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Ramboll
Hannemanns Allé 53
DK-2300 Copenhagen S
Denmark
T +45 5161 1000
F +45 5161 1001
www.ramboll.com

CONTENTS

INTRODUCTION

Background and objectives

The general objective of the technical sections is to provide the relevant generic technical background information to identify the main environmental and social aspects of the exploration, construction, production and decommissioning activities foreseen by Maersk Oil Danish Business Units (Hereafter, Maersk Oil).

The impact assessment carried out for Maersk Oil's five projects (Dan, Gorm, Halfdan, Harald and Tyra) is based on the compilation of the project-relevant aspects and presented in a specific report: the Environmental and Social Impact Statement (ESIS). The likely environmental and social significance of the impacts will be assessed based on the based on their nature, type, reversibility, intensity, extent and duration of the planned activities to be carried out as well as the sensitivity of the relevant social/environmental receptors being exposed. In addition, the environmental and social impacts of the project deriving from the vulnerability of the project to risks of major accidents are assessed.

The technical sections document will be updated should any new procedures or practices with significant implications for environmental or social aspects be implemented at Maersk Oil.

Seven technical sections are defined to cover the activities related to Maersk Oil's project:

Technical section	Revision
A – Seismic	3 (2015-06-30)
B – Pipelines and Structures	2 (2015-04-29)
C – Production	3 (2015-06-30)
D – Drilling	3 (2015-06-30)
E – Well Stimulation	2 (2015-04-29)
F – Transport	3 (2015-06-30)
G – Decommissioning	2 (2015-04-29)

Definitions and abbreviations

ALARP	As Low As Reasonably Practicable
BAT	Best Available Techniques
bbls	Blue barrels (approximately 159 litres)
BHA	Bottom Hole Assembly
BEP	Best Environmental Practice
BOP	Blow Out Preventer
CAJ	Controlled Acid Jetting
Coiled tubing	Long metal pipe spooled on a large reel. The pipe is pushed into wells and used for interventions, e.g. injection of chemicals at a defined depth
CRI	Cuttings Re-Injection
D	Dimensional (as in 2D, 3D and 4D)
dB	Decibel
DEA	Danish Energy Agency
DSV	Diving Support Vessel
DUC	Danish Underground Consortium, a joint venture with A. P. Møller – Mærsk, Shell, Chevron and the Danish North Sea Fund
E&P Forum	Predecessor to International Association of Oil & Gas Producers (IOGP)
EC	European Commission
Environmental/Social Aspect	Element of an organization's activities, products or services that can interact with the environmental and societal receptors
Environmental/Social Impact	Any change to the environment/society, whether adverse or beneficial, wholly or partially resulting from an organization's environmental/social aspects.
Environmental and Social Risk	Combination of the likelihood of an event and its environmental and social impact.
ESIS	Environmental and Social Impact Statement
FSO	Floating Storage and Offloading
GBS	Gravity-Based Structure
Hz	Hertz
Intelligent Pig	A pig (as described below) that carries sensors and data recording devices to monitor the physical and operational conditions of a pipeline. They are most commonly used to detect any metal loss due to corrosion and mechanical damage.
MEG	Mono Ethylene Glycol
mg/l	Milligrams per litre
MPD	Managed Pressure Drilling
OBC	Ocean bottom cables
OBN	Ocean bottom nodes
OSPAR	Oslo and PARis Conventions for the protection of the marine environment of the North-East Atlantic
OCTT	Offshore Cuttings Thermal Treatment
PLONOR	Pose Little or No Risk to the Environment
PMDS	Poly Dimethyl Siloxanes
PPD	Pour Point Depressing agent (Depressant)
ppm	Parts per million
Pig	Pig is the industry name given to devices that are inserted into pipelines and used to clean, inspect, or maintain the pipeline as they pass through it
ROV	Remotely Operated Vehicle
STAR	Slim Tripod Adapted for Rigs
T	Tonnes
TEG	Tri Ethylene Glycol
THPS	Tetrakis (Hydroxymethyl) Phosphonium Sulphate
µPa	Micropascal
UBD	Under Balanced Drilling
Upheaval buckling	Vertical displacement of pipeline due to axial compression forces caused by high temperature and/or pressure of the fluid carried in the pipeline.
VSP	Vertical Seismic Profiling
WBM	Water Based Mud
WO	Work Over

A. SEISMIC DATA ACQUISITION

The present section "A – Seismic Data Acquisition" covers operations related to the acquisition of seismic data by Maersk Oil in the Danish North Sea. The editorial history of the section is summarized below:

	Revision	Changes
A – Seismic	0 (2015-01-07)	n. a.
A – Seismic	1 (2015-01-29)	Update following Maersk Oil review
A – Seismic	2 (2015-04-29)	Update following Maersk Oil review
A – Seismic	3 (2015-06-30)	Update following Maersk Oil review

A.1 Purpose

In exploration, seismic investigations provide information to interpret the geological structure of the sub-surface and to define the location of potential hydrocarbon reserves. Seismic surveys are also carried out by Maersk Oil over producing fields after several years of production to estimate remaining reserves (e.g. location and volume of remaining reserves) and to optimise production. High resolution multi-channel seismic data is acquired as part of drilling hazard site surveys to map and identify potential hazards to the installation of drilling rigs and to the drilling operation. High resolution single channel seismic data is acquired as part of seabed and shallow geophysical surveys to map seabed and shallow soil conditions for the design and installation of pipelines, platforms and other structures.

A.2 General description

Reflection seismic is a method used to map the geological structure of the earth's subsurface from reflected sound signals. For a marine seismic survey the method involves directing a sound pulse towards the seafloor and recording the reflected energy. The recorded seismic data are processed and interpreted to provide information about the structure and lithology of the sub-surface.

Sound pulses are generated by an array of airguns that release a bubble of compressed air. Seismic airguns generate low frequency sound pulses. During a seismic survey, guns are fired at regular intervals as the vessel towing the source is moving ahead. The sound pulse is directed towards the seabed and the reflected sound is detected by hydrophones mounted inside one or several cables (streamers) that are towed behind the survey vessel.

Two types of survey vessels are used for the seismic data acquisition:

- Seismic survey vessels (used for 2D, 3D, 4D marine seismic surveys)
- Survey vessels (used for drilling hazard site surveys, pipeline route surveys and other shallow geophysical surveys)

Additionally, supply vessels are sometimes used as source vessels during some types of borehole seismic surveys and such dedicated source vessels may also be used during other seismic surveys, such as seismic undershoots or Ocean Bottom Cable (OBC) or Node (OBN) surveys.

A.3 Seismic surveys

Typical seismic surveys in connection with oil and gas exploration and exploitation include:

- 2D, 3D and 4D towed streamer seismic surveys, OBC and OBN seismic surveys,
- Drilling hazard site surveys and shallow geophysical surveys, and
- Borehole seismic surveys.

A.3.1 2D marine seismic surveys

2D marine seismic date is acquired by a single multi-channel streamer, towed behind a survey vessel, together with a single source (airgun array). The reflections from the subsurface of the sound pulse emitted by the source are recorded along a profile directly below the sail lines, producing a 2D image of the sub-surface geology. The survey lines are typically run in a large grid of lines with several kilometres interval. They are typically used to get a general understanding of the geology of an area before further exploration activities are initiated (Figure A-1). The duration of a 2D seismic survey ranges from a few weeks up to a few months depending on the size of the area to be surveyed.

The signals from the airguns are short, sharp pulses typically emitted every 12.5 to 25 m (about 6 to12 seconds), generating relatively low frequency sound waves (5 to 200 Hz). The airgun array sources generate energy with sound pressure levels (peak to peak) in the order of 244 dB relative to 1 µPa at 1m.

Historically 2D marine seismic surveys have been used for early exploration and Maersk Oil has acquired a significant amount of 2D seismic data in the Danish North Sea. However, 2D marine seismic is no longer commonly used in mature oil areas and it is unlikely that Maersk Oil will acquire 2D marine seismic data in the Danish North Sea in the future.

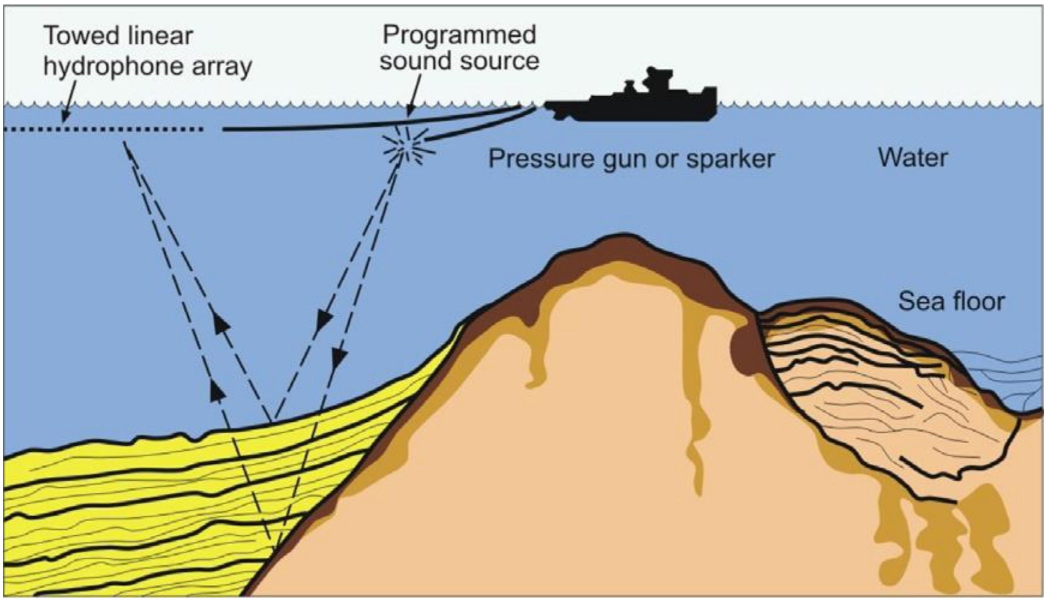


Figure A-1 Schematic illustration of a 2D marine seismic survey /1/

A.3.2 3D seismic surveys

3D seismic surveys provide more detailed image of the subsurface geology than a 2D seismic survey, because a 3D seismic survey is acquired in a much denser grid. 3D seismic is usually conducted in areas, which have already been covered by previous 2D seismic.

In 3D surveys, groups of sail lines (or swaths) are acquired with the same orientation, unlike 2D where the lines are typically acquired in a sparse grid of crossing lines with orientations defined relative to the dominant geological structure. The 3D sail line separation is normally in the order of 300 to 600 metres, depending on the number of streamers deployed. During most 3D surveys, one or two airgun source arrays and numerous streamers (6 to 16) are towed behind a single survey vessel, resulting in the simultaneous acquisition of many closely spaced subsurface lines (see Figure A-2). The typical distance between subsurface lines is 25 metres. The result of a 3D survey after data processing and interpretation is a 3D geological model of the subsurface, from which maps showing geological features can be extracted.

During 3D surveys, a supporting vessel is often placed in front of the survey vessel to clear the way, and another support vessel sails behind the swaths to mark the end of the towed equipment.

A seismic survey vessel is typically 100 metres long and 30 metres wide and tows one or two seismic airgun arrays behind the vessel, with multiple streamers which can be up to 8 kilometres long and cover a swath of up to one kilometre wide.

As in 2D seismic, the signals from the airguns are short, sharp pulses typically emitted every 6 to 12 seconds, generating low frequency sound waves (5 to 200 Hz). The airguns generate an energy with sound pressure levels (peak to peak) in the order of 244 dB relative to 1 µPa at 1m /2//4//5/.

3D seismic surveys can also be acquired using Ocean Bottom Cables (OBC) or Nodes (OBN). These are systems that use sensors placed directly on the sea floor for receiving the seismic signals generated by seismic airgun sources as illustrated in Figure A-3. For OBC and OBN surveys the seismic sources are generally the same as those described above for 2D and 3D seismic surveys.

3D surveys cover from about hundred square kilometres up to a few thousand square kilometres and can take several months to complete.

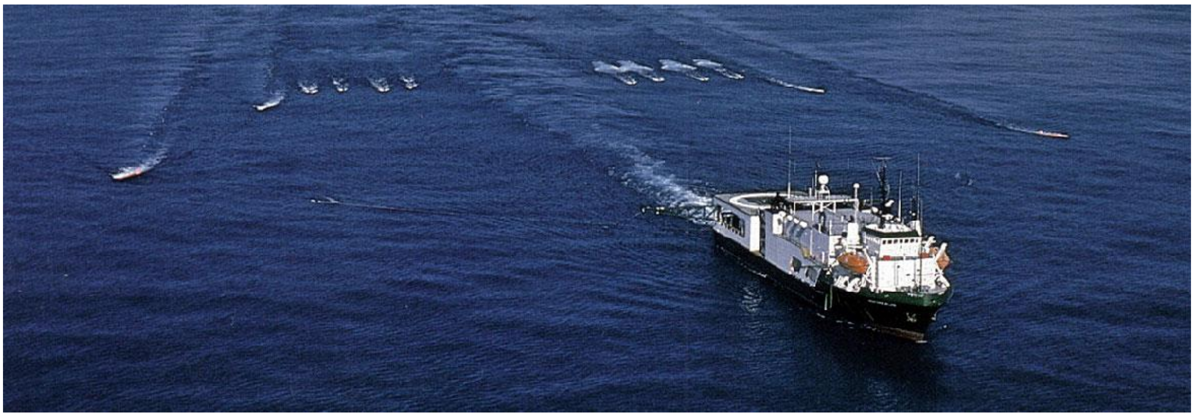


Figure A-2 3D seismic survey /6/

A.3.3 4D seismic surveys

4D seismic is 3D seismic surveys repeated over a period of time. The method involves acquisition, processing, and interpretation of repeated 3D seismic surveys over a producing hydrocarbon field. The objective is to determine the changes in the reservoir over time by comparing the repeated datasets. A typical final processing product is a time-lapse difference dataset (i.e., the seismic data from Survey 1 is subtracted from the data from Survey 2), the difference shows where reservoir changes have occurred.

4D repeat surveys are performed as 3D seismic with towed streamers or with ocean bottom nodes or ocean-bottom cables repeated at the same location over time (possibly several years). The advantage of nodes and bottom cables is that they can be accurately placed in their previous location after being removed from the previous survey, since ideally the survey should be an exact repeat of the baseline survey (earlier seismic survey) in order to best observe reservoir changes.

Like 3D surveys, 4D repeat surveys cover from about 100 square kilometres up to a few thousand square kilometres and can take several months to complete. In most cases 4D surveys are less extensive, because they are usually focused over a single producing field or a few neighbouring fields. The frequency of repetition of the seismic survey will depend on data requirements and will usually be every 2 to 6 years.

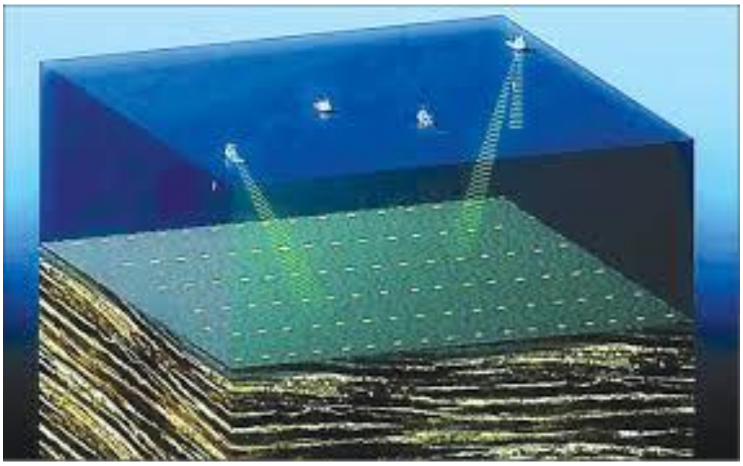


Figure A-3 Schematic illustration of a 3D or 4D survey using ocean bottom nodes /3/

A.3.4 Drilling hazard site surveys and shallow geophysical surveys

Prior to drilling a well a drilling hazard site survey is conducted to identify and map all potential hazards to the installation of the drilling rig and to the drilling operation. The results of the survey are used for planning the safe installation of the drilling rig and to plan the well and drilling operations, such that any hazard is mitigated.

A drilling hazard site survey in the Danish North Sea typically takes around a week within an area of 1x1 km, covering both the proposed drilling location and planned relief well locations, and includes the following:

- 2D high resolution (HR) multi-channel seismic data,
- 2D high resolution single channel sub-bottom profiler data,
- Side scan sonar data,
- Multi-beam and single beam echo-sounder data,
- Shallow seabed soil samples,
- Magnetometer (optional).

Similarly shallow geophysical surveys are conducted to support the design, engineering and construction of pipelines, platforms and other production facilities. The survey equipment and vessel used is the same as for drilling hazard site surveys but excluding the 2D HR multi-channel seismic spread. During as-built surveys of e.g. pipelines, survey sensors are typically deployed by Remotely Operated Vehicle (ROV) and also include video cameras for visual inspection.

The 2D HR multi-channel seismic spread deployed on drilling hazard site surveys are similar to conventional 2D marine seismic surveys spreads, except for the smaller volume of the source and a shorter streamer that is typically 600 m long. The typical signal level form the seismic source is 230 - 240 dB relative to 1 μPa at 1m (peak to peak) and the shot point interval typically 6.25 m (around 3 seconds). The source and streamer are towed at a depth of 2.5-3 meters to enable higher frequency and higher resolution seismic data to be recorded.

2D HR single channel sub-bottom sources can be divided into electrically generated sources (e.g. pinger, boomer and sparker) and pneumatically generated sources (e.g. airgun and water-gun). The receiver for pinger/chirp systems is an integral part of the seismic source (transceiver) whereas the other systems employ a separate single channel streamer. 2D HR single channel seismic is used to investigate the shallow stratigraphy of the shallow part of the seabed to a maximum depth around 100 m depending on the source and the nature of the seabed. Operating frequencies of sparker and boomer systems are in the range 200 Hz – 5 kHz with signal levels around 204-227 dB relative to to 1 µPa at 1m (peak to peak). Pinger and chirp systems operate at frequencies in the range 3-40 kHz with signal levels around 120 – 208 dB relative to 1 µPa at 1m (peak to peak).

Side-scan sonar is used to provide an acoustic "image" of the seabed to identify and map natural and man-made seabed features like boulders, outcrops, pipelines, wellheads and other seabed features. The side scan sonar data may also to some extent be used for classification of seabed sediment types. Operating frequencies of side scan sonar systems vary according to application but are in the range 100-900 kHz, with acoustic signal levels in the order of 220dB relative to 1 µPa at 1m (peak to peak).

The single and multi-beam echo-sounders are used to record bathymetry data for mapping of seabed topography and morphology.

Seabed soil sampling by e.g. gravity corer to a depth of 1-2 metres is carried out to determine the seabed soil conditions and to support the interpretation of the side-scan sonar and the single channel seismic data.

Optionally a magnetometer is used to identify and map ferrous objects on or just below the seabed, e.g. pipelines cables, abandoned wellheads, etc.

A.3.5 Borehole seismic surveys

Borehole seismic or vertical seismic profiling (VSP) is used to provide depth and velocity parameters around a well, which combined with surface seismic data, can help calibrate results and give specific reservoir features around a well hole.

Borehole seismic is conducted with a number of geophones that are lowered into a well hole to record data from a seismic source. The seismic source can be deployed in different ways: either from an airgun source at the platform (rig-sourced) or towed behind a small source boat.

The duration of vertical seismic profiling is normally short – one to two days and the maximum noise level is 244 dB re 1µPa at 1m (peak to peak), but usually smaller (in the order 232 dB re 1 µPa at 1m).

A.4 Alternatives

In exploration for oil and gas there are a number of different geophysical methods to be used for gaining information of the geology of the subsurface, e.g. gravity field measurements and magnetic measurements. But these are not alternatives to the seismic investigations, as these other geophysical methods cannot provide data and information with the same fidelity and level of detail as seismic. Maersk Oil monitors technological development to ensure that seismic data acquisition is applying the best available technique.

A.5 Environmental and social aspects

The following summarises the environmental and social aspects related to seismic surveys that are considered in the project-specific impact assessment.

A.5.1 Planned activities

The main environmental and social aspects related to Maersk Oil's marine seismic data acquisition include:

- Fuel consumption and emissions from survey vessel,
- Acoustic noise generated by the vessels and the seismic equipment,
- Physical disturbance of the seabed by equipment.

A.5.1.1 Fuel consumption and air emissions

Typical fuel consumption for the different types of survey vessels are listed in Table A-1. The consumption varies depending on whether the vessels are during acquisition or transit. It should be noted that fuel consumption will vary greatly dependent among other on the type, size and age of the survey vessels and that the actual fuel consumption may vary from the general numbers in the table.

Table A-1 Daily fuel consumption estimates for survey vessel types.

Description	Type of vehicle	Typical fuel consumption during acquisition Tonnes/day	Typical fuel consumption during transit Tonnes/day
2D, 3D, 4D seismic survey	Seismic source vessel	35	25
Drilling hazard site surveys and shallow geophysical surveys	Shallow geophysical survey vessel	6	12
Borehole seismic survey	Supply vessel	1,7	3,8

Emission factors for estimating the emissions to air from vessels are shown in Table A-2. The values are based on industry experience and are used for calculating the emissions, based on the estimated consumption of fuel.

Table A-2 Emission factors for vessels /7/

Emissions (t / t fuel)	t CO_2	t NO_x	t N_2O	t SO_2	t CH_4	t nmVOC
Vessels	3.17	0.059	0.00022	0.0020	0.00024	0.0024

A.5.1.2 Noise

The seismic source generates acoustic noise levels that can potentially impact plankton, benthic communities, fish, marine mammals and seabirds. The noise generated by the survey vessels propeller and thrusters are additional sources of acoustic noise in relation to the seismic activities.

A.5.2 Accidental events

Accidents with potential environmental and social consequences could occur as a result of a loss of primary containment event related to seismic surveys performed for or by Maersk Oil following:

- Vessel collision with riser or platform
- Vessel collision with other vessels
- Major accidents on the vessels
- Minor accidental spills or releases

A.5.3 Summary

The main environmental and social aspects related to marine seismic data acquisition are listed in Table A-3.

Table A-3 Environmental and social aspects and impact mechanisms from seismic investigations

Operation	Activity	Impact mechanism	Potential receptor
Seismic investigations	2D, 3D/4D, shallow geophysical surveys and borehole seismic	Noise from survey vessel and seismic sources	Plankton, benthic communities, fish, marine mammals, seabirds
		Emissions to air	Climate and air quality
		Restrictions on other vessel traffic	Marine spatial use, fishery and tourism
	3D and 4D seismic using	Physical disturbance of	Sediment quality, benthic

Operation	Activity	Impact mechanism	Potential receptor
	ocean bottom nodes or cables: deployment of seismic bottom equipment (ocean bottom nodes and cables)	seabed	communities, fish, cultural heritage, marine spatial use, fishery
	Shallow geophysical surveys, seabed sampling	Physical disturbance of seabed	Sediment quality, benthic communities, fish, cultural heritage, marine spatial use, fishery
Accidental events	2D, 3D/4D, shallow geophysical surveys and borehole seismic	Oil spill due to vessel collision with risers or platforms	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
		Chemical spill due to vessel collision with supply vessel	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
		Oil spill due to vessel collision with oil tanker	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism

A.6 References

/1/ M., Slatt Roger Developments in Petroleum Science, chapter 4 - Tools and Techniques for Characterizing Oil and Gas Reservoirs, 2013

/2/ OGP, International Association of Geophysical Contractors. "An overview of marine seismic operations", report No.448 April 2011

/3/ http://geoscienceworld.org/

/4/ Gausland, I. "Seismic Surveys Impact on Fish and Fisheries", Norwegian Oil Industry Association (OLF). March 2003

/5/ Caldwell, J.,Dragoset, W. "A brief overview of seismic airgun arrays. August 2000

/6/ http://www.thrustmaster.net/applications/offshore/seismic-vessel/

/7/ E&P Forum, 1994. Methods for Estimating Atmospheric Emissions from E&P Operations. Report No. 2.59/19. September 1994.

B. PIPELINES AND STRUCTURES

The present section "B – Pipelines and Structures" focuses on the types which Maersk Oil uses in the North Sea. The editorial history of the section is summarized below:

	Revision	Changes
B – Pipelines and Structures	0 (2015-01-07)	n. a.
B – Pipelines and Structures	1 (2015-01-29)	Update following Maersk review
B – Pipelines and Structures	2 (2015-04-29)	Update following Maersk review

B.1 Pipelines

B.1.1 Purpose

Steel pipeline are used by Maersk Oil to transport fluid (oil, condensate, pressurized gas, water or chemicals) between platforms and between platforms and onshore.

B.1.2 General description

Pipelines vary in length depending on the distance between connecting points and diameter depending on the expected volume of fluid to be transported.

Pipelines are buried to a depth of ca. 1.5-2.0 m below the seabed surface to secure the pipeline in position and to reduce the risk of damage from fishing gear or anchoring.

To protect pipelines from impact or corrosion, a number of preventive measures are used (e.g. sacrificial anodes) and maintenance operations are carried out (e.g. inspections, cleaning by pigging – see Section B.1.4). In areas, where pipelines are surfacing (e.g. upheaval buckling or pipeline connection), the pipelines are protected by concrete mattresses or rock dumping. The risers at the installations are, where they are not situated between the legs of the platforms, protected by fenders against collision by supply vessels and other vessels at the installations /1/. Finally, to further reduce the risk of damage, a 200 m safety zone is established on each side of the pipelines routes, in which anchoring and trawling are forbidden according to the Danish *Order on protection of marine cables and pipelines* /2/.

All pipelines are equipped with pressure alarms for registration of possible leakages, and with valves for isolation of the pipelines from the platforms.

B.1.3 Installation of new pipelines

New installation of pipelines may be required in case of new fields or platform developments or in case of replacement of existing pipelines. Where it is technically feasible without jeopardizing safety, new pipelines are lined close to the existing pipeline infrastructure.

Installation of pipelines typically includes the following major steps:

- Pre-investigation of the pipeline route: geological and sediment investigations of the proposed pipeline route ensuring that seabed conditions are suitable for installation, and that no obstacles are present. Seismic operations in connection with this phase are covered in the technical section A - Seismic.

- Pipe-lay: pipeline is laid using a specialized pipe-lay vessel (Figure B-1), on which the sections of pipe are welded together on the deck, while the sections of the pipeline are progressively laid on the seabed.

- Trenching, burial and protection of the pipeline: the pipeline is trenched and buried to a depth of ca. 1.5-2.0 m below the seabed surface. Trenching of the pipeline into the seabed is done either by ploughing, water jetting or as mechanical cutting.

- Pre-commissioning: The pipeline is first flooded with treated seawater that contains low concentration of corrosion inhibitor (typically max 500 ppm) to prevent pipeline damage. Thereafter, the pipeline is cleaned and impurities are removed by pigging. After cleaning, the pipeline is pressure-tested using treated seawater. During those operations a total volume of treated seawater, corresponding to about 305% of the pipeline volume, is discharged to the sea.

- Commissioning (including gas filling): the pipeline is emptied and connected to the production facilities.

Figure B-1 Pipe-lay vessel in operation

The total duration of the installation of a pipeline depends on the size of the pipeline and lasts typically up to 3 months.

B.1.4 Maintenance

Regular maintenance work is performed for ensuring the continuous safe operation of the pipeline system.

External visual inspections by remotely operated vehicles (ROVs) are regularly scheduled for pipelines movement (e.g. changes in seabed configuration, upheaval buckling), foreign objects near the pipeline (trawl nets, debris), etc.

Internal corrosion protection of the pipelines takes place either chemically or physically. Corrosion inhibitors are added to the transported products. Hydrate inhibitor is added to pipelines which transport wet gas (see Technical Section C – Production).

Depending upon the inventory being transported by a pipeline and the operating conditions, pigs are sent regularly (weekly to yearly) through each pipeline to control the build-up of harmful deposits which could result in uncontrolled internal corrosion in the pipelines.
"Intelligent Pigs" are deployed in the pipelines at variable intervals determined by an individual pipelines risk status to confirm integrity of the pipelines and to monitor locations within the pipeline that can be affected by corrosion and mechanical defects.

Whenever a pig is introduced into or recovered from a pipeline the access point (pig trap) is first depressurised and drained in a controlled manner. When the trap door is opened a drip tray routed to the closed drain system will catch and residual liquids still remaining in the trap. Traps are fitted with safety devices that prevent them being opened whilst still under internal pressure.

B.1.5 Alternatives

The alternative to using pipelines to transport the produced hydrocarbons to shore would be to use an offshore storage tank (e.g. a GBS (Gravity-Based Structure) or an FSO (Floating Storage and Offloading)) unit where the hydrocarbons are produced, and frequent shipment to shore in tankers. Maersk Oil uses pipelines as the most cost efficient and safest method for transporting hydrocarbons, both offshore and onshore. FSO systems may be used as back-up systems.

B.2 Structures

B.2.1 Purpose

Offshore structures provide the necessary facilities and equipment for production of oil and gas in the marine environment. If exploration drilling proves successful and shows that production is economically feasible, a fixed production facility will be placed at the site.

B.2.2 General description

The facility may consist of one or several platforms, or one integrated production platform. In Denmark, due to the location and water depth of the producing fields, the production facilities are placed directly on the seabed. The facilities are primarily powered by gas turbines, whereas diesel generators are used for cranes etc. Diesel is also used as a back-up system for the main gas turbine system (see also Technical Section C - Production).

In Figure B-2 the elements and functions of the various parts of a producing offshore installation is shown.

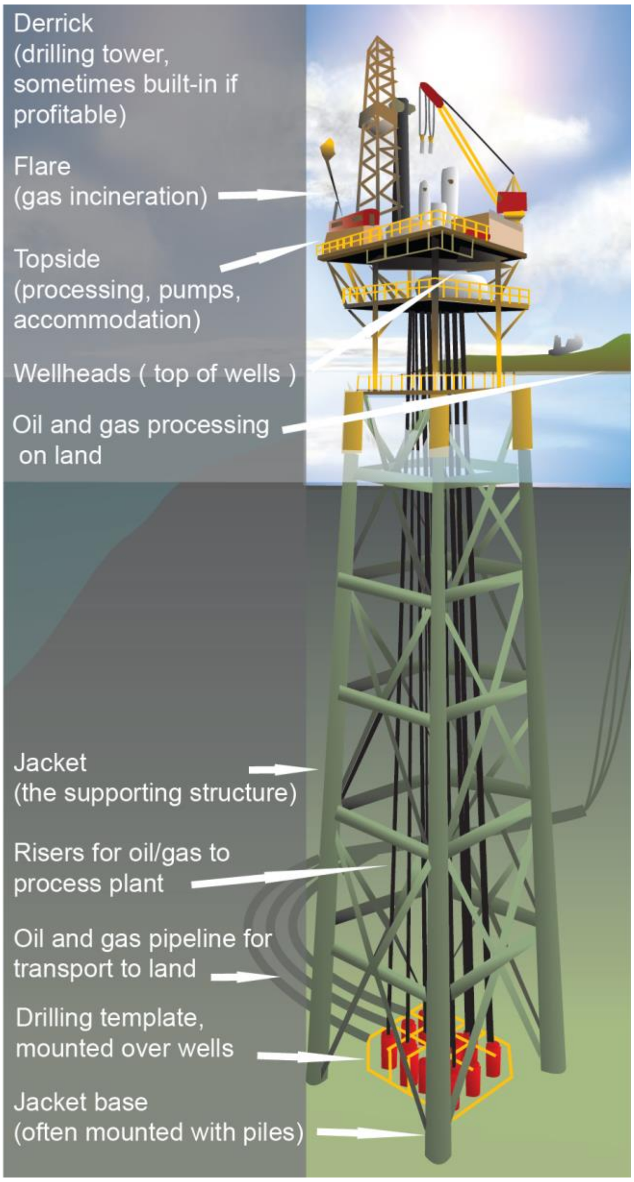


Figure B-2 **Principle sketch of an offshore producing installation (from /4/; reproduced with kind permission from offshoreenergy.dk)**

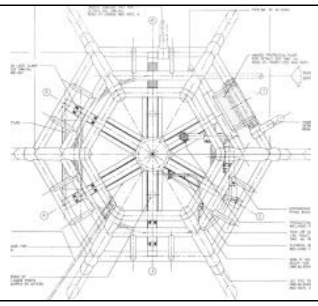
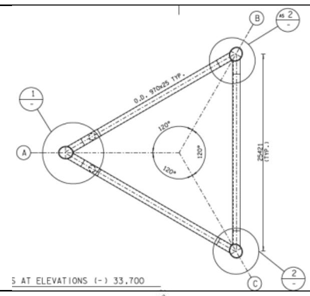
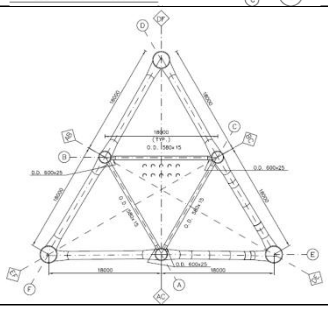
To reduce the risk of collision between vessels and installations, a 500 m safety zone is established around fixed installations where anchoring and trawling are forbidden according to *Order on safety zones and zones for observing order and prevention danger* /3/.

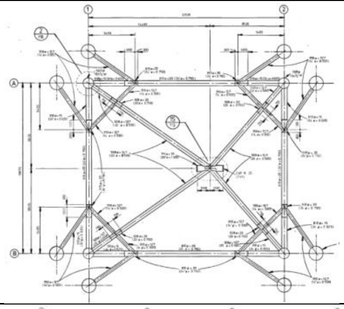
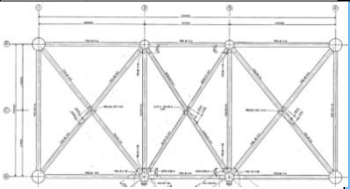
In the Danish North Sea, two types of platforms are used; manned main processing/production platforms and satellite platforms. Most of the satellite platforms are unmanned and are remotely operated from the manned platforms. The unmanned platforms are regularly visited for maintenance and possible repair works.

B.2.3 Alternatives

Table B-1 provides an overview of the various types of structures that can be considered in the relatively shallow water of the Danish part of the North Sea (typically 35-70 meters). The space, capacity, and operability requirements (e.g. number of wells, weight of the topside) of the project will determine the size and configuration of the type of installations.

Table B-1 **Overview of typical installations in the North Sea, with advantages (Pros) and disadvantages (Cons) of each type of structure outlined**

Concept	Top view	Typical use						Pros	Cons
		Processing	Flare	Accommodation	Wellhead	Bridge module	Riser		
Sub-sea completion								Inexpensive fabrication	Few wells (1-4) High operational costs
Mono Tower, Suction bucket foundation	Presently not part of the assets. Technical feasibility studies are ongoing to evaluate the concept for future use in DUC area							Light weight substructure. "Quiet" installation without pile driving	Limited number of well slots (4-7) and topsides weight. Limited number of piles; hence not suit-able for all soil conditions
Mono Tower, Driven pile	Presently not part of the assets. Technical feasibility studies are ongoing to evaluate the concept for future use in DUC area							Light weight substructure. Inexpensive fabrication	Limited number of well slots (4-7) and topsides weight. Limited number of piles; hence not suit-able for all soil conditions
STAR platform (Slim Tripod Adapted for Rigs)								Light weight substructure	Limited number of well slots (6-10) and topsides weight. Limited number of piles; hence not suit-able for all soil conditions
3-legged steel platform								Light weight substructure	Limited number of well slots (10-15) and topsides weight. Limited number of piles; hence not suit-able for all soil con-ditions

4-legged steel platform								Larger number of wells and heavy topsides. Ample space for risers and J-tubes.	Heavy
8-legged steel platform								Larger number of wells and heavy topsides. Ample space for risers and J-tubes.	Heavy. May require alternative installation e.g. launching which is more expensive

Maersk Oil's DBU largest processing and production facilities consist of several 3 to 8 legged platforms connected with bridges. STAR (Slim Tripod Adapted for Rigs) are also often used for unmanned satellite platform. The layouts of a STAR platform and a 4-legged jacket platform are shown in Figure B-3.

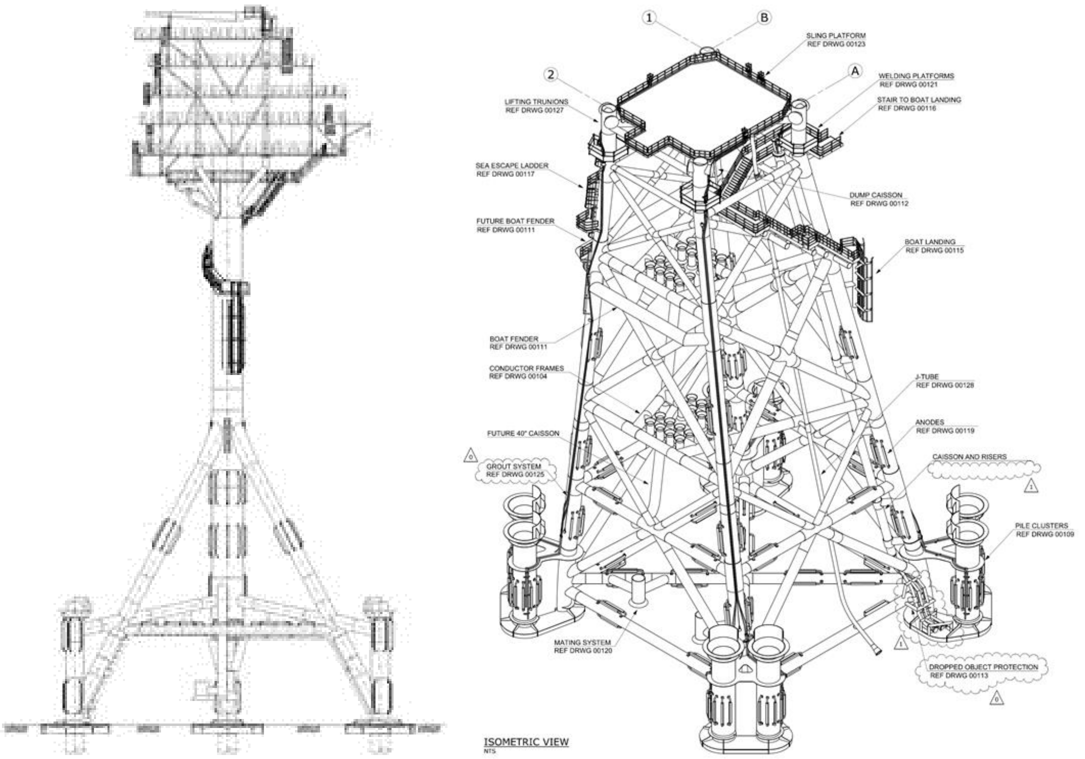


Figure B-3 Sketch of a typical STAR platform (left) and 4-legged (right) jacket

B.2.4 Installation of new structures

Adding new installations might be required as part of the future field developments.

With the exception of sub-sea completion, the installation of a platform is divided into 2 to 3 steps: installation of the jacket on the seabed, installation of the topside and installation of a bridge if required. The platform parts are typically transported on a barge from onshore (see Figure B-4). The jacket is first placed on the seafloor and secured to the seabed by several piles driven some 40-65 m into the seabed; then the topside is placed. In Table B-2 the footprints of each type of installation is shown. In addition, the number of pile sleeves, the typical driven pile length and the duration of the pile driving is shown, for each type of installation.

Figure B-4 Tyra SE-B facilities (jackets, top side and bridge) – tugged to location in 2014

Table B-2 Leg spacing (footprint) and piling requirements for each installation type

Concept	Number of pile sleeves	Footprint at seabed	Typical driven pile length	Duration per pile (maximum)
Sub-sea completion	None	8mx8m	N/A	N/A
Mono Tower, Bucket foundation	None	18m diameter	15m (no driving)	N/A
Mono Tower, pile driven	(1)	6m diameter	20m	4h
STAR platform	3	25mx30m	45m-55m	1h
3-legged steel platform	3	30mx36m	45m-55m	1h
4-legged steel platform	4-12	25mx25m	50m-65m	1h
8-legged steel platform	16-20	30mx55m	40m-50m	1h

In Table B-3 the service duration of vessels used for installation of each of the typical installations outlined in Table B-1 is shown.

Table B-3 Estimated duration of work vessel use for establishing new installations. d = days

Concept	Crane vessel	Tug boat (1 large + 2 small)
Sub-sea completion 1)	4 d (mobilization) 4 d (installation sub)	6 d (transport) 4 d (installation)
Mono Tower, Bucket foundation	6 d (mobilization) 2 d (installation jacket) 3 d (installation top)	6 d (mobilization) 7 d (installation sub) 3 d (installation top)
Mono Tower, pile driven	6 d (mobilization) 3 d (installation jacket) 3 d (installation top)	6 d (mobilization) 7 d (installation sub) 3 d (installation top)
STAR platform	6 d (mobilization) 7 d (installation jacket) 3 d (installation top)	6 d (mobilization) 7 d (installation sub) 3 d (installation top)
3-legged steel platform	6 d (mobilization) 7 d (installation jacket) 3 d (installation top)	6 d (transport) 7 d (installation sub) 3 d (installation top)
4-legged steel platform	6 d (mobilization) 8 d (installation jacket) 3 d (installation top)	6 d (transport) 10 d (installation sub) 3 d (installation top)
8-legged steel platform	6 d (mobilization) 10 d (installation jacket) 4 d (installation top)	6 d (transport) 10 d (installation sub) 4 d (installation top)
1) Diving support vessel applied to Sub-sea completion, duration 6 d		

B.2.5 Maintenance

Integrity of structures is ensured through surveys where issues such as marine fouling, scour, and check of cathodic protection effectiveness are carried out. In addition, monitoring of corrosion, integrity of the structures and visual surveys for damage is carried out.

B.3 Environmental and social aspects

Here, we summarize the environmental and social aspects related to pipelines and structures and select those to be further considered in the project-specific impact assessment.

B.3.1 Planned activities

The main environmental and social aspects related to Maersk Oil's presence and construction of pipelines and structures include:

- Presence of the structures,
- Work vessel traffic,
- Emissions to air,
- Underwater noise
- Discharges to sea (planned and accidental),
- Change of the seabed morphology and sediment dispersion,
- Use of resources and production of waste,
- Socio-economic contribution to the society.

B.3.1.1 Fuel consumption and air emissions

Fuel consumption and emissions related to pipeline installation are directly related to duration of the installation operations; thus dependent on the length of the pipeline. Guard vessels are used during the entire duration of the operations (approximately 3 months) and diving support vessel is expected for various underwater inspection and tie in work for approximately 1 month, regardless of the size of the pipeline.

In Table B-4 the typical work speed for vessels along with the fuel consumption is outlined. For Guard Vessels and Diving Support Vessels (DSV's), the fuel consumption is not directly related to the pipe lay speed; the fuel consumption is therefore shown for a typical duration for establishing one pipeline.

Table B-4 Fuel consumption of vessels used for construction of new pipelines

Vessel type	Work velocity	Daily consumption [t]	Consumption/pipeline [t/km]
Pipelay vessel	2 km/day	34.2	17.1
Survey vessel	2 km/day	4.3	2.1
Trenching vessel	5 km/day	17.1	3.4
OOS vessel	5 km/day	4.3	0.9
Guard vessel	App 3 month service	0.4	38.4 t/pipeline
Diving support vessel (DSV)	App 1 month service	10.2	307 t/pipeline

In Table B-3 the duration of service of the vessels used for installation of each of the typical installations outlined in Table B-1 is shown. The corresponding fuel consumption of these vessels, and of an accommodation rig, is outlined in Table B-5.

Table B-5 Duration and fuel consumption for structures installation

Installation type	Vessel type	Days	Daily consumption [t]	Total consumption [t]
Subsea completion	Crane vessel	8	50.0	400
	Large tug boat	10	12.8	128
	Small tug boat	10	2,14	21.4
	Diving support vessel (DSV)	6	10.3	61.5
	Total vessels	-	-	**611**
Mono Tower, Suction bucket foundation	Crane vessel	11	50.0	550
	Large tug boat	16	12.8	205
	Small tug boat	16	2,14	34.2
	Total vessels	-	-	**789**
Mono Tower, Pile driven	Crane vessel	12	50.0	600
	Large tug boat	16	12.8	205
	Small tug boat	16	2,14	34.2
	Total vessels	-	-	**839**
STAR platform, 3-legged platform	Crane vessel	16	50.0	800
	Large tug boat	16	12.8	205
	Small tug boat	16	2,14	34.2
	Total vessels	-	-	**1039**
4-legged platform	Crane vessel	17	50.0	850
	Large tug boat	17	12.8	218
	Small tug boat	17	2,14	36.3
	Total vessels	-	--	**1104**
8-legged platform	Crane vessel	20	50.0	1000
	Large tug boat	20	12.8	256.2
	Small tug boat	20	2,14	42.7
	Total vessels	-	-	**1299**

Installation type	Vessel type	Days	Daily consumption [t]	Total consumption [t]
Accommodation rig	Accommodation rig	1	4.6	4.6
	Rig move Large tug boat	8	12.8	102
	Rig move Small tug boat 1	8	2.1	17.1
	Rig move Small tug boat 2	8	2.1	17.1
	Total, rig move boats	-	-	**137**

Emission factors for estimating the emissions to air from vessels are listed in Section A – Seismic.

B.3.1.2 Noise

Noise is generated during pipelay and seabed intervention work and by the general operation of vessels.

B.3.2 Accidental events

Accidents with potential environmental and social consequences could occur as a result of a loss of primary containment event related to the installation, maintenance and presence of pipelines and structures following:

- Pipeline rupture (corrosion or erosion) and collision
- Vessel collision with riser or platform
- Vessel collision with other vessels
- Minor accidental spills or releases

B.3.3 Summary

The main environmental aspects related to the installation and operation of pipelines are listed in Table B-6. The main environmental aspects related to the installation and operation of structures are listed in Table B-7.

Decommissioning of the pipelines is covered in the technical section G - Decommissioning.

Table B-6 Environmental and social aspects and impact mechanisms from pipelines

Phase	Activity	Impact mechanism	Potential receptor
Pipeline installation	Pipe lay and seabed interventions work	Burial of seabed surface	Sediment quality, benthic communities, fish, cultural heritage, marine spatial use, fishery
		Turbidity/sedimentation increase	Water quality, plankton, fish, marine mammals, seabirds
		Seabed morphology change	Sediment quality, benthic communities, fish, cultural heritage, marine spatial use, fishery
		Noise	Plankton, benthic communities, fish, marine mammals, seabirds
		Restrictions on vessel traffic and fishery	Marine spatial use, fishery and tourism
	Pre-commissioning	Discharge of treated seawater	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds,

Phase	Activity	Impact mechanism	Potential receptor
			protected areas
	Vessel operation	Emissions to air	Climate & air quality
		Discharges to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, protected areas
		Waste production	Contribution to waste pool
		Resource use	Use of non-replenishing resources
	Installation works generally	Impact on tax revenue and workforce	Employment and tax revenue
Pipeline operation	Exposed pipeline surface, stones and similar	Physical impact on seabed - hard substrate	Sediment quality, benthic communities, fish, cultural heritage, marine spatial use, fishery
Accidental events	Pipeline leaking due to e.g. corrosion, collision with anchor	Oil leak	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
		Release of gas	Climate & air quality, marine spatial use and fishery
	Spill during pigging	Release of oil/ chemicals	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
	Vessel collision	Release of oil/ chemicals	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism

Table B-7 Environmental and social aspects and impact mechanisms from structures

Phase	Activity	Impact mechanism	Potential receptor
Structure installation	Platform installation	Burial of seabed surface	Sediment quality, benthic communities, fish, cultural heritage, marine spatial use, fishery
	Pile driving	Noise	Plankton, benthic communities, fish, marine mammals, seabirds
	Vessel operation	Emissions to air	Climate & air quality
		Discharges to sea	Water quality, sediment quality, plankton, benthic

Phase	Activity	Impact mechanism	Potential receptor
			communities, fish, marine mammals, seabirds, protected areas
		Waste production	Contribution to waste pool
		Resource use	Use of non-replenishing resources
	Installation works generally	Impact on tax revenue and workforce	Employment and tax revenue
Structure operation	Presence of structure	Light	Plankton, fish, marine mammals, seabirds
		Restrictions on vessel traffic and fishery	Marine spatial use, fishery and tourism
		Impact on employment and socio-economy	Danish society and workforce
	Installations resting at seabed	Seabed scouring - local erosion around platform legs	Sediment quality, benthic communities, fish, cultural heritage, marine spatial use, fishery
		Footprint - occupation of seabed surface	Sediment quality, benthic communities, fish, cultural heritage, marine spatial use, fishery
	Presence of platform legs in water	Physical impact and hard substrate (platform legs)	Plankton, fish
Accidental events	Collision between vessel and structure	Oil or chemicals spill from vessel	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism

B.4 References

/1/ Maersk Oil, 2011. Vurdering af virkninger på miljøet fra yderligere olie og gas aktiviteter i Nordsøen. Juli 2011.

/2/ Danish Ministry of Energy, 1992. Order no. 939 of 27 November 1992. Order on protection of marine cables and pipelines.

/3/ Danish Ministry of Energy, 1985. Order no. 657 of 30 December 1985. Order on safety zones and zones for observing order and preventing danger.

/4/ Offshoreenergy.dk, 2014. Offshore Book Oil & Gas, 3rd edition, May 2014.

/5/ E&P Forum, 1994. Methods for Estimating Atmospheric Emissions from E&P Operations. Report No. 2.59/19. September 1994.

C. PRODUCTION

The present section “C - Production” focuses on methods related to production that Maersk Oil operates in the North Sea. The editorial history of the section is summarized below:

	Revision	Changes
C – Production	0 (2015-01-07)	n. a.
C – Production	1 (2015-01-29)	Update following Maersk review
C – Production	2 (2015-04-29)	Update following Maersk review
C - Production	3 (2015-06-30)	Update following Maersk review, chemicals use

C.1 Purpose

Processing is required to separate the fluid extracted from the reservoir (a mixture of oil, gas, water, and solid particles), and before Maersk Oil can export the oil and gas onshore and discharge or re-inject the treated water. Initially, the mixture coming from the reservoir may be mostly hydrocarbons but over time, the proportion of water (water cut) increases and the fluid processing becomes more challenging. The fluid may be processed through different Maersk Oil facilities before export.

C.2 Overview of oil, gas and water production

Separation of oil, gas and water usually takes place in several stages by use of centrifugal forces or gravity. Different operating units are required to assist the process but the general process is as follow.

The produced fluid flows through into two 3-phase separators – a high pressure (HP) separator and a low pressure (LP) separator operated in series. There, the fluid is separated by gravity in three fractions: oil, gas and water . The principles of a three-phase separator are shown in Figure C-1 /1/. Hydrocyclones may be used to further separate water and oil by centrifugation. At the end of the separation process, the stabilised crude oil is exported onshore or to other facilities for further treatments whereas the gas is collected and treated.

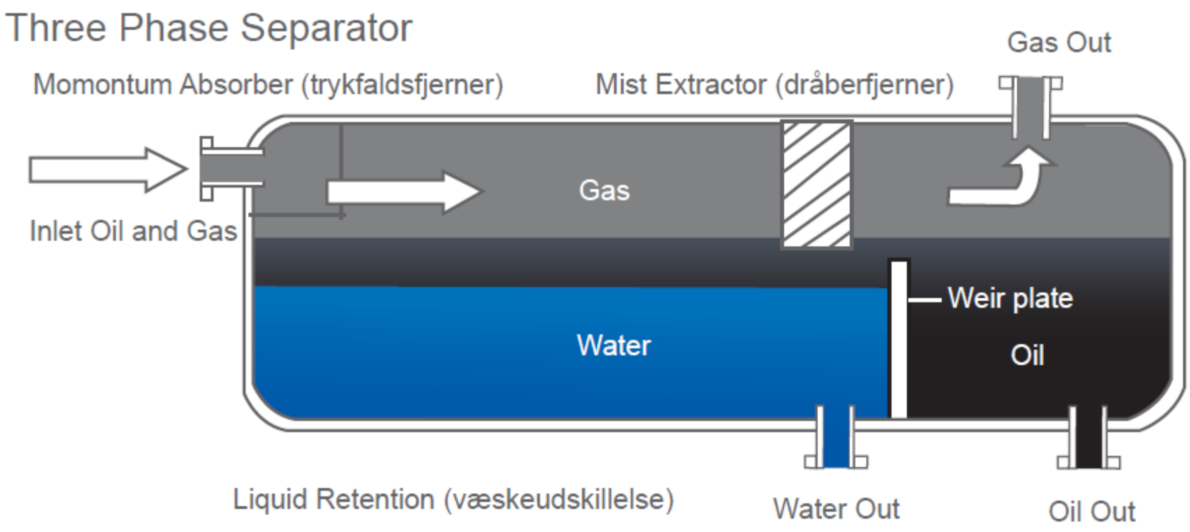


Figure C-1 Sketch of a 3-phase separator (from /1/; reproduced with kind permission from offshoreenergy.dk)

Gas from the separator is treated for impurities (e.g. H_2S) compressed and dried before it is used as lift gas in a production well, as fuel gas for the gas turbines or exported to other facilities or onshore. A very small portion of the gas is flared. Flaring is necessary for safety reasons in case of no or insufficient gas compression capacity or in case of emergency caused shutdowns, process upsets etc.

After treatment, the produced water can be either discharged to sea or directly re-injected into the reservoir, where the physical properties of the field and the volume of produced water allow it. The produced water is monitored for its oil in water content.

The energy required to power Maersk Oil process and accommodation facilities is often a mixture of self-produced natural gas or diesel supplied by ship. Natural gas is used as fuel gas in gas turbines operating as drives for power generators and direct drives for main gas compressors and high-pressure water injection pumps. Diesel is used in dual-fuel gas turbines, for cranes and for emergency equipment such as fire pumps etc. Electricity generated by onsite turbines is used for lighting, accommodation and driving of all other process equipment than the major direct driven equipment.

C.3 Alternatives

Reservoir fluid must be separated and stabilized for a safe transport. There are no alternative to the overall process operations described above. Maersk Oil is continuously optimizing the use and discharge of chemicals, by continuously re-evaluating the design, process and maintenance of its facilities and when selecting materials and substances to use offshore. Maersk Oil frequently reviews the feasibility of produced water reinjection.

C.4 Environmental and social aspects

Here, we summarize the environmental and social aspects related to production and select those to be further considered in the project-specific impact assessment.

C.4.1 Planned activities

The main environmental and social aspects related to Maersk Oil's production of oil and gas includes:

- Emissions to air
- Noise
- Discharges to sea (planned and accidental)
- Waste production,
- Socio-economic contribution to the society.

Emissions are primarily caused by flaring and the combustion of gas and diesel in turbines/engines on production platforms. A facilities specific estimate of flaring and energy requirement is provided in the impact assessment.

C.4.1.1 Fuel consumption and air emissions

Emissions of CO_2 are primarily caused by flaring of gas and the combustion of gas and diesel in turbines/engines on stationary production platforms. NO_X and SO_X emissions are typically caused by the use of fossil fuels for energy production and gas flaring.

A facilities specific estimate of flaring and energy requirements is provided in the impact assessment.

C.4.1.2 Production chemicals

Maersk Oil uses production chemicals to optimise the processes of fluid production, separation and transport. Use of chemicals is not only necessary for the technical performance, but also for integrity of the equipment and general safety of the operation (i.e. by reducing corrosion). Chemicals are required for an efficient separation of oil and water, reducing the concentration of oil in the produced water being discharged to the sea.

Fraction of the added chemicals will either become part of the oil fraction and sent to shore or in the water fraction and discharge to sea or re-injected into the reservoir. Chemical use and discharge to sea is only permitted after authorisation from the Danish Environment Protection

Agency (Miljøstyrelsen). The amounts and types of chemicals are continuously controlled and optimised.

The inventory of Maersk Oil main chemicals, their general use and partitioning in water/oil phase are presented in Table C-1. Also presented in the table is their colour coding according to OSPAR 2010 /2/:

Black: These are prohibited except in special circumstances and have not been used by Maersk Oil since 2005.

Red: These are environmentally hazardous and contain one or more components that, for example, accumulate in living organisms or degrade slowly. OSPAR recommendations dictate that the discharge of these chemicals must end by 1 January 2017. Since 2008, Maersk Oil has been phasing out red chemicals, using them only if safety, technological and environmental arguments demand. Discharges have decreased sharply since 2010.

Green: These contain environmentally acceptable components recorded on OSPAR's PLONOR list that 'Pose Little or No Risk' to the environment.

Yellow: These are chemicals not covered by the other classifications and can normally be discharged.

Maersk Oil is continuously pursuing best practicable options for substitution of chemicals to more environmentally friendly solutions.

Maersk Oil has been phasing out the use of red chemicals since 2008. Discharge of red chemicals is not expected, but may occur in limited quantity in case safety, technological and environmental considerations cannot be met by alternative products, subject to pre-approval by DEPA.

Table C-1 **Use and purpose of the various production chemicals, shown together with the fate of the chemicals (approximate proportion in the oil and water stream, respectively, indicated with number of +)**

Product type	Use / Purpose	Colour coding	Solubility	
			Oil	Water
Acid Green	Multiple uses offshore. Used for dissolving deposits of inorganic scale (typically carbonate- or sulfide- based scales) in for instance well, pipeline, valve, filter, hydrocyclone, etc. cleaning operations. Also used for pH adjustment and for well stimulation.		0	++++
Antifoam	Foam treatment chemicals. Surfactant chemistry. The anti-foam is very often insoluble in the foaming liquid. Reduces or removes foam caused by for instance pressure release or agitation of a liquid. Typically based on insoluble oils, silicones (for instance, Poly Dimethyl Siloxanes (PDMS) and fluorosilicones), certain alcohols, stearates or glycols.		+++	+
Antifreeze (Glycol)	Typically used offshore is Mono Ethylene Glycol (MEG, EthyleneGlycol). Very often used for to reduce freezing point of water based chemicals and liquids. In many systems also used as hydrate inhibitor.Mono Ethylene Glycol (MEG) is typically used as antifreeze compound in closed cooling/heating systems. In some cases also Tri Ethylene Glycol (TEG) is used. Reduces the freezing point, and also increases the boiling point, of the cooling/heating liquid. The Antifreeze expands the operation range of the heating/cooling liquid.		0	++++
Biocides	Multiple uses. Reduces growth of microorganisms in pipelines, process systems, tanks, drain systems, closed systems, sea water, water injection systems etc. Offshore chemistries typically based on hypochlorite (sea water treatment), aldehydes (or aldehyde releasing agents) or THPS (Tetrakis (Hydroxymethyl) Phosphonium Sulfate) is used. Use offshore is mostly related to corrosion prevention or H_2S related issues such as reservoir souring.		+	+++

Product type	Use / Purpose	Colour coding	Solubility	
			Oil	Water
Corrosion control chemicals	Multiple uses. Used for inhibiting corrosion in pipelines, process systems, closed systems, water injection systems etc.		+	+++
Demulsi-fier	Offshore demulsifiers are used to increase the speed of separation of emulsions formed by oil and water. A frequently used synonym for demulsfier is emulsion breaker. A demulsifier is often formulated for a specific emulsion. A demulsifier may contain between two and five different active compounds dissolved in solvents. The different compounds affect the surface tensions of oil/water droplets and contaminants present in the emulsion. Normally the term demulsifier is offshore used for the oil soluble product injected up stream of oil/water separators, for to achieve low BS&W (low water content) in the exported oil phase.		+++	+
Drag reducer	Drag Reducers, or flow improvers, are used to increase the throughput of a liquid in a pipeline where the pipeline capacity or the available pressure drop (dP) is limited. The efficiency of the drag reducer is dependent on the degree of turbulence in the pipeline, the higher Reynolds number the higher efficiency.		++++	0
Glycol, TEG	Tri Ethylene Glycol (TEG) is typically used offshore in gas dehydration systems and in some cases also as antifreeze agent.		++	++
H_2S scavenger	H_2S Scavengers used offshore are typically used for H_2S removal in the gas. Typically based on high pH triazine chemistry. Should in general be injected in wet gas at high temperatures to be most efficient.		+	+++
Methanol	Methanol is offshore mostly used as hydrate prevention.		0	++++
Oxygen scavenger	Typically bisulfate based chemistries are used in sea water injection systems to remove the oxygen in the water. Offshore normally injected in the return water in the bottom of the deoxygenating tower.		0	++++
Scale inhibitor	Scale Inhibitors are used for preventing scale deposits in pipelines, valves and process systems. Scale will typically be an issue when there is a change of equilibrium of the salts in the water phase. Offshore when produced water is depressurized this will typically lead to carbonate scaling. Sulphate scaling is a typical problem when waters with different salt contents are mixed, e.g. when sulfate-containing seawater is mixed with barium-containing produced water.		+	+++
Solvent	Solvents are used to dilute active materials into manageable solutions, and are commonly added to commercial chemical formulations. Although water is in itself a solvent, the term is mostly used for oil solute products.		++++	0
Surfactant	Surfactants are compounds that reduce the surface tension between two liquids or between a liquid and a particle. The surfactant molecule will have one end that is hydrophobic and another end that is hydrophilic.		++	++
Water clarifier	Long chained and anionic charged polymers based on poly acrylates are commonly used water clarifiers in the North Sea region. Synonyms used offshore for Water Clarifiers are typically: flocculant, reversed emulsion breaker, reversed demulsifier, deoiler, water treatment chemicals, polymers, etc. Water Clarifiers collects smaller oil droplets into larger flocks and thereby enhance the speed of separation of oil and water. Water Clarifiers are water soluble chemistries and these products are normally injected in the produced water outlet of separators.		0	++++
Water Injection Chemical	Several products are used to treat water before it can be injected into the reservoir. Typically used are hypochlorite (biocide), biocides, oxygen scavengers, defoamers, coagulants (se Water Clarifiers), scale inhibitors and nitrates.		0	++++

Product type	Use / Purpose	Colour coding	Solubility	
			Oil	Water
Wax dissolver	Wax dissolvers are solvents with solubility properties towards paraffinic hydrocarbons. Efficiency of different solvents that are available depends on temperature. In low temperature pipelines only heavy aromatic solvents will be able to dissolve wax. There are restrictions on the use of such heavy aromatic solvents (both occupational and environmental reasons) and frequent pigging of pipelines are essential for to keep pipelines clean of wax deposition.		++++	0
Wax inhibitor	Wax inhibitors are polymers with gelling properties linked to paraffinic content of the crude oil. They work by reducing the pour point of the crude oil. A frequent synonym for Wax Inhibitors is Pour Point Depressing Agent (Depressant, PPD). Offshore wax inhibitors are mostly based on Acrylates or Ethylene Vinyl Acetates that are formulated in a solvent package. Some wax inhibitors also contain wax dispersing chemistry (Surfactant chemistry).		++++	0

C.4.2 Accidental events

Accidents with potential environmental and social consequences could occur as a result of a loss of primary containment event related to production activities following /3/, /4/:

- Process system failures
- Vessel collision with riser or platform
- Vessel collision with other vessels
- Failure of crane resulting in a dropped load
- Well blowout
- Minor accidental spills or releases

C.4.3 Summary

The main environmental aspects related to production of oil and gas is listed in Table C-2.

Table C-2 Environmental and social aspects and impact mechanisms from production

Phase	Activity	Impact mechanism	Potential receptor
Normal Production	Power generation	Use of resources (gas, diesel)	Use of non-replenishing resources
		Emissions to air	Climate and air quality
		Generation of noise, light	Plankton, benthic communities, fish, marine mammals, seabirds
	Safety flaring	Use of resources	Use of non-replenishing resources
		Emissions to air	Climate and air quality
	Venting from cold vents	Release of unburned hydrocarbons	Climate and air quality
	Produced water discharge	Oil and chemicals in produced water to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, protected areas
	Cooling water discharge	Local seawater temperature change, biocide	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, protected areas

Phase	Activity	Impact mechanism	Potential receptor
	Sewage discharge	Organic substances to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, protected areas
	De-scaling operations at hazardous caisson	Discharge of scale or chemicals to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, protected areas
	Cleaning of separators, hydro-cyclones etc.	Production of waste, possible including NORM for deposit onshore	Employment, onshore facilities
	Waste production	Production of waste for re-use, incineration and deposit onshore	Employment, onshore facilities
	Tax revenue		Tax revenue
	Employment offshore and onshore		Employment
Accidental events	Spill of oil or chemicals due to process system failure	Oil or chemicals to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
	Discharge of drain water, bilge water, thread lubricant and annular fluid	Cleaning agents and similar to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
	Collision between vessel and structures	Oil or chemicals spill from vessel	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
	Fugitive emissions from seals, welds, valves, flanges etc.	Emissions to air	Climate & air quality, marine spatial use and fishery

C.5 References

/1/ OSPAR (the Oslo and Paris Commissions), 1992. Convention for the protection of the marine environment of the North-East Atlantic.

/2/ OSPAR, 2010. OSPAR Recommendations 2010/4 on a Harmonized Pre-Screening Scheme for Offshore Chemicals.

/3/ Oil Spill Response Limited, 2015. Oil Spill Risk Assessment, Xana-1X. Maersk Oil Document CONS0848 Rev00

/4/ Oil Spill Response Limited, 2014. Oil Spill Risk Assessment, Siah NE-1X. Maersk Oil Document CONS0874 Rev02

D. DRILLING

The present section “D - Drilling” focuses on drilling methods that Maersk Oil uses in the North Sea. The editorial history of the section is summarized below:

	Revision	Changes
D – Drilling	0 (2015-01-07)	n. a.
D – Drilling	1 (2015-01-29)	Update following Maersk review
D – Drilling	2 (2015-04-29)	Update following Maersk review
D - Drilling	3 (2015-06-30)	Update following Maersk review, accident statistics, re-drill

D.1 Purpose

Drilling of wells is necessary for extracting oil and gas resources. Wells are used for transporting the fluid (a mixture of oil, gas, water, solids and non-hydrocarbon gasses) from the geological reservoir to Maersk Oil’s producing installations, where fluid processing takes place (see Technical Section C – Production). Wells are also used for injection of water (seawater or produced water) or gas to increase reservoir pressure and enhance the oil and gas recovery rates.

D.2 Well construction

The well life cycle is separated in several operational phases: drilling, completion, stimulation and abandonment. Furthermore, an ageing well may require maintenance during its operating life.

Offshore drilling takes place from fixed installations, or mobile jack-up drilling rigs, semi-submersible rigs and drill ships. In the relatively shallow-water Danish sector of the North Sea, Maersk Oil drilling operations are usually carried out from jack-up drill rigs (Figure D-1). These rigs are towed to the drilling position and subsequently elevated (jacked-up) above the sea by 3 or 4 supporting legs. At the basis of the legs, spud cans rest on the seafloor for stability of the rig. Spud cans cover a total area of several hundred m^2 and may sink to a depth of 1-3 meters into the seabed.

Figure D-1 Typical jack-up drilling rig (Maersk Endeavour), here situated at the Kraka STAR platform

Drilling of a well starts with hammering (driving) a conductor into the seabed. Conductors serve as a guide for the drill string. Maersk Oil typically uses 26’’ (66 cm) or 24" (61 cm) conductors, and driving of a single conductor takes approximately 6-8 hours. When carrying out a drilling campaign, the conductors can either all be installed in the beginning of the campaign (batch setting) or individually installed as the first thing when drilling each well. Conductors can only be driven in the sediment one after each other. Drilling the conductor down, as it is sometimes done for exploration wells, has a risk of destabilizing the platforms and is therefore not used when drilling at an existing platform. Furthermore, the distance from the planned drilling track to existing wells is evaluated when drilling close to existing facilities and existing wells. Depending on the outcome of the evaluation, production from existing wells might be temporarily closed while drilling the new well.

Drilling takes place by means of a drill bit mounted at the bottom of a drill string suspended in the derrick (Figure D-2). As Maersk Oil wells can be several kilometres long, wells are drilled in several sections. For each section, the drill string which consists of drill pipes that are screwed together provides the torque for the drill bit to work its way through the geological formations.

Maersk Oil often uses horizontal wells to increase the reservoir coverage. The well is gradually inclined while it is being drilled so that it becomes horizontal in the reservoir and follows the oil-bearing layers. This drilling technique is especially used in thin chalk reservoirs. The horizontal part of the well can have a length of more than 5,000 m. The effective length of a well can further be increased by drilling of side tracks, in case operational problems or the subsurface geology requires so.

During the drilling, drilling mud, (a mixture of water or oil with various chemicals is pumped down the drill string, through and around the drill bit. The drilling mud has several critical functions in drilling operations. The drilling mud flushes crushed drilled material (cuttings) up through the well on the outside of the drill pipe and back to the rig. Additionally the drilling mud has several other uses including valuable safety functions such as preventing blow outs as well as cooling and lubricating drill bits. Chemicals are added to the mud to provide the required properties (weight, viscosity, rheology, lubrication, pH control, anticorrosion) to continue safe operations. For example, barite (mostly $BaSO_4$) can be used as a weighting agent to control pressure in the borehole and prevent blowouts.

In general, water-based drilling mud is the preferred option, due to its lower cost and more environmental-friendly properties. However, oil-based mud (OBM) is required for some demanding drilling operations (e.g. drilling of highly deviated sections or High Pressure High Temperature conditions). This is also the case when drilling through water-sensitive sections of clays or shales, because interactions of the formation with water will cause the drill pipe to stick to the walls of the hole to slough in. Often, both water-based and oil-based drilling muds are used in the same wells for different sections /1/. The mud that is recirculated to the surface is cleaned from cuttings and reused. Eventually the mud cannot be reused and is discharged along with cuttings (water based mud section) or collected and brought to shore (oil based mud section) along with cuttings.

As drilling proceeds, the drill string is extended with new pipe until the end of the section. After the borehole is drilled, the drill string is removed and steel pipes are lowered in the borehole to form the casing of the well and secured in position by cement. For water-based sections, the material used for cementing (mostly cement and chemicals) is discharged to the sea. The casing and cement are essential to ensure the structural integrity of the well. Then, the procedure is repeated with a progressively smaller-sized drill bit. Maersk Oil typical well is designed with a top-hole casing of section drilled with a drill bit of typically 16’’-22’’ (41-56 cm) whereas the liner located in the reservoir typically have a final diameter of 7" (18 cm) within an 8.5’’ (22 cm) borehole (see also D.8.1.5).

When drilling has reached the target location in the reservoir, the well is "completed". The production casing is perforated at several places to provide free path for the fluid exchange between the reservoir and the well (Figure D-3). Subsequently an inner string is installed to cover the perforations with sleeves which can either give access to the perforation or cut it off. The connectivity between the well and the hydrocarbon reservoir is in the end improved by stimulation. A full description of stimulation is provided in the technical section *E – Well stimulation*.

Maersk Oil sometimes uses a CAJ liner stimulation and completion technique instead of perforating each interval and installing the inner string. CAJ liner is a non-cemented pre-drilled liner which ensures a very efficient stimulation of large section of horizontal reservoir if the reservoir section is uniform /2/. Both completion and stimulation uses a mixture of chemicals and occasionally sand grains that will be partly discharged to sea (see technical section E – well stimulation).

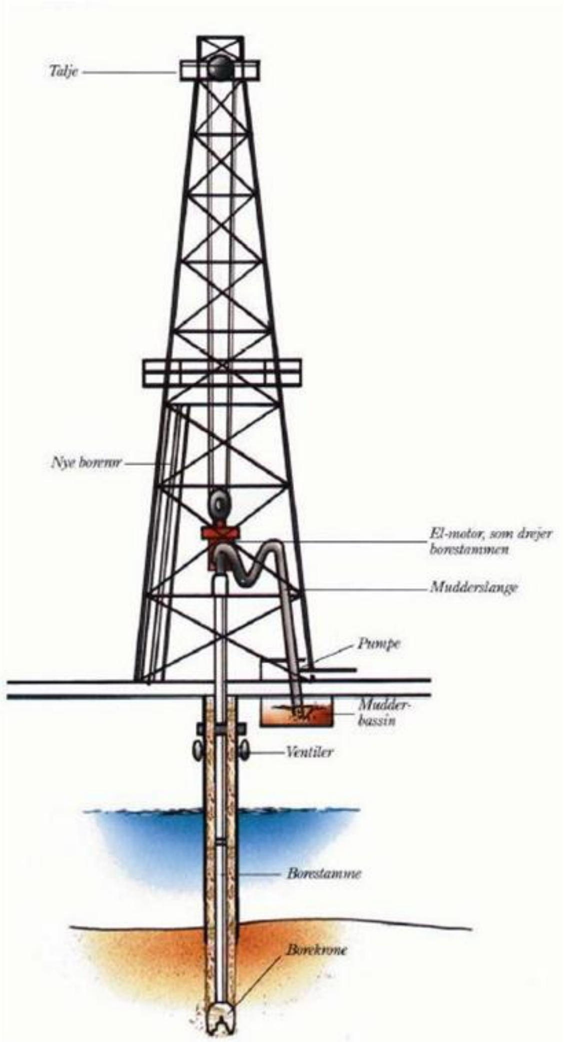


Figure D-2 Sketch showing the functioning of a drill rig

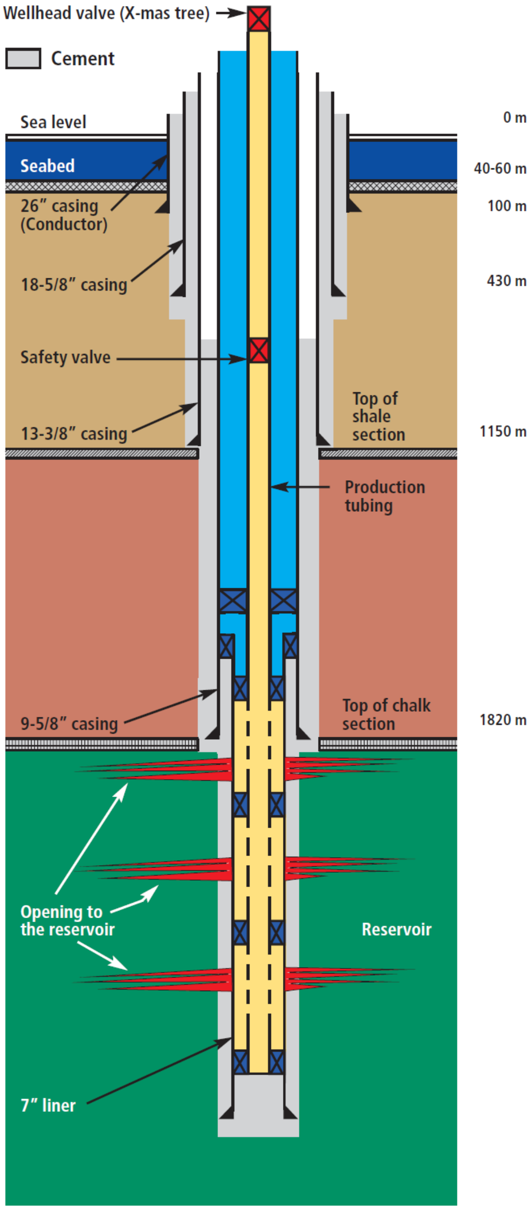


Figure D-3 Well chart for a typical production well (three zones)

Overall, Maersk Oil estimates that a typical well will take between 60 and 150 drilling days from conductor driving to well completion/stimulation depending on the complexity of the well.

D.3 Drilling using expandable liner and Managed Pressure Drilling (MPD)

Mature reservoirs from where production has taken place for a number of years usually are characterized by large pressure differences. Drilling new production wells in such reservoirs requires that part of the reservoir section is isolated by a casing, before the rest of the well is drilled.

To avoid the hole diameter to be reduced due to the extra casing, an expandable liner can be used. Using this method requires that the 9-5/8'' (24 cm) casing is exchanged with a 10-3/4'' casing. The subsequent section will be covered with an 8-5/8'' (22 cm) liner which is expanded with a special tool, where after the remaining part of the well can be drilled to 8-1/2'' (22 cm) hole diameter. This expandable liner is only used to cover shorter sections (a couple of hundred feet) with different pressure regime.

Another way of managing the large differential pressure in the reservoir sections on mature fields is using Managed Pressure Drilling (MPD) equipment. Normally when circulating the drilling fluid around the well the friction will apply extra pressure on the formation on top of the actual fluid weight. When the well is not circulated the hydrostatic pressure of the fluid will equal the formation pressure plus a safety margin.

The MPD technique allows the mud-weight to be reduced so that the production takes place while drilling and the friction plus the mud-weight is enough to counteract the formation pressure. When the well is not producing, a rotating head on top of the BOP and a choke manifold is used to apply the required extra pressure when not producing and therefore no friction add to the hydrostatic pressure.

By using MPD, a larger differential pressure can be drilled using the same size of hole. Maersk Oil will be using this technique on some of the wells in the mature areas.

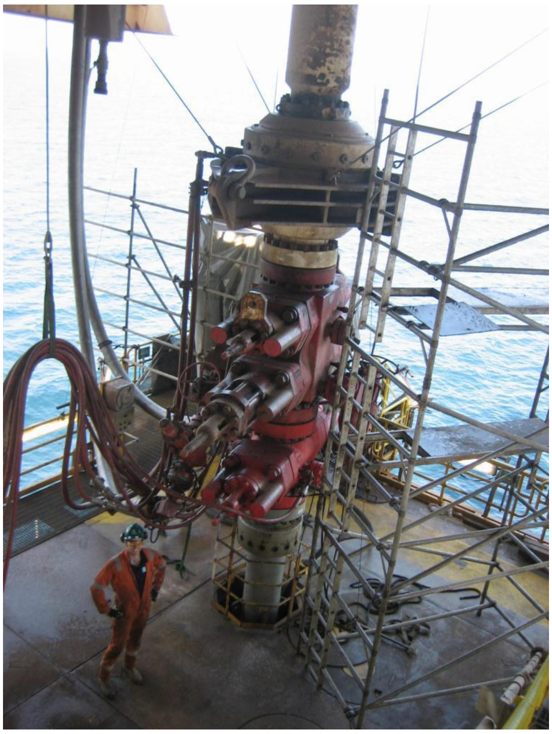


Figure D-4 Blow-Out Preventer (BOP) at the ENSCO 71 drilling rig

When drilling close to existing facilities, the distance with existing wells and the planned drilling track is evaluated and existing wells that are situated within a safety zone are temporarily closed during drilling operations.

D.4 Re-drill

When production from a well is no longer profitable, the well slots may be used to access additional resources. This is done either as slot recovery or re-drilling.

Slot recovery: The redundant well is abandoned, a new conductor is placed on the seabed reusing the slot of the original well, and the well is drilled and completed from the new conductor as a normal well.

Re-drill (also called side track): Sections of the redundant well are re-used. Before starting a re-drill, the well's top completion has to be retrieved and the reservoir section abandoned with cement plugs. Ehen the original well is secured, a hole is milled in the casing and the new well is drilled and completed as a normal well. The re-drill can be done from any of the casings installed (e.g. out of the production casing or the intermediate casing) depending on the state of the old casing and the geological targets for the new well.

D.5 Maintenance

Well interventions may be required for maintaining the well integrity or for optimizing production or injection. These interventions are usually carried on wells that have been producing or injecting for a number of years and suffers from damage, corrosion or malfunctions.

For small repair work, it might be sufficient to make a repair directly from the production installation by using wireline or coil tubing technology to lower equipment and measurement device into the well.

Figure D-5 Well intervention at Halfdan, 2012

For medium-sized well repair works, a hydraulic repair unit or a drilling rig is used for withdrawal and installation of production inner string. A tower with hoisting equipment is placed directly above the well. When using a hydraulic repair unit, the well is typically pressurized, and all liquids and gas from the well are transported directly to the processing units of the platform.

For major repair work, it is necessary to center a drilling rig above the well in order to repair the production casing (Workover – WO), change out the tubing or similar. WO operations may require the use and discharge of chemicals to the sea.

The following WO types are typical done by Maersk Oil:

Minor WO: This includes changing out the production tubing (completion). A plug is inserted (deep set plug) in the production tubing below the production packer to have a barrier against the reservoir. Then the x-mas tree is replaced with Blow Out Preventer (BOP) to be able to pull the old completion and replace it with a new completion.

Minor WO with scale: This is performed in case the completion has been filled with scale over the years and therefore has a reduced diameter. The completion is milled out to be able to set a deep set plug below the production packer. The rest of the work is similar to what was described above for Minor WO.

Medium WO: This is performed when the production casing is corroded. The casing is repaired by running a so-called scab tie-back liner where-after a new completion is installed.

Medium WO with scale: Is performed in case the completion has be filled with scale over the years and has a reduced diameter and needs to be milled out to set a deep set plug below the production packer. The rest of the work is the same as described as in Medium WO.

Major WO: This type of WO entails a repair or renewal of parts or entire lower completions, repair of pressures behind the production or intermediate casings, milling operations, stuck tools, etc. These are more complex WO's.

A typical well intervention may range from 20 to 90 days depending on the complexity of the job for major WO.

D.6 Well Abandonment

When a platform well has become obsolete, it will be abandoned using a drilling rig. The abandonment is done by retrieving the upper completion string and subsequently placing cement plugs in the wellbore ensuring that two barriers are in place between hydrocarbon bearing formations and surface. The barriers will be designed to ensure integrity for all foreseeable exposures and will be tested after placement. The actual number of plugs and their placement will depend on the individual well conditions, however, the drawing below show one scenario.

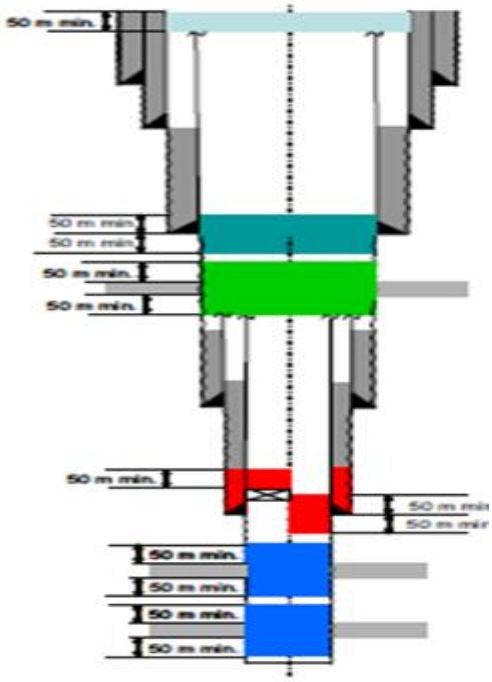


Figure D-6 **Example of abandonment scenario for a well. The coloured areas represent cement plugs**

A number of old exploration wells have been left temporarily suspended to enable possible later tie-back. Some of these wells will in the upcoming years be permanently abandoned by placing cement plugs in the wells and removing the casings above the seabed and re-establish same. This work will be done either by a dedicated vessel or by moving a drilling rig onto the location pending individual assessment of the work needed.

D.7 Alternatives

There is no alternative to drilling for offshore extraction of oil and gas.

D.8 Environmental and social aspects

Here, we summarize the environmental and social aspects related to drilling and select those to be further considered in the project-specific impact assessment.

D.8.1 Planned activities

The main environmental and social aspects related to Maersk Oil's drilling activities include:

- Drilling rig presence,
- Air emissions from drilling platform power combustion engine,
- Noise from conductor driving, drilling and platform machinery
- Discharges to sea
- Resources use
- Waste production

The presence of the drilling rig has a direct impact on the environment, by occupying an area of the seabed, by impacting the currents and waves where it is situated, and by acting as an artificial reef. In addition, the presence of the rig with its lighting might have a visual impact on migrating birds passing by the area.

Fuel combustion to power pumps, generators and compressors results in the emissions carbon dioxide (CO_2), nitrogen oxide (NO_X), nitrous oxide (N_2O), methane (CH_4), other volatile organic compounds (nmVOC) and sulphur oxide (SOx). Fuel combustion to power tug vessels used for the rig move is also a source of emissions. Fuel consumption in relation to cargo and personnel transport to drilling platform is already covered in section F. An estimate of emissions can be derived from the total fuel consumption for two types of platforms and tug boats (Table D-9).

The highest levels of noise in connection with drilling are created when conductors are rammed down. Also other parts of the drilling operation produce significant levels of noise.

In connection with the drilling and maintenance of a well, the following materials are used and discharged: drilling mud, drill cuttings, cement and chemicals.

Drilling mud and drill cuttings represent the most important discharge to the sea. WBM and cuttings (WBM sections) will be discharged to the sea whereas OBM and cuttings (OBM sections) will be brought onshore to be dried and incinerated. Water-based drilling mud and drill cuttings may contain traces of oil from the reservoir. We monitor the oil content carefully to ensure the average concentration of oil in the discharged mud or drill cuttings does not exceed 2%.

Alternative to disposal of cuttings (OBM sections or slop) such as Cutting Re-Injections (CRI) and Offshore Thermal Cuttings Cleaner treatment (OTCC, also called ROTOmill) are used in the industry. In CRI, cuttings are directly re-injected through the existing well into the formation. CRI can only be achieved in specific geological conditions and has not been found feasible so far. In OTCC, oil and water are extracted by thermal process, while the treated solids can be then discharged due to their low oil content (less than 1%). This technology can only be implemented with specific drilling rig. Maersk Oil frequently re-evaluates the CRI and OTTC possibilities when planning for new wells.

A fraction of the chemicals used in drilling mud or during the cementing, completion, work-over and abandonment operations will be discharged. Most of the chemical discharged are on the OSPAR PLONOR list (Pose Little Or No Risk to the environment). An estimate of the inventory of the chemical use and discharge is provided for five different types of wells expected by Maersk Oil (Table D-2 to Table D-6). Chemicals are classified in accordance with OSPAR Recommendation 2010/4 on a Harmonised Pre-screening Scheme for Offshore Chemicals /3/.

D.8.1.1 Overview of material use and discharge in connection with drilling of wells

In connection with the construction of a well, the following materials are used, see Table D-1:

- Drilling mud,
- Drill cuttings,
- Cement,
- Chemicals used for stimulation, completion.

Only the material used or collected in the water based section is discharged to sea, whereas all materials originating from the oil based section are collected and brought onshore.

All mud systems contain chemicals to obtain the following properties:

- Lubrication,
- Build filtercake towards the formation,
- Adjust viscosity and rheology,
- Adjust the weight,
- Reduce swelling,
- Maintain stable pH.

Table D-1 Estimates of drill cuttings per well section

Hole section section (")	Casing (")	Section Depth MD (m)	Cuttings Mass[1] (ton)	Mud in Cuttings[2] (%)	Mud Density[2] (SG)	Cuttings and mud (ton)	Mud Type[3]
22	18 3/8	0-500	332	5	1.2	340	WBM
17 ½	14	500-1,500	420	5	1.5	432	WBM
16	13 3/8	500-1,500	351	5	1.5	361	WBM
13 ½	10 3/8	1,500-5,000	926	10	1.64	984	OBM
13½	10 3/8	1,500-5,000	980	20	1.64	1103	WBM
12 ¼"	9 5/8	1,500-5,000	763	10	1.64	811	OBM
12 ¼	9 5/8	1,500-5,000	807	20	1.64	908	WBM
8 ½	7	2,500-6,000	403	20	1.4	446	OBM or WBM
6	5	2,500-6,000	201	20	1.4	222	OBM or WBM
8 ½	CAJ	2,500-10,000	403	20	1.4	446	WBM
6	CAJ	2,500-10,000	201	20	1.4	222	WBM

[1]: Including washout, estimated to 2% (22-16''), 5% (13½-12 ¼'') and 10% (8½-6''),
[2]: Estimated, based on experience,
[3]: WBM: Water Based Mud, OBM: Oil Based Mud.

D.8.1.2 Drilling mud

Different types of drilling mud will be used based on the well and reservoir properties.

In the upper part of the well (22" (56 cm) section) sea water is used with prehydrated bentonite and lime.

Pre-hydrated bentonite is partially re-used to drill the top sand part of the next section (16" (41 cm) or 17-1/2" (44 cm) hole size). The mud is converted to a dispersive sea water/ lime system when drilling the bottom clay part of the section.

The next section (12-1/4" (31 cm) or 13 ½" (34 cm) hole size) is normally drilled through overpressure Tertiary shale. An inhibitive system will be used to make sure that the clay does not take in any water from the drilling mud and swell up.

Low toxic Oil Based Mud (OBM) is normally used to drill this section as most of the wells are highly deviated. OBM is also used to drill under High Pressure High Temperature (HPHT) conditions. The material from these sections is transported onshore for treatment and disposal.

For vertical or low inclination wells, Inhibited Water Based Mud (WBM) may also be used. KCL/Glycol is normally used, but High performance WBM could also be an option for long vertical exploration well.

Fine barite has been introduced recently as weighting agent and so far only shows a good performance.

Reservoir (8 ½" (22 cm) size) is generally drilled with a low solid WBM system which is compatible with the formation drilled. These are simple mud systems with mainly viscosifier and fluid loss control additives. Acid soluble additive can also be added as a bridging package.

When drilling wells with long horizontal sections and multilateral wells it can be necessary to continue with one additional section (6" (15 cm)). In this case same mud as for the 8-1/2" (22 cm) section will be used.

Low toxic OBM can also be used in case of long horizontal section.

The biggest amounts of the chemicals which are being discharged with the mud are on the OSPAR PLONOR list (Pose Little Or No Risk to the environment) and will be categorized as 'green' chemicals. With time, more chemicals will be substituted with more environmental friendly chemicals.

No red chemicals are discharged to the sea as they are only used in low Toxic OBM system.
In some cases where the drilling causes special problems, such as decreasing hole stability or huge amounts of losses to the formation, gas or oil in the mud etc. following products can be used:

- Lost Circulation Material (LCM)
- Antifoaming
- pH adjustment
- Barite to increase the weight
- Corrosion inhibitors
- Biocides
- Adjustments of the viscosity and rheology

D.8.1.3 Drill cuttings

Cuttings from the formation collected in the water-based mud section of the well will be discharged to the sea whereas cuttings from the oil based mud section will be brought to shore where they will be dried and incinerated.

Alternative to disposal of cuttings are cutting re-injections (CRI) and Offshore Cuttings Thermal Treatment (OCTT or ROTOmill), cf. section D.8.1. Maersk Oil is planning to use this technology in the future.

There is no limit for the amount of oil to be discharged into the sea when using WBM drilling, but Maersk Oil strives to keep the oil concentration below 2%.

D.8.1.4 Cement

The 18-5/8" (47 cm) and 13-3/8" (34 cm) casing are cemented on the outside against the formation all the way to the seabed. Excess cement is discharged to the sea. The 9-5/8" (24 cm) casing will be cemented around 2000 ft into the 13-3/8" (34 cm) casing. The discharge to sea only occurs when the hole size has decreased or if the cement does not set uniformly. A spacer is pumped between the mud and the cement to avoid any contamination.

The 7” (18 cm) liner is not cemented all the way back to the surface, but only to the lower part of the 9-5/8” (24 cm) casing. For this job additional spacer and cement will be pumped to make sure that this objective is met. The same goes for the 5” (13 cm) casing if this is run.

If a CAJ liner (Controlled Acid Jet) will be run it will not be cemented.

The cement is an API blend Class G with additives (retarder, fluid loss reducer, to make it gas tight). The spacer contains sea water with a few additives, mainly salts, polymers and weighing agents.

D.8.1.5 Chemicals

Before drilling chemicals can be permitted for use and discharge offshore, an application must be submitted to the Danish authorities. Part of the application is an environmental classification of each chemical carried out in accordance with the OSPAR Recommendation 2010/4 on a Harmonised Pre-screening Scheme for Offshore Chemicals /3/. The below colour coding system used by the Danish operators are based on the criteria outlined in OSPAR, 2010 /3/ (as presented in section C.4).

The use and discharge of chemicals used for five typical types of Maersk Oil wells (section D.2) are shown in Table D-2 to Table D-6. As is the case for production chemicals, cf. section C.4, discharge of red chemicals is not planned.

Well type 1 - 7" cemented liner + WBM in 12.25":

22" section: 0 - 500 mMD with Prehydrated Bentonite
16" section: 500 - 1500 mMD with SW/Lime/native Clay
12.25" section: 1500 - 5000 mMD with KCl/ Glycol
8.5"section: 5000 - 6000 mMD with low solid WBM

Table D-2 Use and discharge of chemicals per well – well type 1

	OSPAR	Usage per well	Discharge per well
	Classification	Tons	Tons
Drilling mud		1800	1800
		923	923
		0	0
Cement		79	10
		28	3.4
		0	0

Well type 2 - CAJ liner + WBM in 12.25"

22" section: 0 - 500 mMD with Prehydrated Bentonite
16" section: 500 - 1500 mMD with SW/Lime/native Clay
12.25" section: 1500 - 5000 mMD with KCl/ Glycol
8.5"section: 5000 - 10000 mMD with low solid WBM

Table D-3 Use and discharge of chemicals per well – well type 2

	OSPAR	Usage per well	Discharge per well
	Classification	Tons	Tons
Drilling mud		2421	2421
		994	994
		0	0
Cement		631	76
		14	1.7
		0	0

Well type 3 - 7" cemented liner + OBM in 12.25"

22" section: 0 - 500 mMD with Prehydrated Bentonite
16" section: 500 - 1500 mMD with SW/Lime/native Clay
12.25" section: 1500 - 5000 mMD with low toxic OBM
8.5"section: 5000 - 6000 mMD with low solid WB;

Table D-4 Use and discharge of chemicals per well – well type 3

	OSPAR	Usage per well	Discharge per well
	Classification	Tons	Tons
Drilling mud		1943	414
		700	28
		53	0
Cement		760	88
		21	2.4
		0	0

Well type 4 - CAJ liner + OBM in 12.25"

22" section: 0 - 500 mMD with Prehydrated Bentonite
16" section: 500 - 1500 mMD with SW/Lime/native Clay
12.25" section: 1500 - 5000 mMD with low toxic OBM
8.5"section: 5000 - 10000 mMD with low solid WBM

Table D-5 Use and discharge of chemicals per well – well type 4

	OSPAR	Usage per well	Discharge per well
	Classification	Tons	Tons
Drilling mud		2535	1007
		768	96
		53	0
Cement		631	74
		15	1.7
		0	0

Well type 5 - OBM in 7" cemented liner + OBM in 12.25"

22" section: 0 - 500 mMD with Prehydrated Bentonite
16" section: 500 - 1500 mMD with SW/Lime/native Clay
12.25" section: 1500 - 5000 mMD with low toxic OBM
8.5"section: 5000 - 6000 mMD with low toxic OBM

Table D-6 Use and discharge of chemicals per well – well type 5

	OSPAR	Usage per well	Discharge per well
	Classification	Tons	Tons
Drilling mud		2272	107
		952	0
		75	0
Cement		758	88
		21	2.4
		0	0

The fate and amounts of cuttings (water based and oil based) in connection with the different types of wells are summarized in Table D-7.

Table D-7 Fate of cuttings (water based and oil based) per well

Type of cuttings	Fate	Well Type 1	Well Type 2	Well Type 3	Well Type 4	Well Type 5
Total water-based (t)	Discharged	1605	1759	798	952	683
Total oil-based (t)	Collected	0	0	763	763	1032

D.8.1.6 Workover - Completion fluid

When the production casing is installed it will be filled with inhibited seawater to protect against corrosion. It is estimated that 3000 bbls of inhibited seawater are needed per well. The chemicals required for this is outlined inTable D-8.

D.8.1.7 Abandonment

When a well is abandoned it will be filled with inhibited seawater. It is estimated that 3000 bbls of inhibited seawater are needed per well. The chemicals use and discharge required for this operation are shown in Table D-8.

Table D-8 Use and discharge of chemicals per well

	OSPAR	Usage per well	Discharge per well
	Classification	Tons	Tons
Completion fluid		0.6	0.6
		5.9	5.9
		0	0
Abandonment		0.6	0.6
		5.9	5.9
		0	0

D.8.1.8 Fuel consumption and air emissions

The daily fuel consumption of a large and a small drill rig, respectively, is shown in Table D-9, together with the fuel consumption of supporting vessels. In addition, the daily fuel consumption connected with a rig move is shown.

Table D-9 Daily fuel consumption, operation of drill rigs and support vessels

Installation/Activity	Vessel type	Daily consumption (t)
Drilling, large rig	Large Rig, e.g. Noble Sam Turner	11.4
	Guard vessel	0.6
Drilling, small rig	Small Rig, e.g. Ensco 70	6.4
	Guard vessel	0.6
Rig move	Tug boat, large	12.8
	Tug boat, assist 1	2.1
	Tug boat, assist 2	2.1

D.8.2 Accidental events

Accidents with potential environmental and social consequences could occur as a result of a loss of primary containment event related to drilling performed for or by Maersk Oil following /4/, /5/:

- Well blowout
- Vessel collision with riser or platform
- Vessel collision with other vessels
- Minor accidental spills or releases

Well blowout and well release frequencies, based on data from US Gulf of Mexico and North Sea (Norwegian and British Sector) from SINTEF offshore blowout database 2013 /6/, are in the range (lowest frequency blow out – highest frequency well release) 7.5 x 10^{-6} to 3.3 x 10^{-4} per year in maintenance and operation. For development the frequencies are in the range 3.8×10^{-5} to 6.4×10^{-3} per well, wildcat drilling specifically 6.6×10^{-4} to 6.6×10^{-3} per well.

Vessel collision frequencies are considered in section F.

D.8.2.1 Barriers for avoiding loss of well control (accidental events)

Maersk Oil uses two independent barriers to avoid uncontrolled release of reservoir fluid to the surface while constructing the well (blowout event). In case one of these barriers fails, the operations are stopped until the faulty barrier has been restored. Different barriers are used for the drilling or the production phases.

During drilling, high density drilling mud is the first barrier. It is used to ensure that there is sufficient hydrostatic pressure in the well bore to prevent oil or gas from flowing into the well bore and back to the surface.

The second barrier is the casings, the cement, the well head and the Blow-Out Preventer (BOP), which is placed at the top of the well string to regulate and monitor wellbore pressure. The BOP can be closed automatically or by rig operators when the hydrostatic pressure induced by the flow of drilling mud fails to retain the inflow of reservoir fluid.

During production, the so-called X-mas tree serves as blow-out preventer.

D.8.3 Summary

The relevant environmental and social aspects related to Maersk Oil drilling activities are listed in Table D-10 and are further considered in the project-specific impact assessment.

Table D-10 Environmental and social aspects and impact mechanisms from drilling and maintenance of wells

Phase	Activity	Impact mechanism	Potential receptor
Drilling	Power generation	Use of resources (gas, diesel)	Use of non-replenishing resources
		Emissions to air	Climate and air quality
		Generation of noise, light	Plankton, benthic communities, fish, marine mammals, seabirds
	Pile driving of conductors	Noise	Plankton, benthic communities, fish, marine mammals, seabirds
	Flaring / test production (only if not possible to produce into a pipeline)	Use of resources	Use of non-replenishing resources
		Emissions to air	Climate and air quality
	Discharge of drill mud and cuttings and chemicals	Drill mud, cuttings and chemicals (WBM) discharge to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, protected areas
	Cooling water discharge	Local seawater temperature change, biocide	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, protected areas
	Sewage discharge	Organic substances to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, protected areas

Phase	Activity	Impact mechanism	Potential receptor
	Cleaning of drill pipes etc.	Production of waste, possible including NORM	Deposit
	Waste production	Production of waste for re-use, incineration and deposit	Waste treatment facility, deposit onshore
	Tax revenue		Tax revenue
	Employment offshore and onshore		Employment
Accidental events	Spill of oil due to well blow-out	Oil to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
	Spill of OBM to the sea due to loss of containment	Oil to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
	Spill of oil due to collision with approaching oil/chemicals tanker or bunker vessel	Oil or chemicals to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
	Discharge of drain water, bilge water, thread lubricant and annular fluid	Cleaning agents and similar to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism

D.9 References

/1/ OGP (International Association of Oil & Gas Producers), 2003. Environmental aspects of the use and disposal of non-aqueous drilling fluids associated with offshore oil & gas operations. OGP Report No. 342, May 2003.

/2/ Hansen, J.H. & Nederveen, N., 2002. Controlled Acid Jet (CAJ) Technique for Effective Single Operation Stimulation of 14,000+ ft Long Reservoir Sections. SPE European Petroleum Conf., 29-31 October, Aberdeen, UK. SPE-78318.

/3/ OSPAR, 2010. OSPAR Recommendation 2010/4 on a Harmonised Pre-screening Scheme for Offshore Chemicals.

/4/ Oil Spill Response Limited, 2015. Oil Spill Risk Assessment, Xana-1X. Maersk Oil Document CONS0848 Rev00.

/5/ Oil Spill Response Limited, 2014. Oil Spill Risk Assessment, Siah NE-1X. Maersk Oil Document CONS0874 Rev02.

/6/ Lloyd’s Register Consulting, 2014. Blowout and well release frequencies based on SINTEF offshore blowout database 2013. Report for SINTEF Offshore Blowout Database sponsors, Rev. A, 11 March 2014.

E. WELL STIMULATION

The present section "E – Well Stimulation" focuses on operations related to stimulation of wells carried out by Maersk Oil in the North Sea. The editorial history of the section is summarized below:

	Revision	Changes
E - Well Stimulation	0 (2015-01-07)	n. a.
E - Well Stimulation	1 (2015-01-29)	Update following Maersk review
E - Well Stimulation	2 (2015-04-29)	Update following Maersk review

E.1 Purpose

The purpose of well stimulation is to improve the contact between the well and reservoir, thereby facilitating hydrocarbon extraction for a production well and water injection for an injection well. In Maersk Oil's tight reservoirs in the North Sea, well stimulation is essential. Re-stimulation can also be performed later in the life of a well when the producing/injection zone becomes damaged (e.g. caused by scale). Well testing is performed to evaluate the production potential of a well after stimulation.

E.2 Types of Well Stimulation

E.2.1 Stimulation and fracturing

Stimulation is usually performed by creating fractures and cracks in the rock bearing hydrocarbons, thereby improving the contact between the well and the formation. Crack and fissures are generally induced by injection of a fluid (a mixture of chemicals and sand). Stimulation operations are usually carried out from a dedicated stimulation vessel via a drilling rig (Figure E-1). Maersk Oil uses two main types of stimulation techniques.

Matrix acid stimulation and acid fracturing:
During matrix-acid stimulation, a strong acid (typically, 15% HCl) is pumped into the well to generate numerous small channels and fractures (Figure E-2, upper panel). For acid fracturing, a similar acid is injected but using a pressure high enough to fracture the formation. This forces the acid deeper into the formation and further improves the contact to the well. Injection of acid at high pressure is a common and efficient means of generating fractures in chalk formations where Maersk Oil operates.

Fluid/sand fracturing:
Fluid/sand fracturing is performed by pumping fluid at high pressure. The fluid is used to not only generate cracks and fractures in the formation but also contains coarse sand (propant) that prevents closure of the fractures when the pressure drops /1/.

In addition to acid, chemicals may be added to the well stimulation mixture for several purposes to ensure safe and efficient operations (e.g. pH regulation, emulsifiers/demulsifiers, corrosion inhibitor, H_2S scavengers, surface tension regulation). Most of the chemicals used during well stimulation are consumed or remain in the formation, but stimulation fluid left in the tubing will be discharged to sea when the stimulation is completed.

Figure E-1 Stimulation vessel ready to rig up for well stimulation

E.2.2 Injection in horizontal well

The long horizontal wells employed in the fields operated by Maersk Oil present a special challenge because the stimulation must be efficient throughout the entire length of the well that is in contact with the reservoir. A number of special techniques have been developed to address this challenge.

Controlled Acid Jetting:

Controlled Acid Jetting (CAJ) is a well stimulation technique developed by Maersk Oil for horizontal wells /2/. The technique employs a long, pre-perforated liner, CAJ liner, in the reservoir section of the well. The CAJ liner perforations are located in a manner that efficiently distributes the acid along the entire section. By employing the CAJ liner, it is possible to establish long horizontal wells with a good contact to the reservoir even in sections inaccessible to coiled tubing equipment.

Zonal stimulation:

During zonal stimulation, the well is divided into sections by packing elements (i.e. inserting plugs). This creates access to individual sections through side doors in the production tube that can be opened or shut and allows selective and optimal stimulation (Figure E-2, lower panel).

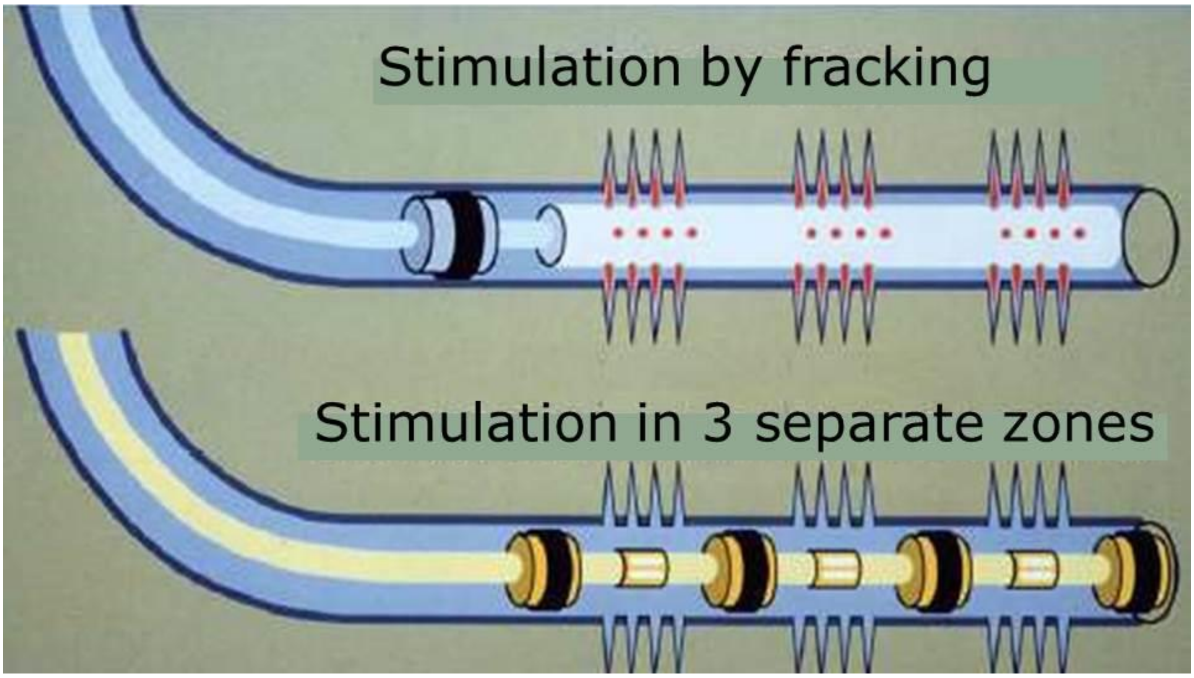


Figure E-2 Stimulation of wells using a CAJ liner (upper panel) and by zonal stimulation (lower panel)

E.2.3 Well testing

After stimulation, wells are tested to evaluate their production capacity, and to determine whether further work is required on the well while the drilling/stimulation rig is available. The oil, gas and water (including reaction products contained in the wells) produced during testing of wells on existing platforms are added to the already operating production line.

Stand-alone wells (mostly exploration wells) that are not connected to any platforms may sometimes require testing. These wells are mainly rig based, and the rig will be equipped with facilities for separation and flaring /1/.

E.2.4 Re-stimulation of wells

Different challenges which may develop during the lifetime of a well and reduced its capacity can be remediated by performing a re-stimulation. Common examples of such challenges are scale deposition in the production tubing, formation plugging with fine rock particles, or formation collapse. Re-stimulation treatments are primarily matrix acid stimulation treatments performed in the same zones and through the same well equipment as the original stimulation method.

E.3 Alternatives

Maersk Oil is working to develop improved techniques for well stimulation, and future developments.

E.3.1 Telescoping CAJ liner

Further development of the Controlled Acid Jet (CAJ) liner (see E.2.2) is currently being investigated to expand the range of wells that can utilize the CAJ acid stimulation method. A current limitation to the CAJ liner is the length of the reservoir section that can be completed due to large differences in pressure from one end of the drilled reservoir section to the other. Current technology limitations only allow a short reservoir section to be drilled before the pressure difference becomes too high. The reservoir section must therefore be drilled, completed, and stimulated in multiple sections, which can be time consuming and costly because it requires a combination of different stimulation and completion types.

The introduction of a telescoping CAJ enables two reservoir sections to be drilled and completed as CAJ liners. With this method, each section can be drilled independently and not influenced by the pressure change in the reservoir. This method, though still under development has the following advantages:

1. Elimination of costly cementing time, chemicals and potential discharge,
2. Elimination of perforating operations,
3. Allows for a single acid stimulation operation, rather than multiple, smaller operations, reducing time spent on the well.

E.3.2 Annular Fracturing or Frac Sleeve Completions

Future sand fracturing operations will consider a new and updated method referred to as Annular Fracturing or Frac Sleeve Completions. This method is similar to zone stimulation methods (E.2.2), but has the following benefits:

1. Drastically reduced time to install and stimulate compared with previous methods,
2. Elimination of a separate perforating operation,
3. Traditional jointed pipe handling is replaced by safer and faster coiled tubing,
4. The ability to place a greater number of fractures; spaced more closely together.

The method uses Frac Sleeves, or sliding sleeves installed in the reservoir liner and cemented in place along with the reservoir liner. These sleeves are illustrated in Figure E-3, panels a and b. The Frac Sleeve is opened or closed using a shifting tool called a coiled tubing Bottom Hole Assembly (BHA). This shifting tool is installed on the end of a long spool of coiled tubing, allowing for faster and safer deployment than traditional jointed pipe. This Coiled Tubing BHA is illustrated in Figure E-3, panel c. The sand fracturing treatment is pumped into the desired open Frac Sleeve in the annulus between the reservoir liner and the coiled tubing.

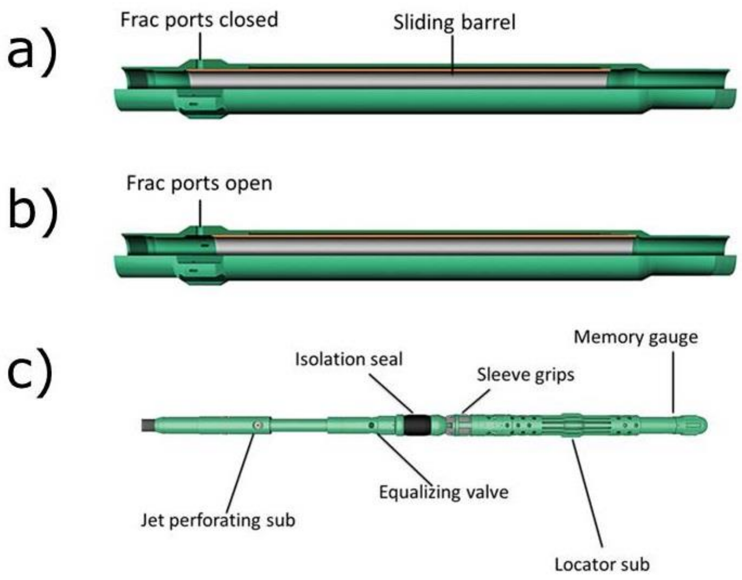


Figure E-3 **Illustration showing the principle in Frac Sleeve completion. Panels a and b show a part of a horizontal well with closed and opened sleeves, respectively. Panel c illustrates the structure of a coiled tubing BHA**

E.4 Environmental and social aspects

Here, we summarize the environmental and social aspects related to well stimulation and select those to be further considered in the project-specific impact assessment.

E.4.1 Planned Activities

The main environmental and social aspects related to well stimulation include:

- Air emissions from stimulation vessels, drilling power combustion engines, and flaring,
- Noise from vessels and platform machinery,
- Chemical discharges

Environmental and social aspects with regard to Maersk Oil's use of drilling rigs (noise, emissions, presence of the rig) in the stimulation process are already covered in section D. No other aspects are expected to come from the alternative methods for stimulation.

E.4.1.1 Energy consumption and emissions to air

The fuel consumption from stimulation rigs are summarized in Table E-1. The table includes the consumption during mob, sailing and loading.

Table E-1 Daily fuel consumption, operation of drill rigs and support vessels

Installation/Activity	Vessel type	Daily consumption [t]
Matrix acid	Mob	17.1
	Sailing	21.4
	Loading	3.4
Acid fracturing	Mob	17.1
	Sailing	21.4
	Loading	3.4
Sand fracturing	Mob	17.1
	Sailing	21.4
	Loading	3.4

Flaring associated with well test may also generate emissions. Flaring in connection with testing of a production well may last up to 3 weeks with an estimated rate of ca. 1500 bopd for an oil well or 15 mmscfd for a gas well. For exploration wells, flaring may last up to 6 days at a rate of ca. 1000 bopd for an oil well or 10 mmscfd for a gas well. Flaring associated to well test are not frequent.

E.4.1.2 Noise

Propellers and dynamic positioning from vessels generates typically low frequency underwater noise with noise level depending on the type, size and activity of the vessels /3/.

E.4.1.3 Chemical discharges

A fraction of the stimulation chemicals used will be discharged to sea. An estimate of the inventory of the chemical use and discharge is provided for three different types of wells stimulation expected to be used by Maersk Oil (Table E-2). Chemicals are classified in accordance with OSPAR guidelines on a Harmonised Pre-screening Scheme for Offshore Chemicals /4/.

Table E-2 Amounts of green, yellow and red chemicals used and discharged per well stimulation

	OSPAR Classification	Usage per well [t]	Discharge per well [t]
Matrix well stimulation		220	140
		2603	522
		0	0
Acid fracturing well stimulation		194	134
		2816	564
		0	0
Sand fracking well stimulation		1385	277
		221	52
		218	0

E.4.2 Accidental events

Accidents with potential environmental and social consequences could occur as a result of a loss of primary containment event related to well stimulation similar to drilling. The barriers in place to prevent these accidental events are also described in section D – Drilling.

E.4.3 Summary

The relevant environmental and social aspects related to Maersk Oil well stimulation activities are listed in Table E-3 and are further considered in the project-specific impact assessment.

Table E-3 Environmental and social aspects and impact mechanisms form well stimulation activities

Operation	Activity	Impact mechanism	Potential receptor
Well stimulation	Discharge of chemicals	Chemicals to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, protected areas
	Disposal of fracturing sand	Sand particles to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, protected areas
	Power generation	Use of resources (gas, diesel)	Use of non-replenishing resources
		Emissions to air	Climate and air quality
		Generation of noise, light	Plankton, benthic communities, fish, marine mammals, seabirds
	Vessel activity	Emissions to air	Climate and air quality
		Generation of noise	Plankton, benthic communities, fish, marine mammals, seabirds
Well test	Flaring	Use of resources	Use of non-replenishing resources
		Emissions to air	Climate & air quality
	Well test	Oil and chemicals to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, protected areas

Operation	Activity	Impact mechanism	Potential receptor
Accidental events	Risk of vessel collision with stimulation rig	Oil and/or chemcial spill to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
	Risk of blowout during stimulation	Oil spill to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
		Gas to air	Climate & air quality, marine spatial use and fishery

E.5 References

/1/ Maersk Oil, 2011. Vurdering af virkninger på miljøet fra yderligere olie og gas aktiviteter i Nordsøen. Juli 2011.

/2/ Hansen, J.H. & Nederveen, N., 2002. Controlled Acid Jet (CAJ) Technique for Effective Single Operation Stimulation of 14,000+ ft Long Reservoir Sections. SPE European Petroleum Conf., 29-31 October, Aberdeen, UK. SPE-78318.

/3/ Genesis, Review and assessment of underwater sound produced from oil and gas sound activities and potential reporting requirements under the marine strategy framework directive, Document No. J71656 – Final Report – G2, July 2011.

/4/ OSPAR, 2010. OSPAR Recommendation 2010/4 on a Harmonised Pre-screening Scheme for Offshore Chemicals.

/5/ Oil Spill Response Limited, 2015. Oil Spill Risk Assessment, Xana-1X. Maersk Oil Document CONS0848 Rev00.

/6/ Oil Spill Response Limited, 2014. Oil Spill Risk Assessment, Siah NE-1X. Maersk Oil Document CONS0874 Rev02.

F. TRANSPORT

The present section "F - Transport" focuses on activities related to transport of personnel and cargo carried out by Maersk Oil in the North Sea. The editorial history of the section is summarized below:

	Version	Changes
F – Transport	0 (2015-01-07)	n. a.
F - Transport	1 (2015-01-29)	Update following Maersk review
F - Transport	2 (2015-04-29)	Update following Maersk review
F - Transport	3 (2015-06-30)	Update following Maersk review, accident statistics

F.1 Purpose

Personnel and cargo are transported daily to support Maersk Oil's continuous production and drilling operations.

F.2 General description

F.2.1 Helicopters

Helicopters are used for personnel transport to/from and between offshore installations. Personnel are transported from Esbjerg Airport with several departures daily to offshore platforms carrying up to 19 passengers at a time (Figure F-1). Once offshore, personnel are shuttled between installations by helicopter or by boat.

Figure F-1 Maersk Oil presently uses EC-225 helicopter (above) and AW-139 helicopter

F.2.2 Vessels

Several types of vessels are being used for various purposes:

- Supply vessels (Figure F-2) are used for transportation of cargo used in production and drilling operations between on- and off-shore locations,
- Service vessels are used to man and service the unmanned satellite installations,
- Standby vessels (Figure F-2) act as man-over-board during drilling, work over and coiled tubing operations. Standby vessels are also employed in connection with maintenance tasks requiring work over the side of the installation.

Other vessels (e.g. tug boats, crane vessel, diving support vessel) are presented in the relevant sections (B – Structures and Pipelines; D - Drilling).

Figure F-2 Supply Vessel (left) and Standby Vessel (right)

F.3 Alternatives

Transportation of personnel by helicopter is fast and flexible, and the possible alternative of using ship-based transport is not practicable, due to the long transport time. Personnel may also get seasick if transported by boat. Ship-based transport is preferred for cargo transport.

F.4 Environmental and social aspects

Here, we summarize the environmental and social aspects related to transport and select those to be further considered in the project-specific impact assessment.

F.4.1 Planned activities

Here, we summarize the environmental and social aspects related to transport activities and select those to be further considered in the project-specific impact assessment.

The main environmental and social aspects related to Maersk Oil's transport activities include:

- Air emissions from helicopters and vessels power combustion engine ,
- Noise generated by boat and helicopter engines.

F.4.1.1 Fuel consumption and air emissions

Fuel combustion to power the engines of helicopters and vessels results in emission of carbon dioxide (CO_2), nitrogen oxide (NO_X), nitrous oxide (N_2O), methane (CH_4), other volatile organic compounds (nmVOC), and sulphur oxide (SOx). An estimate of emissions is derived from the fuel consumption for the different types of vessels or helicopters (Table F-1) and the emission factor listed in Section A – Seismic (vessels) and in Table F-2 (helicopters).

Table F-1 Daily fuel consumption estimates for transport related to production and drilling operations

Description	Type of vehicle	Fuel consumption Tonnes/day
Production (1 project)	Service vessel to satellite	3.42
	Supply vessel	2.17
	Guard vessel	0.26
	Helicopter	1.32
1 drilling rig	Supply vessel	5.06
	Guard vessel	0.60
	Helicopter	0.75

Table F-2 Emission factors for helicopters /1/

Emissions [t / t fuel]	t CO_2	t NO_X	t N_2O	t SO_2	t CH_4	t nmVOC
Helicopters	3.11	0.0125	0.00022	0.0060	0.000087	0.0078

F.4.1.2 Noise

Propellers and dynamic positioning from vessels generates typically low frequency underwater noise with noise level depending on the type, size and activity of the vessels /2/.

Noise from helicopters is almost entirely reflected at the water surface, and even low-flying helicopters will only be heard in the water directly below the helicopter /3/, /4/. The underwater impact of helicopter noise is therefore considered to be limited /3/.

F.4.2 Accidental events

Accidents with potential environmental and social consequences could occur as a result of a loss of primary containment event related to transport activities following /5/, /6/:

- Vessel collision with riser or platform
- Vessel collision with other vessels
- Helicopter crashing onto the helideck or platform
- Minor accidental spills or releases

Vessel collision frequencies resulting in significant damage, based on IOGP Ship/installation collisions, worldwide collision data /7/, are in the range 3.5×10^{-5} to 2.5×10^{-4} per year. Helicopter transport flight accident frequencies involving crash onto installations, based on IOGP Aviation transport accident statistics /8/, and Maersk North Sea flight intensity, are around 1.9×10^{-3} per year.

F.4.3 Summary

The relevant environmental and social aspects related to Maersk Oil transport activities are listed in Table F-3 and are further considered in the project-specific impact assessment.

Table F-3 Environmental and social aspects and impact mechanisms related to transportation activities

Operation	Activity	Impact mechanism	Potential receptor
Helicopter shuttling	Transport of personnel	Use of resources (gas, diesel)	Socio-economic impacts
		Emissions to air	Climate & air quality
Boat transportation	Service, supply, standby vessels	Use of resources (gas, diesel)	Socio-economic impacts
		Emissions to air	Climate & air quality
		Discharge of sewage and ballast water	Marine environment
		Noise from vessel engines	Plankton, benthic communities, fish, marine mammals, seabirds
Accidental events	Boat collision with riser, platform or other vessels	Oil or chemicals to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
	Helicopter crash	Oil or chemicals to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism

F.5 References

/1/ E&P Forum, 1994. Methods for Estimating Atmospheric Emissions from E&P Operations. Report No. 2.59/19. September 1994.

/2/ Genesis, Review and assessment of underwater sound produced from oil and gas sound activities and potential reporting requirements under the marine strategy framework directive, Document No. J71656 – Final Report – G2, July 2011

/3/ COWI, Risk of platform collision from attendant vessels, Report no: 43246-001, Nov 1998. Prepared for Maersk Oil and Gas.

/4/ Richardson WJ, Greene Jr. CR, Malme CI,Thomson DH (1995) Marine Mammals and Noise, Acedemic Press, San Diego, CA, USA.

/5/ Oil Spill Response Limited, 2015. Oil Spill Risk Assessment, Xana-1X. Maersk Oil Document CONS0848 Rev00

/6/ Oil Spill Response Limited, 2014. Oil Spill Risk Assessment, Siah NE-1X. Maersk Oil Document CONS0874 Rev02

/7/ OGP, Risk Assessment Data Directory, Report No. 434 – 16, March 2010. Ship/installation collisions

/8/ OGP, Risk Assessment Data Directory, Report No. 434 – 11.1, March 2010. Aviation transport accident statistics

G. DECOMMISSIONING

The present section "G - Decommissioning" focuses on decommissioning of pipelines and installations relevant for Maersk Oil in the North Sea. The editorial history of the section is summarized below:

	Version	Changes
G – Decommissioning	0 (2015-01-07)	n. a.
G – Decommissioning	1 (2015-01-29)	Update following Maersk review
G – Decommissioning	2 (2015-04-29)	Update following Maersk review

G.1 Purpose

Offshore oil and gas structures (jacket and topside) and pipelines operated by Maersk Oil and which have become obsolete will require decommissioning.

G.2 General description

As a general outset, Maersk Oil proposes to apply the following general decommissioning philosophy.

G.2.1 Well abandonment

Wells will be permanently plugged towards the reservoir and the upper section of the well casing above the seabed will be removed. Well abandonment is described in technical Section "D – Drilling".

G.2.2 Removal of platform facilities and jacket

Following the permanent plugging and decommissioning of wells, residual hydrocarbons and dangerous waste will be removed from the facilities and sent to shore for disposal. It is considered unlikely that opportunities of facility re-use will be forthcoming. The platform facilities and jackets will therefore be removed and brought to shore for dismantling /1/, /2/). Recycling rather than disposal will be maximised. Several removal methods are currently under consideration and preferred options have not yet been decided. As part of the project close out, Maersk Oil will survey the decommissioned areas (see below).

G.2.3 Pipelines

Based on industry experience /3/ and a history of stable pipeline burial in Denmark, buried pipelines will be left in situ. Pipelines will be rinsed from residual hydrocarbons and back-filled with seawater to increase their weight to buoyancy ratio and further increase stability. Appropriate remedial work will be performed to secure pipe ends and crossings: retrenching, burying and cutting off ending sections may be performed to mitigate any risk to other users of the sea. As part of the project close out, Maersk Oil will survey the decommissioned areas (see below).

Pipelines are not covered by OSPAR Decision 98/3. There are no international guidelines on the decommissioning of disused pipelines. In the UK, the following pipelines may be candidates for in-situ decommissioning /4/:

- those which are adequately buried or trenched and which are not subject to development of spans and are expected to remain so;
- those which were not buried or trenched at installation but which are expected to self-bury over a sufficient length within a reasonable time and remain so buried;
- those where burial or trenching of the exposed sections is undertaken to a sufficient depth and it is expected to be permanent;
- those which are not trenched or buried but which nevertheless are candidates for leaving in place if the comparative assessment shows that to be the preferred option (e.g. trunk lines);

- those where exceptional and unforeseen circumstances due to structural damage or deterioration or other cause means they cannot be recovered safely and efficiently.

Judgements regarding the degree of burial or trenching necessary will be undertaken on a case by case basis in the light of individual circumstances /4/.

G.2.4 Close-out inspection

Maersk Oil will perform an inspection of the decommissioned areas to ensure that the seabed conditions do not present a hazard to other sea-users. It is assumed that upon decommissioning the seabed will be free of any restrictions (protection zones), leaving the areas available to other sea users, e.g. fishers. Any requirement for future restrictions may be identified following the survey.

G.3 Alternatives

Overall, Maersk Oil will opt for the decommissioning method which will be in compliance with the applicable legislation at the time when the operations shall be carried out. Furthermore, decommissioning options will be based on project-specific technological, safety, environmental, economic, social, liability and reputational considerations /5/, /6/, /7/. The above decommissioning options selected here are supported by industry experience and based on the present legal frameworks (OSPAR decision 98/3) and technical capabilities.

G.4 Environmental and social aspects

Here, we summarize the environmental and social aspects related to decommissioning and select those to be further considered in the project-specific impact assessment.

G.4.1 Planned activities

The main environmental and social aspects related to Maersk Oil's decommissioning of installations and pipelines include:

- Work vessel traffic,
- Emissions to air,
- Underwater noise,
- Discharges to sea (planned and accidental),
- Change of the seabed morphology and sediment dispersion,
- Use of resources and production of waste,
- Socio-economic contribution to the society.

The detailed environmental aspects related to decommissioning will depend on the methods to be selected in each case.

G.4.2 Accidental events

Accidents with potential environmental and social consequences could occur as a result of collision of vessels (with structures or with other vessels) and subsequent loss of containment.

G.4.3 Summary

The main environmental and social aspects and impact mechanisms related to decommissioning of pipelines and structures are listed in Table G-1.

Table G-1 Environmental and social aspects and impact mechanisms related to decommissioning

Phase	Activity	Impact mechanism	Potential receptor
Decommissioning activities	Vessel operation and cutting	Emissions to air	Climate & air quality
		Noise	Plankton, benthic communities, fish, marine mammals, seabirds
		Discharges to sea	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, protected areas
		Solid waste	Waste production
		Resource use	Use of non-replenishing resources
	Seabed interventions	Burial of seabed surface	Sediment quality, benthic communities, fish, cultural heritage, marine spatial use, fishery
		Turbidity/sedimentation increase	Water quality, plankton, fish, marine mammals, seabirds
		Seabed morphology change	Sediment quality, benthic communities, fish, cultural heritage, marine spatial use, fishery
		Noise	Plankton, benthic communities, fish, marine mammals, seabirds
		Restrictions on vessel traffic	Marine spatial use, fishery, tourism
	Decommissioning works generally	Impact on employment and tax revenue	Employment and tax revenue
Accidental events	Vessel collision	Oil or chemicals spill	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals, seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism
Post decommissioning	Exposed pipeline surface, stones and similar	Physical impact on seabed and hard substrate	Sediment quality, benthic communities
Accidental events	Risk of leakage from pipelines, structures or wells	Oil or chemical spill	Water quality, sediment quality, plankton, benthic communities, fish, marine mammals,

Phase	Activity	Impact mechanism	Potential receptor
			seabirds, cultural heritage, protected areas, marine spatial use, fishery, tourism

G.5 References

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/4/ Department of Energy & Climate Change (DECC), UK, 2011. Guidance Notes - Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998. Rev. 6, March 2011.

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