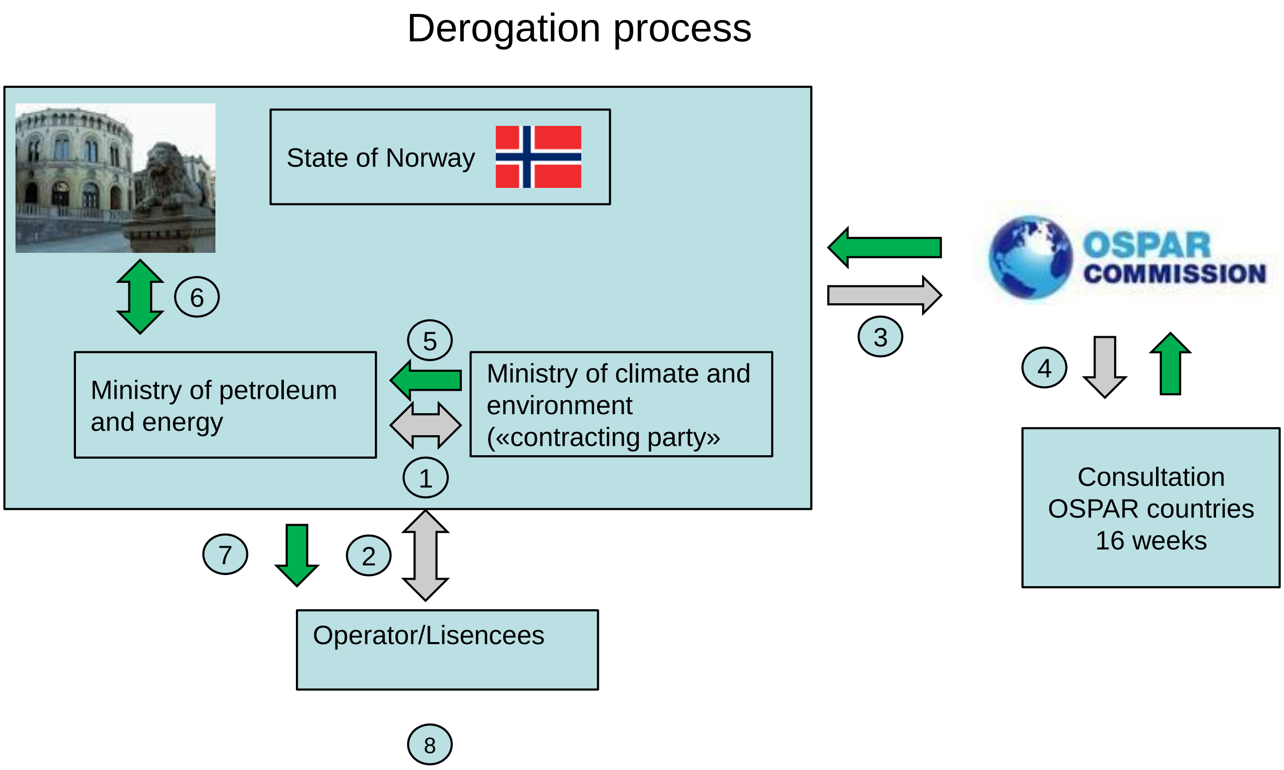
Table 4-1. Some approved or in process derogation cases for not removing offshore structures and the presence or not of drill cuttings piles. Web page visited March 2017 for UK installations: https://www.gov.uk/guidance/oil-and-gas-decommissioning-of-offshore-installations-and-pipelines **.**

Installation	Cuttings pile	Derogation	Comment
Brent A	Y	Y (in process)	Leave the footings and cuttings pile on the seabed
Brent B, C and D	Y	Y (in process)	Leave the GBSs and cuttings piles on the seabed
NW Hutton	Y	Y	Leave the footings and cuttings pile on the seabed
Miller	Y	Y	Leave the footings and cuttings pile on the seabed
Murchison	Y	Y	Leave the footings and cuttings pile on the seabed
Frigg TCP2, CDP1, TP2, MCP01	N	Y	Leave the concrete structure at the site.
Ekofisk Tank	N	Y	Leave the concrete structure at the site.

An OSPAR derogation decision process for Norway is described below:

- Dialogue between the State[4] and the operator, normally the operator is requested to prepare the technical documentation for the derogation process ("OSPAR derogation document"). There are no formal timeline directions for this part of the process.
- Consultation among contracting parties, 16 weeks.
- Disposal decision by the State, for derogation normally by Parliament. No defined timeframe for this process, however if a decision by Parliament at least 6 months should be expected (the Frigg case took 15 months).

The process is further illustrated and described in Figure 4-1. The authorities initiate the formal derogation process following the licensee's recommendation to dispose of facility in situ.



1. National authorities decide to apply for derogation. Formally Ministry of Climate and Environment is the national contracting party, however experience shows that Ministry of Petroleum and Energy in practice is managing the process.
2. Operator is asked to present technical documentation, communication normally with MPE
3. The State issues the application for derogation to OSPAR executive secretary
4. Derogation process 16 weeks, if objections from more than one contracting party, 32 weeks
5. Coordination of decision basis,
6. Case sent to government or parliament for decision
7. Decommissioning permit with requirements
8. Execution of disposal

Figure 4-1. Norwegian process for OSPAR derogation

[4] Formally the Norwegian interests should be represented by MCE however in practice in the past it has been coordinated by MPE

A derogation process will be initiated by the national authorities, communicating with the OSPAR Secretariat (as per Appendix 3 to the OSPAR 98/3 Decision). In Norway, the factual documentation (as per Appendix 2 to the OSPAR 98/3 Decision) will be managed by the Ministry of Petroleum and Energy (MPE) (documentation provided by the operator) while the Ministry of Climate and Environment (MCE) formally manage the process towards the OSPAR secretariat (and the countries). In practice, however MPE has also had this role in previous derogation processes.

5 EXPERIENCE FROM SAMPLING OF CUTTINGS PILES

5.1 Arguments for characterising cuttings piles

The OSPAR implementation report (OSPAR 2009b) indicates that there is no further sampling or reporting on the cuttings piles required, since the environmental effects are of less concern and they can be left for natural degradation. However, the high-level reporting in 2008 was based on available data; partly based on analytical results, but also a significant number of modelling data and desktop studies of estimated discharges and accumulations at the seabed, without a significant amount of empirical data. Such data are necessary for a knowledge based decision making process.

The environmental authorities generally expect updated information, and environmental evaluations for each individual pile in a decommissioning plan. Hence, collection of information from the cuttings piles can be required for various reasons;

- To collect updated information about the status of the pile
- To evaluate the environmental impacts from the pile under the present conditions
- To possibly verify that the cuttings pile is below the OSPAR criteria
- To evaluate environmental effects from subsea activities which disturbs the cuttings
- To calculate the cuttings volume needed to be handled (dredged) during a platform removal operation
- To evaluate the requirement for environmental monitoring during platform removal operation and in the years thereafter
- To collect input data for modelling

The industry practice has been to sample the cuttings pile as part of planning for removing offshore facilities, some for documentation in the EIA. The results from characterisation and analyses have been used in assessment of management options for cuttings piles and associated environmental impacts have been presented in the ES/EIA for decommissioning the installation/field (e.g. Shell 2017a, CNR 2013, DNV 2009). The data collection has also been used to support the conclusion about the piles versus the OSPAR thresholds, and documenting that natural degradation is the best environmental strategy. This assessment has been based on data from the actual pile, generic assumptions, laboratory tests (leaching experiments), or modelling (UKCS).

5.2 Sampling techniques

The OSPAR guidelines (OSPAR 2017a) and the Norwegian Oil and Gas Association guidance for characterisation of drill cuttings piles (NOROG 2016) should be consulted for suitable sampling techniques and analyses. The historical surveys of cuttings piles have in general referred to the previous guidance document (OLF 2003) and/or the guideline for offshore environmental monitoring for sampling and analyses (NEA 2016a, OSPAR 2017b).

The complexity and magnitude of the different surveys have varied significantly. Some piles have been surveyed several times with various techniques, and some have been investigated once with a simple method and on a few sample locations only. There are also cuttings piles with no available reported analytical data.

Coring devices have in general been successfully deployed at cuttings piles (Figure 5-1). Over the last 20 years a significant number of samples have been collected from cuttings piles in the North Sea. Most of the samples have been collected with corers operated by ROV. This technique is today the most commonly used and recommended sampling method for drill cuttings piles (NOROG 2016, IOGP 2016, Genesis 2016).

The short ROV operated corers are efficient for multiple sampling and requires no lifting operation of the sample tool with cranes (however, deployment and retrieval of the ROV with winch system is needed). The drill cuttings material is in general suitable for such sampling since the material is relatively soft and sticky. However, there may be some challenges with; debris and cement inside the pile, mussel and fauna layer at the top, and accessibility of part of the pile. In a few cases the seabed/cuttings have been very soft and the sampling have been reported as challenging.

Due to the geometry of the steel footing, jacket piles and members, there can be limited passages for the ROV and high risk for snagging of the tether. In addition, the operator of the platform may also have limitations on subsea activities to reduce the risks for damaging the assets. Relatively few samples are therefore collected inside the area of steel jacket foundation.

Some (longer, deep penetration) samples have been collected with more sophisticated equipment. These have been operated with ROVs or deployed with crane and winch. Various grabs, box corers and gravity corers have successfully been applied.

Grab has mainly been used at more distant locations (> 100m) from the platforms and is recommended if the fauna community is to be addressed in the analyses. Usage of grab is the standard tool for regular Norwegian offshore environmental monitoring (mainly at > 250m distance and outwards form the platforms).

Description of various techniques for characterisation and sampling of drill cuttings piles can be found in different publications (e.g. Genesis 2016; IOGP 2016; OGUK 2013ab, OSPAR 2017a and NOROG 2016).

Figure 5-1. Various still photos of ROV operated corer sampling at drill cuttings pile surfaces. Note the variable quality at different locations. A sectioned corer sample is shown in the lowest image.

5.3 HSE issues with drill cuttings sampling

Lifting operations of sampling tools is one of the main hazards and for offshore work there are rules to be followed. The cranes and winches should be handled by the trained crew on the vessel and the on-board routines should be adopted to.

Operational hazards presented by using equipment and lifting operations should be addressed before the survey and mitigated through training, procedures, HAZIDs and safe job analyses.

Any HSE issues, learning and suggestion for improvements from safe job analyses and practical experience should be included in the reporting from the surveys. Such comments are rare in the drill cuttings pile survey reports (and in seabed sampling reports in general).

The cuttings samples may smell of H_2S or oil (diesel and aromatic compounds) and may contain hazardous chemicals which require the use of proper PPE. Gloves, coveralls or rainwear and boots should therefore be worn. In most cases, good ventilation of the work area will be the best solution for reducing risk from gas exposure, but gas masks (or a fresh air hose breathing apparatus) may be used if needed.

There have been few reported HSE issues during the handling of samples, but some have experienced temporarily discomfort from working with the cuttings in confined spaces.

There are no reported issues with respect to elevated radiation levels in cuttings piles. Measurements have in general indicated background radiation levels only. A cuttings pile is composed of rock fragments with some used drilling mud and this material is not comparable with scale deposited in pipelines and process systems. The LSA and scale originate mainly from compounds in produced water.

Cuttings material which have been collected, but not bagged for analyses, have been disposed of in a container or equivalent, or returned back to sea. Oily/contaminated wash water from the sampling have been collected in drain/slop tanks or discharged directly to the sea.

Similarly, cuttings material attached to retrieved sampling tools (e.g. ROV) have been washed off and routed to slop system in the ROV hangar.

No significant evidence or issues with oil sheen on sea surface have been reported from drill cuttings sampling operations.

6 APPLICATION OF ANALYTICAL RESULTS

6.1 Volume and distribution of the cuttings

The distribution and volume of the cuttings pile is important information for the management of the cuttings independent of disposal solution. Hence, these two figures should be reported. A large volume covering the foundation of the platform require more dredging effort than a thin coverage, if the platform is to be removed. I.e. it influences on the possible techniques for dredging solutions and the feasibility of such operations. Calculations of the extent of any dredging operation (volume and location/accessibility) is important input to the assessment of management solutions.

For dredging operations, the amount of native seabed and marine growth (mussel shells layer on the top) should also be estimated since it influences on time usage for the marine operations and possible environmental effects. In application to the authorities it is also recommended to estimate cuttings volume, seabed material and possible marine growth to be dredged.

Only samples of drill cuttings should be included in the reported values for the piles (cuttings). Samples representing the native seabed should be omitted when discussing the pile material. The separation of the cuttings from the original seabed can be difficult and the choice/selection of samples should be described. It will often be based on contamination levels, other sediment characteristics (grain size, odour, appearance), or the location of the sample point.

The THC level in the samples can be used as an indicator if the materials have remnants of oil based mud or not. A THC level above 50mg/kg (adopted by OSPAR to be the limit for significant contamination, i.e. where influence on the benthos can be expected (OSPAR, 2006)) can indicate presence of oil based mud. However, it should be noted that in the 70- and 80-ties some percentages of diesel could be added to the water based mud. This generates cuttings which is contaminated with oil/THC. Barium (barite is used as a weighting agent[5]) is an excellent tracer for drill fluids discharges since it is used in most wells and the natural background level is low. Elevated barium levels can be found far away from the release point and also in samples where the THC content is low. Unlike THC the metal is not degraded, but inert and stable in the sediment. Barium (and oil) may however be discharged continuously via produced water outlet and this can potentially influence on the concentrations found in the sediment surface.

6.2 Amount of contamination

The drill cuttings piles are in general very heterogenous with respect to contamination levels. Both horizontal and vertical zonation can be significant. The evaluation of sample/results to be used in the description of contaminant levels and environmental evaluations is therefore challenging. There can be situations where a sample is contaminated, but the adjacent sample are not. It is suggested to use the OSPAR limit of 50mg THC/kg as a guidance to assess if a sample is to be regarded as presenting contaminated drill cuttings or not.

The selection of samples to be included in the reporting as being representative for cuttings can influence greatly on the outcome of the findings, e.g. when calculating the load (amount) of contaminants in a pile. Such estimates are based on a concentration (mg/kg dry weight of cuttings) of the pollutant and volume of the cuttings pile (the pile volume must be converted into dry weight). Calculation of a worst, average and low case is useful to indicate the possible range of the content in the

[5] Ilmenite ($FeTiO_3$) are used in drill fluids for some wells and Ti (titanium) should be included in the monitoring surveys at NCS.

pile. The load of contaminants is found by multiply the total dry weight of cuttings with the measured concentration of the pollutant. Hence, the calculations do take into account the water content and density (weight) of the cuttings (the volume should be estimated from a MBES survey). The density and water content data (use average values, they can vary significantly within a pile) should be available form analyses of actual cuttings material, but if they are not, the input example values (Table 6-1) may be used.

Table 6-1. Example of how to calculate the amount of a contaminant in a pile. Volume x density x dry weight% x concentration.

	Drill cutting pile volume (m^3)	Density of wet material (g/cm^3)	Mass of dry matter %	Mass (kg) of dry matter in drill cutting pile	Concentration of THC mg/kg dry material. Low, average and worst case	Kg of THC in the pile
Low case values	1 000	1.8	0.7	1 260 000	99	126~130
Mean values	1 000	1.8	0.7	1 260 000	999	1 259~1 300
Worst case values	1 000	1.8	0.7	1 260 000	9 999	12 599~13 000

The reported figures should be rounded off to indicate the uncertainty in the calculations.

The uppermost layer of the cuttings piles is most important for the environmental conditions for the benthic fauna and potential for loss of contaminants into the ambient water (Figure 2-2). The results from deeper sections are used to look at variation of the contamination with increasing depth and the figures are relevant if any dredging is planned. Due to the large heterogeneity generally found in the cuttings piles, the peak value can be randomly located.

Reporting of drill cuttings piles have been based on maximum, minimum, average and median concentrations values for all samples pooled, or for selected areas/layers of the pile. Also, distance to the platforms has been used to group various samples. It is recommended to use several figures to describe the level of contaminants, and maximum, minimum (i.e. the range) and mean/average should be reported. For presentation in a summary a reasonable estimate of average concentration of pollutants is beneficial. The reported figures should be rounded off to indicate the uncertainty in the calculations (the input data).

The discussion of the measured THC level in the cuttings (most relevant for the OSPAR assessment) should be emphasised. However, the other contaminants and analysed parameters should also be reported and comments made if there are findings of interests.

7 ENVIRONMENTAL EFFECTS FROM DREDGING OPERATIONS

7.1 Subsea release of particles

Dredging and subsea disposal of the material (relocation operations) results in spreading and sedimentation of particles. The environmental effects from the particles have similarities to the effects from discharge of cuttings and mud from drilling operations (the toxicity is however depending on the concentration of contaminants). Hence, some relevant information about effects both from discharges from drilling and from dredging operations are discussed below.

The environmental effects from discharging fresh drill cuttings are generally most evident up to about 100m distance from the platforms and are, based on current practice, rarely evident beyond 500m (Research Council of Norway 2012, Bakke et al. 2013, IOGP 2016, Genesis 2016, DNV 2013a). Minor volume of very small particles (e.g. barite) can drift further away, however not causing significant effects.

The cuttings piles are generally located within a 50-100m perimeter from the installations. The largest piles are generally caused by previous drilling with discharge of OBM residues. One of the largest piles at the NCS have a volume of 45 000m^3 and covers an area of 20 000m^2 (0.02km^2), Research Council of Norway (2012). The amount and quality of material discharged, release location (distance above the seabed), water depth and currents at the site are factors that determine influence area. The environmental footprint of the cuttings piles became significantly reduced after the discharge of oil based drilling fluids in practice was terminated in the early 1990's (Research Council of Norway 2012, Bakke et al. 2013, OSPAR 2009a).

In this section 'dredging' is generally describing relocation of the cutting/seabed solids at the seabed level. Application of any other options for drill cuttings pile dredging operations (recover to surface) have so far been very limited and of experimental/test character only (at NW Hutton, UKOOA 2002, OSPAR 2009c).

7.2 Dredging methods

Suction dredging is the most commonly used technique for removal/relocation of cuttings at the basis of the platforms. The suction hose and nozzle is accurately manoeuvred by a ROV or attached to a jointed arm at a bottom crawler/dredger remotely operated from a vessel. The suction force is generated by pumps and the cuttings material is transported in pipes to designated disposal area. Water ejector pumps are popular since the suction force is generated by pressurised water flow and by no moving parts (e.g. impellers) which could be obstructed by debris or other items in the cuttings. However, blockage of pumps and hoses can be anticipated during dredging of cuttings. This is typically caused by items in the material and possibly by solids if the flow is too low for sufficient transportation in the hose.

Water jetting has also been applied for removal of sediments and cuttings. This technique can be very efficient to move a large volume in short time, but most of the sediments settles nearby the excavated area and cannot be routed to designated sites. The plume of water and solids may also be larger (but possible for a shorter period) compared to suction dredging.

7.3 Particle dispersion and sedimentation

The plume of water and solids is typically released about 2m above the seabed in horizontal direction to minimise the amount of vertical dispersion (Figure 7-1, Figure 7-2). An increased diameter of the end of the exhaust hose, reduces the flow speed and the dispersion of particles. The release point is relocated at intervals to avoid generating considerable heaps on the seabed. The main part of the solids settles within a few meters from the hose end. Significant sedimentation is only to be expected some tens of meters from the dredging hose release point. At 100m distance the sedimentation will be in the order of mm or less. The smallest particles may drift for a km or so before they settle (DNV 2012ac, DNV GL 2014a, 2015). The sedimentation outside a dredging area can be comparable to particle distribution from discharges during drilling campaigns (DNV 2013a, Bakke et al. 2013, MD 2013, OSPAR 2016).

It is recommended to base the assessment of environmental effects from dredging operations on environmental monitoring data from comparable projects. There are several examples and data sets available from both UKCS and NCS operations. Any possible requirement for monitoring of a dredging campaign should be evaluated and agreed upon with the authorities as a part of application and permitting process. The use of modelling tools to generate 'theoretical effects' are briefly mentioned below.

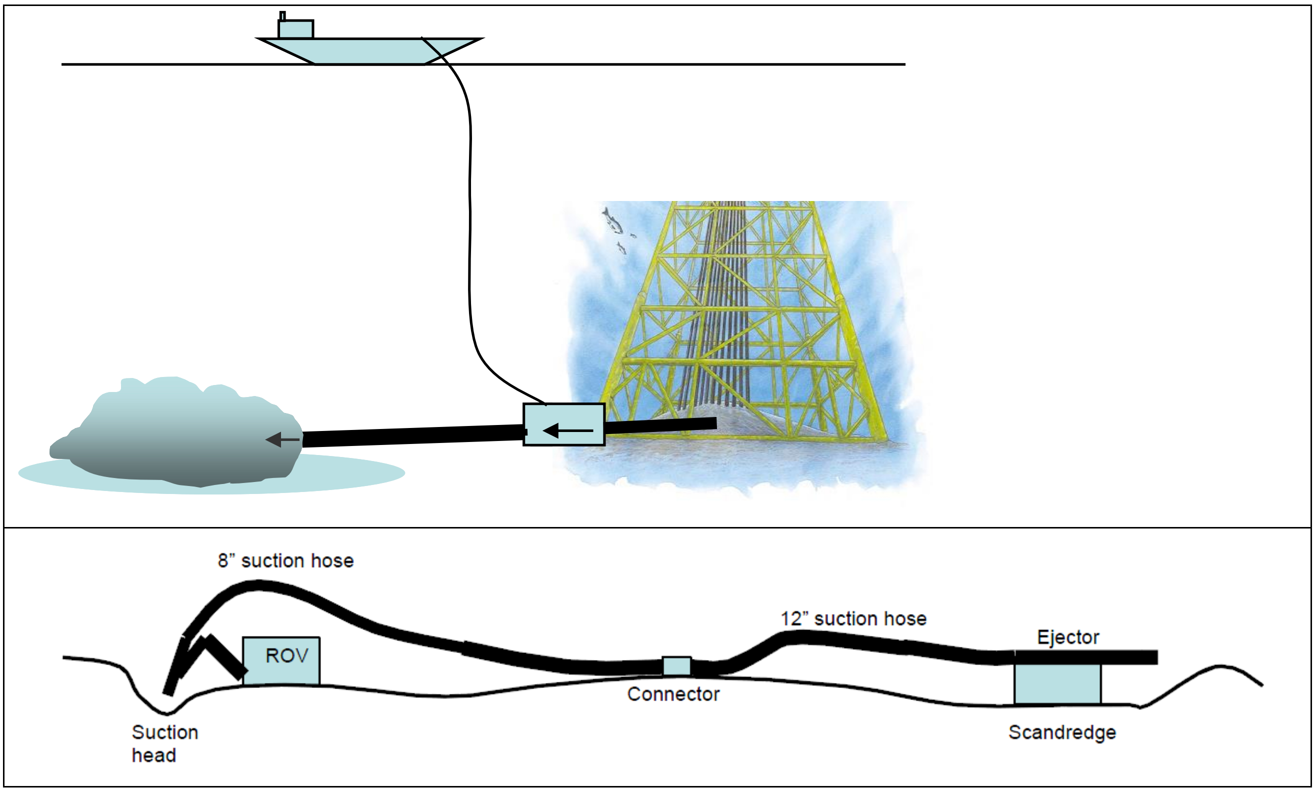


Figure 7-1. Sketch of a dredging spread principle (DNV 2012c).

The environmental consequences on water living organisms and seabed fauna from drill cuttings disturbance have been modelled for several fields at the UKCS. This model tool was developed during the UKOOA JIP on drill cuttings. In 2012 the model was applied to do risk assessment of drill cuttings disturbance at Valhall (BMT Cordah 2012).

For the Brent field decommissioning programme various drill cuttings disturbance scenarios and effects were modelled. The modelled output is assessed to be conservative with respect to environmental effects (Shell 2017a). For instance, the relocation of 7 735m^3 of cuttings at Brent C storage cell-top (by suction dredging) with a THC concentration of 333 626mg/kg (maximum value) over 65 days, resulted in a 15.9km^2 large area on the seabed were PEC:PNEC[6] ≥1, i.e. the fauna was predicted to be effected by the settled THC. The seabed area covered with >1 mm sedimentation was much less, 0.07km^2. In the water column a volume of 1.3 million m^3 was predicted to have a concentration above effect limit (PEC:PNEC ≥1) for about 1 000 hours. The effect distance in the water was 4.2km at the maximum (Shell 2017ab).

There are alternative model tools that can predict concentration, dispersion and sedimentation of particles and chemicals (e.g. DREAM, Dose-related Risk and Effects Assessment Model, by SINTEF and its Partrack model for drilling discharges). ERMS (2006) presented a framework for Environmental Impact Factor for drilling discharges. The models DREAM/Partrack can also be applicable for dredging operations. 'Seafan -Seabed Footprint Analyzer' is a tool for multiple runs of particle dispersion modelling to get a statistical output of the likely dispersion scenarios (DNV GL 2017).

It is recommended to perform additional validation of the modelling tools and compare the results to *in situ* measurements/monitoring results of actual drill cuttings relocation operations.

7.4 Effects from dredging

The cuttings piles are commonly inhabited by several bottom dwelling species although parts of the piles may be dominated by anoxic conditions and development of a bacterial mat (*Beggiatoa* spp). The existing fauna at the cuttings will be removed during a dredging operation and possible covered with cuttings at the disposal area. Similarly, will the fauna living at the disposal area be covered by the dredged solids and be eliminated. The amount of sedimentation will decrease with increasing distance and at a certain limit, the fauna will be less smothered from the sedimentation and can survive the load.

The effects on the bottom fauna from the settlement of dredged particles are comparable with effects from discharges from drilling. The amount of sedimentation influence on the effects. Both cuttings with water and oil based mud based influence on the covered sediment conditions. The fauna can possibly withstand some mm of sedimentation, but only a few species or none can tolerate to be covered by several cm or more. The tolerance can be influenced by the duration of the sedimentation, i.e. if it occurs during hours or weeks and at repetitive intervals. The sedimentation can also influence on the oxygen level in the sediments and reduction of oxygen has an obvious negative effect on the fauna (Trannum 2010, 2014). Decreased oxygen levels are likely to be of most importance and the changes in grain size and toxicity of contaminants have less effects (Trannum 2011). Sedimentation of cuttings also influence on bioturbation and food supply for the fauna.

7.4.1 Toxicity

Environmental monitoring of dredging operations detects pollutants dispersed in the water. Toxic levels have been detected to occur temporarily near the discharge. The effects on biota from the contaminants in the dredged cuttings is less obvious and difficult to monitor and separated from the direct and secondary effects from the particles themselves. The relationship between concentrations of contaminants in the water and in the solids, and the direct effects on the fauna are influenced by several factors. Toxicity of drilling discharges have been significantly studied (e.g. summarised by Bakke et al. 2013, IOGP 2016). Effect concentrations values exists for some of the components, based on toxicity

[6] PEC, Predicted Environmental Concentration. PNEC Predicted No Effect Concentration. PEC:PNEC, an environmental risk assessment ratio of the PEC and PNEC. A value of 1 or above is indicative of a potential risk of environmental damage.

tests in laboratory, but how these compares with the *in situ* conditions is difficult to measure. Lethal or sub-lethal effects can be predicted from concentrations of the pollutants, but the actual/direct effect is difficult to observe on biota in the field. The results from environmental monitoring of produced water discharges are relevant for comparison of concentrations of pollutants from a cuttings pile dredging operation.

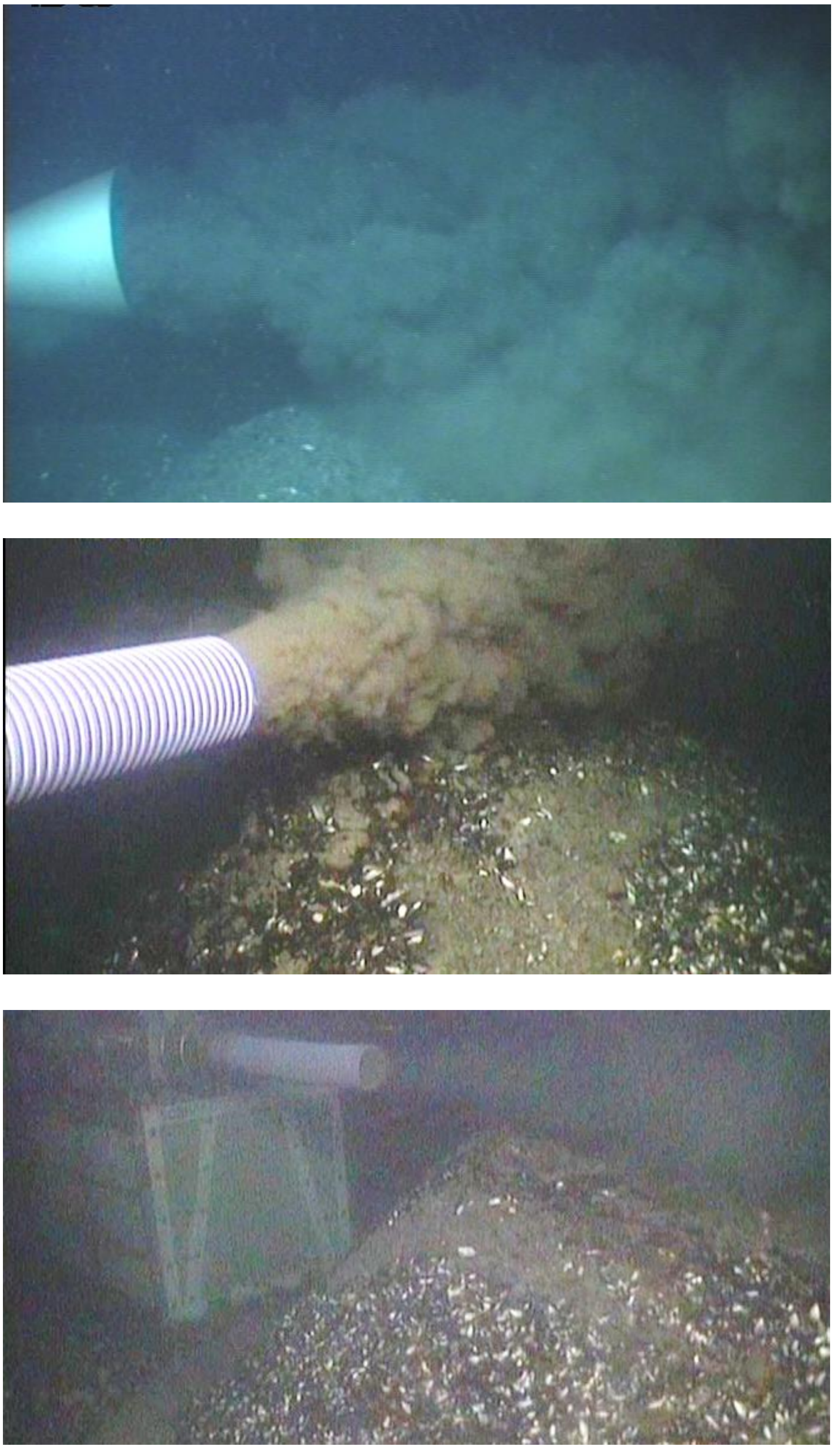


Figure 7-2. Photos of subsea suction dredging exhausts. Sediment/water plume at the top and middle, and a heap of settled materials (a significant volume of shells from mussels) at the bottom.

Testing of leaching from drill cuttings material indicates that the contaminants have low water solubility, but are bound to the particles (OSPAR 2016). Most of the dispersed pollutants therefore follow the solids to the seabed where they settle.

The effects on the benthic fauna from the pollutants (and the particles themselves) are surveyed during the environmental monitoring programmes of the fields. At stations where there is a co-variance between fauna community composition and sediment parameters, this relationship can indicate effects from the discharge and which parameter represent the highest influence. However, these surveys usually document the conditions at 250m distance and outwards from the platforms. At such distance, there is less influence from drilling discharges and from a possible dredging campaign. It is recommended to include more proximate stations (e.g. 100 m distance) pre and post drill cuttings disturbances to measure the influence on the seabed conditions.

7.4.2 Other effects

The turbidity plume influence on visibility and light penetration (decrease primary production), and can clog gills or feeding apparatus on organisms, but it will be rapidly diluted. The effects on water living organisms are therefore likely to be local and not permanent, hence there is no effect on the ecosystem/populations.

Cuttings piles with content of oil based drilling muds seems to be relatively stable and the contaminants persist for many years. The degradation of the organic pollutants (oil) is slow within the piles. The oil is present several decades after the cuttings were discharged. Low bioturbation (the effects from animals living and burrowing in the seabed) in the cuttings and supply of oxygen is likely to be the main limiting factors for biodegradation. At some cuttings piles it is a significant layer of blue mussels and shells which originate from the upper part of the jacket. Such a layer reduces the transport of oxygen and anoxic conditions may develop.

Some oil escapes via pore water into the water column and erosion may take a part in the degradation. A dispersion of material into the water followed by sedimentation over a larger area will supply oxygen and enhance the biodegradation, and this can be regarded as a positive effect from dredging.

In some dredging operations at Ekofisk the project has planned to first relocate the polluted material (cuttings) and then to some extent cover it with native sediment (excavation of the seabed below the cuttings), COPSAS 2012. This process has been suggested as to reduce the bioavailability of the contaminated material and thereby reduce the impacts on the environment. Another effect of such procedure is that the biodegradation of organic pollutants will be less in the cuttings when it is covered into the seabed, since oxygen supply is restricted.

Oil droplets emerging from dredging operations of cuttings (or other subsea operations in the cuttings) have been reported to generate small and vanishing spots of blue sheen on the sea surface (BP 2014, and pers. communication with COPSAS). The oil sheen is not likely to pose any environmental effect, but seabirds should not be exposed to this at the sea surface. Cuttings materials attached to equipment or other items retrieved from the seabed and lifted through the splash zone can also be a source of local oil sheen.

OSPAR (2009c) concludes that external disturbances (i.e. relocation at the seabed, recovery of cuttings to surface, and bottom trawling) have limited effects on the cuttings piles. It will result in some resuspension of material and dispersion of particles. The main part of the suspended material settles locally and the contaminants are mainly associated to the particles and sinks back to the seabed.

The OSPAR conclusions are based on four research trials, mainly:

1) Trawling at outer Moray Firth at an abandoned single well location drilled with a unique synthetic oil based mud. A heavy monkfish trawl was used and the most intense disturbance area was passed over 17 times in a 9 days' period. The main part of the cuttings was distributed within 2 km from the original site. The concentrations of contaminants were expected to have little environmental significance. A 3D mathematical model was developed to predict the dispersion, and the simulation was similar to the field measurements. Reference is made to FSR-ML 2000.

2) Ekofisk and Albuskjell drill cuttings piles surveys, experiments and modelling. The documents discuss effects from dredging and trawling on cuttings piles. The conclusions from this work indicate less dispersion of oil from cuttings by trawling compared to dredging. Reference is made to DNV 2006a and UKOOA 2002.

3) Drill cuttings recovery test at N W Hutton platform. A small part of the cuttings pile was transferred to surface by suction dredging. Minor dispersion of cuttings was observed and little secondary pollution was discernible at a distance of 100m from the dredging operations. Reference is made to CEFAS 2001 and UKOOA 2002.

4) The documents describe the environmental effects on the seabed conditions from decommissioning activities at the Hutton field (TLP and well templates). During decommissioning, it was necessary to clear the redundant foundation and well templates of any overlying cuttings material to enable removal operations. This involved the use of high-pressure water jets and caused the suspension of significant amounts of oil contaminated cuttings into the water column and re-deposition on the seabed. The conclusions from the study were that disturbance of the cuttings pile due to decommissioning activities at the Hutton site had no major effect on the spatial distribution of cuttings contamination or the biological communities present in the seabed located greater than 100m from the original location. Reference is made to ERT 2004.

In 2016, OSPAR confirmed their conclusions from 2009 about environmental effects from disturbance of drill cuttings (OSPAR 2016). No significant impacts on the marine environment is expected, but locally there will be some disturbance and influence on the seabed conditions.

In a field test with trawling in a polluted fjord in Norway, the results indicate that a single 1.8km long trawl pass created a 3-5 million m^3 sediment plume with about 9t contaminated sediment (Bradshaw et al 2012). A plume 15 - 18m above the seabed and 120 - 150m wide with suspended sediment was found behind the trawl. Bioavailable contaminants from the sediments was detected in the plume/water. It should be noted that the sediment characteristics in the fjord is different to in the North Sea or in drill cuttings, hence the data cannot be directly transferred to an offshore situation.

Results presented by Molvær (Molvær 2009) also demonstrated that organic pollutants (dioxins) were suspended into water after bottom trawling in a contaminated Norwegian fjord. Parts of the solids stayed suspended in the water column for days after the trawling test.

As a part of the UKOOA drill cuttings research program (UKOOA 2002), BMT started to develop a model to estimate impacts from disturbance of a drill cuttings pile (BMT 2002, 2004). They estimated that as much as $20m^3$ of solids were dispersed into the water ($15m^3$ settled within the pile area and $5m^3$ outside) from a single pass of a bottom trawl (BMT 2002).

In the UK there is a routine to carry out a test trawl of the area adjacent to installations after decommissioning to verify that there is no unknown obstacle at the seabed (BP 2013). Such operations are not common in Norway, but the seabed is being surveyed (debris removed, rock dump design) to ensure that there will be no problems for trawling post decommissioning and end-disposal.

7.4.3 Recovery of benthic fauna

The process for the fauna to recolonize or adapt to the new conditions after a dredging campaign takes in general a few years only (OSPAR 2009d), since many of the species are adopted to changing conditions and have a high potential to inhabit available habitats. The process may start within months with settling of larvae from the water or by mobile specimen. Field experiments in the 1980's with oil and water based mud exposed in trays at the seabed indicated poor recolonization even after about five years in the oil based mud (referred to in Bakke et al. 2013). Local environmental conditions at the site and quality of the discharge (such as water depth, sediment grain size, level of contaminants (oil), oxygen supply, H_2S level in the sediment, toxicity (oil/water based mud) and volume of mud versus clean native seabed) and the duration of sedimentation influences on the recolonization process (UKOOA 2000, OSPAR 2009d, Bakke et al. 2013, IOGP 2016, Trannum 2011, 2014). Jones et al. (2012) observed poor recovery of mega fauna even after 10 years at areas completely covered with drill cuttings (discharge from drilling operations with water based drilling fluid) at deep water in the Faroe-Shetland Channel.

The environmental monitoring of dredging at the Albuskjell 2/4 F platform indicated moderate influence of the fauna composition at 100m distance. This impact was less obvious, but still detectable three years later. The fauna samples illustrate how the benthic animal community successive develops and adapt in three years' time. See Section 7.4 for further details.

7.5 Examples of drill cuttings relocation operations and environmental monitoring

Some additional examples on other minor disturbances of cuttings piles or heavily contaminated seabed sites offshore are listed in Appendix A. OSPAR 2009c discuss the influence from two drill cuttings dredging/relocation operations at the Hutton field. One test of drill cuttings recovery operation and a large scale relocation operation (by water jetting) required for removal of redundant seabed installations. The OSPAR document sum up the main findings from the environmental monitoring.

Greater Ekofisk area

During the years 2010-2011 a dredging campaign was performed to allow for several platform jacket removal at Ekofisk (COPSAS 2012). Both drill cuttings and native sediment material were relocated at the seabed by suction dredging and disposed of at the vicinity of the platforms. In total about 16 000m^3 material was relocated at 7 redundant platforms and 7 800m^3 of this volume was drill cuttings and about 3 250m^3 was native seabed. Significant volume of marine fauna (~ 4 450m^3, mainly blue mussels originate from the jacket splash zone) was present on top of the cuttings pile and needed to be relocated. The THC contamination level in the cuttings had an average concentration of about 1 100mg/kg.

Environmental monitoring was performed during a period of relocation of drill cutting at the Albuskjell 2/4 F platform. Both an operation specific monitoring campaign and the general (every third year) monitoring survey were performed at the site. Submerged monitoring rigs were deployed in a period and the seabed in the dredging and disposal area was sampled at several intervals (DNV 2010, 2012c). The level of contaminants in the water (measured in passive samplers and caged blue mussels) was comparable to concentrations found in a gradient from produced water discharges. Sedimentation of particles (in sediment traps) and the major influence was found to be within 100m distance. However, small particles (measured as elevated levels of barium in sediment traps) was detected at up to 2 000m distance.

The 2011 general monitoring of the seabed at 100 - 2000m distance from the platform found the benthic fauna at 100 and 250m distance to be somewhat disturbed from the sedimentation from the dredging. The conditions were not poor, but the composition of the benthic community was different from the other and more distant sampling locations (Akvaplan-Niva 2012, DNV 2012c). Three years later the differences between three of the four 100m distance stations and the more distant stations were still detectable, but less obvious than in 2011 (DNV GL 2015). Hence, the fauna composition close to the dredging area was becoming more similar to the conditions in general and the dredging in 2010 had no longer any significant influence on the fauna composition.

In 2011 the TCH levels were measured to 42, 49 and 100mg/kg at three of four stations at 100m distance from the Albuskjell 2/4 F platform. At the other stations the level was about 10mg/kg. This survey was done after the dredging campaign was finish in 2010 and the results indicated increased levels of THC in the sediments proximate to the platform. In 2014 the survey was repeated; the THC levels was reduced at most of the stations and all stations had a concentration of 12mg/kg or less (DNV GL 2015). The gradient around the platform was less obvious and the seabed conditions were 'normalised'. The metal concentration in the sediment had a similar trend, elevated levels at 100m (and 250m) distance in 2011, and reduced contamination in 2014.

Valhall

There have been two major dredging campaigns at the Valhall field. In 2012 a redundant pipeline section was excavated before removal. A mass flow excavator (T4000 dredger, a large water jet) was used in this operation, and mainly natural sediment (some contaminated cuttings, 5 700- 57 000mg THC/kg) was relocated (in total about 1 500-2 000m^3).

In 2014 drill cuttings and seabed sediments were relocated to prepare for a Jack-up rig intake. About 3 500m^3 of material (2 800m^3 was drill cuttings) was dredged by suction dredging and relocated to designated areas locally (BP 2014). The cuttings material was contaminated with oil based drilling mud (THC concentrations of 20 000 – 80 000mg/kg, maximum 155 000mg/kg).

Specific environmental monitoring was performed at both operations (DNV 2012a and DNV GL 2014a). The seabed was sampled in the dredging area as well as in the disposal areas and submerged monitoring rigs were deployed in a gradient from the site. In addition to the specific monitoring programs, the 'standard' offshore environmental monitoring survey, covered the environmental conditions more distant area from the platform. As a part of the monitoring of the dredging the 2014 survey was expanded to include a few more proximate stations compared to the normal 500 m distance stations in 2011 (and before).

The 2012 environmental monitoring was performed during the mass excavation to measure the spreading of particles and associated contaminants. The monitoring measured a significant sedimentation (> 10cm) within 50m from the site. Small amounts of particles could be traced at the reference station 1 km from the site. The amount of particles was highest close to the seabed (2m) compared to 10m above. The levels of water soluble pollutants were comparable to finding in areas with produced water discharge.

The 2014 specific monitoring during dredging, detected elevated concentration of oil compounds in the water and settlement of particles in an area 200-400m from Valhall (DNV GL 2014a). Influence on water living organisms from oil derived compounds is possible within this area. However, the effects would be of temporary character. On the seabed, close to the platform (i.e. at the pile area mainly), the environmental conditions were documented as poor, before and after the dredging, and there were no major changes of environmental conditions in the deposition area. Particles from the dredging and low levels of contaminants could be traced far away (reference stations at 5km distance), but concluded not likely in concentrations that could have any negative impact on the benthic fauna.

The ‘standard’ seabed monitoring performed after the dredging in 2014 identified a gradient from contaminated seabed at 220 – 500m distance, and improved conditions further away (DNV GL 2015). THC levels at about 2 000 mg/kg were measured at two stations (222 and 275 m from the field centre). The high THC concentration could be an effect from the dredging operation earlier this year. The sediment had also significant concentrations of barium and other metals compared to the other stations. The two stations had not been sampled in the previous surveys. Hence, historical development of the conditions could not be investigated. In 2014 the fauna composition was also influenced at the proximate stations (220-500m distance) compared to the stations further away, but the conditions were not poor. The changes in the fauna composition could likely be a result from the dredging operations.

The Valhall field was also included in the 2017 monitoring of the southern part of NCS. The results will be issued in draft report March 2018. Preliminary results of the chemical analyses indicate a significant reduction in the contamination close to the field centre, compared to in 2014. The highest THC level was less than 200 mg/kg, compared to about 2 000 mg/kg in 2014. This indicate a significant improvement of the conditions at these two proximate stations compared to the 2014 results. The fauna composition for 2017 is currently not available.

Other dredging operations

At the Oseberg field 350-500m^3 of contaminated cuttings were relocated in 2005. The environmental monitoring measured significant sedimentation and changes in contamination levels at 200m distance, but at 250-350m distance no effects were identified (DNV 2005).

At the Sleipner A platform about 2 500m^3 of cuttings were relocated in 2011 by a Scan Machine dredging tool (Statoil 2011). The cuttings were contaminated by oil/THC and were deposited adjacent to the platform. Environmental monitoring performed during the operation had a limited scope. No significant effects were identified at 250m distance (the mot proximate station) in the Regional Monitoring survey at Sleipner A in 2012 (DNV 2012d). Barium levels however, increased at several stations around Sleipner A in 2012 compared to the previous survey.

7.6 The fate of drilling discharges in the Barents Sea

This issue was requested by NOROG to be discussed briefly during the reporting of the cuttings pile experience and management. It should be noted that the discharges in the Barents Sea differs from the former discharges which generated large oil contaminated cuttings piles discussed in this report. In the Barents Sea the main operations have been single wells (or a few at templates) and discharge of cuttings from top well sections with water based mud. This do not generate a huge pile of oil contaminated cuttings.

In principle, the environmental effects and discharge from drilling operations can be expected to be similar in the Barents Sea as for other comparable areas – with differences due to local sensitivities.

From the first well was drilled in June 1980 and till 2017, 126 exploration wells (have been drilled in the Barents Sea (MPD, Ministry of Petroleum and Energy, 2017). In the periods from 1994-2000, 2001-2005 and in 2010, no exploration wells were drilled. In addition, there have been production wells drilled at the Snøhvit and Goliat fields.

The issue with discharges from exploration wells (and in particular from the top-hole section(s)) in the Barents Sea and areas with particular vulnerable fauna have been addressed in several documents from the environmental authorities (e.g. SFT 2006, KLIF 2010, KLIF 2012, NEA 2016bc).

From 2003-2011 there was a "zero discharge" regime for the petroleum activities in the Lofoten-Barents Sea area (White paper 38, 2003-2004). No discharge of any drill cuttings was allowed (but accepted for top hole section(s)). The stricter (prescriptive) regulations for discharge of produced water and drill cuttings in the Lofoten-Barents Sea area were withdrawn in 2011 (with the enforcement of the White paper 10, 2010-2011) and the regulations are now the same as for other parts of the NCS (risk based, "zero harmful discharge" regime).

The industry practice (and expectations from the environmental authorities) have been to perform environmental baseline surveys before exploration well drilling in the Barents Sea. This practice in the Barents Sea developed since there was less available information about the seabed conditions in the area and any valuable/vulnerable fauna should be protected. The environmental guidelines state that a baseline survey is required before production well drilling and for exploration wells in areas with valuable/vulnerable fauna or in areas where there are no detailed information about the seabed conditions (NEA 2016a). The environmental baseline surveys (e.g. DNV 2006b, 2008b, 2013, DNV GL 2014b, Mannvik et al. 2011) have detected areas with boulders, sea pens and sponges plus other valuable organisms, but also sites with mud/sand and less vulnerable habitats. Hence, the Barents Sea seabed conditions and associated fauna vary significantly between areas but also locally – as for other ocean areas. The seabed conditions in some parts of the Barents Sea have also been mapped in the MAREANO -project and results can be found at www.mareano.no.

As there are few fields in operation in the Barents Sea, the regular environmental monitoring is limited geographically (except for the baseline surveys referred above). To gain knowledge about potential effects of exploration drilling, ENI Norge founded a project to study the environmental footprint of deposition of drill cuttings in the south-western Barents Sea (Akvaplan-niva 2016).

Seven locations that were drilled in the period between 1987-2015 were visited in 2014 and 2015. A visual survey to map the spatial extent of drill cuttings deposition was carried out at each location and sediments were sampled at various distances from the drill hole for biological and geo-chemical measurements and analyses. The maximum visible extent of drill cuttings at freshly-drilled locations was between 250 – 290m from the centre, but generally reduced to less than 50m at the older locations (from three to more than 25 years post-drilling). Local oxygen depletion was evident at the newly drilled locations but most of the older locations showed signs of recovery. Drilling activities caused some local changes in the benthic faunal communities, including some reduction in numbers of species and numbers of individuals in the affected areas, but not at an ecosystem scale, nor was total defaunation observed, even up to 30 m from the drill hole. In summary, the visible footprint of deposited drill cuttings seems generally to be reduced to less than 50m within three years of a drilling event, although some specific bio-geochemical impacts may persist at greater distances. These findings are comparable with that found from similar studies in other areas (DNV 2013a, Research Council of Norway 2012, OSPAR 2016).

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APPENDIX A. OVERVIEW OF CUTTINGS PILES AND SEABED ACTIVITIES AT THE NCS

The table below summaries information about drill cuttings piles and activities disturbing contaminated sediments at the NCS. The list is not likely to be exhaustive, but is according to DNV GLs current knowledge. There are several cuttings piles with no information public available and these are omitted from the list. Some of these omitted sites are listed in the cuttings pile screening report from 2008 (DNV 2008a).

Table A-1. Summary of fields with known drill cuttings and/or contaminated seabed (adjacent to cuttings piles mainly). The phrase 'mapping' indicate a MBES (multi beam echo sounder) survey or equivalent of the bathymetry (pile area and volume). The figures for contamination of THC in the table are based on the most recent or relevant surveys. If the reports don't present the average or range THC figures, this has been subjectively estimated from THC results in the documents. ' – ' in a cell indicate lack of information. Contact the Operator (or DNV GL) for further information.

Field	Drill cuttings pile	Contami-nated sediments	Dredging or other activity	Site specific survey or monitoring during dredging activity	Sampling tools	THC average or range in cuttings	Survey year
Albuskjell 1/6 A The platform has now been removed.	Yes	Yes (but low concentrations)	Jacket removal	Mapping and sampling in 1998 and 2005. A few corers collected in 2008. Topography and volume mapping in 2010.	Gravity corer and grab	2-50	1998, 2005, 2008, 2010
Albuskjell 2/4 F. The platform has now been removed.	Yes	Yes (but low concentrations in 1999)	For removal of jacket in 2010.	Mapping and sampling in 1998. Topography in 2005. During dredging and after dredging in 2010 and 2011	ROV operated corer and grab	1100	1998. 2005, 2010
Ekofisk 2/4 A	Yes	Yes	Dredging for pipeline in 2004.	Mapping and sampling in 1998. Topography mapping and sampling in 2012	Vibro corer, ROV operated corer, gravity corer and grab	18700	1998, 2000, 2002, 2004, 2005, 2012
Ekofisk 2/4B	Yes	Yes	No	Mapping and sampling	Vibro core and box corer	157-22500	1998
West Ekofisk 2/4 D The platform has now been removed.	Yes	-	Jacket removal	Topography and volume mapping	Vibro core	120-4405	1998, 2005, 2010
COD 7/11 A	Yes	-	Jacket removal	Topography and volume mapping	-	-	1998. 2005, 2010

Field	Drill cuttings pile	Contami-nated sediments	Dredging or other activity	Site specific survey or monitoring during dredging activity	Sampling tools	THC average or range in cuttings	Survey year
The platform has now been removed.							
Ekofisk 2/4 W The platform has now been removed.	-	-	Yes	Topography and volume mapping	-	-	2010
Edda 2/7C The platform has now been removed.	-	-	Yes	Sampling, topography and volume mapping	Grab	-	1998, 2010
Ekofisk 2/4 C	Yes	Yes	No	Sampling, topography and volume mapping in 1998 and 2012	Vibro corer. ROV operated corer.	2300	1998, 2012
Ekofisk 2/4 E (Tor)	Yes	Yes	No	Mapping and sampling in 2012	ROV operated corer	47500	2012
Ekofisk area in general	NA	Local contamination outside drill cuttings piles.	Installation of Permanent Reservoir Monitoring (PRM) system (seismic cables in the seabed)	No.	Grab	<10 in general for the area	……. 2011 2014 (2017)
Valhall DP	Yes	Yes	Removal of obsolete pipeline section, preparation for jackup arrival	Mapping of pile in 2010 and 2011. Monitoring during two dredging campaigns in 2012 and 2014.	ROV operated corer, grab, gravity corer, vibro corer, stinger corer	2000-150000	2010 2011 2012 2014
Valhall area in general	NA	Local contamination outside	Installation of PRM	No.	Grab	<10 in general for the area	……. 2011 2014 (2017)

Field	Drill cuttings pile	Contami-nated sediments	Dredging or other activity	Site specific survey or monitoring during dredging activity	Sampling tools	THC average or range in cuttings	Survey year
		drill cuttings piles					
Statfjord A	Yes	Yes	Preparation for cessation /Impact Assessment	Mapping and sampling of pile. A significant number of samples.	ROV operated corer. Large gravity corer. Grab	2000-150000	2011
Statfjord B	?	Yes, Leakage from injection well?	?	Seabed anomaly survey	ROV operated corer.	45-43000	2013
Grane	-	Yes, Leakage from injection well.	Installation of PRM	Mapping of contamination from leakage deposition at the seabed	Most likely ROV operated corer.	10000-58000	2010
Snorre	-	Yes, Leakage from injection well.	Installation of PRM	Mapping of contamination from leakage deposition at the seabed	Most likely ROV operated corer.	5000-18000	2010
Sleipner	Yes	Yes	Installation of pipeline in 2011-2012. Dredging of cuttings.	Mapping and sampling survey prior to dredging.	Vibrocore	43000	2010
Oseberg B	Yes	Yes	Installation of riser. Dredging of cuttings.	Sampling survey. Monitoring during dredging.	ROV operated corer. Grab.	10000-145000	2003 2005
Oseberg C	-	Yes, Leakage from injection well. Discovered in 2010.	-	-	-	-	-
Veslefrikk	Yes	Yes, Leakage from injection well	Preparation for cessation	Mapping and sampling of pile.	ROV operated corer. Grab	9-123000	2015
Njord	No	Yes, Leakage from injection well.	Riser management	Survey of leakage deposits from injection well. Water column	ROV operated corer. Grab	1000-70000	2011 2013 2014 2015

Field	Drill cuttings pile	Contami-nated sediments	Dredging or other activity	Site specific survey or monitoring during dredging activity	Sampling tools	THC average or range in cuttings	Survey year
				monitoring (effects on fish from contaminated seabed) in 2014.			
Visund	Yes	Yes, Leakage from injection well	Riser manage ment over several years (2009-2015).	Mapping and sampling of cuttings and depositions of injection well leakages. Environmental monitoring of subsea activities.	ROV operated corer. Grab. SPI camera.	3000-160000	2007 2008

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