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EIA of disposal of marine growth from Maureen at Aker Stord

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Preface

The oil platform Maureen Alpha (MA) and the Articulated Loading Column (ALC) are to be decommissioned at Aker Stord, at the island Stord on the western coast of Norway. The project is a joint venture by Aker Offshore Partner, Aker Maritime Contractors and Aker Stord (Aker). After mooring the structures at the site Digernessundet, Aker are planning to discharge marine growth above sea level to the recipient.

Rogaland Research (RF) was contacted by Aker to perform an environmental impact assessment (EIA) of the disposal of marine growth to the recipient. This is a part of the EIA of the whole decommissioning process of Maureen and Articulated Loading Column.

Acknowledgement,

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Stavanger, 29. March 2001

Øyvind F. Tvedten, project leader

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Summary

The oil platform Maureen Alpha (MA) and the Articulated Loading Column (ALC) are to be decommissioned at Aker Stord, at the island Stord on the, western coast of Norway. After mooring the structures at Digernessundet, Aker is planning to discharge marine growth above sea level to the recipient. The growth consists of mussels, seaweed, corals, anemones, worms, sea-squirts etc. The purpose of removing the biota inshore is mainly to avoid odour problems from decaying marine life. It will also make the construction clean and safer to work on (e.g. cut into parts) later. The recipient is deep (270-310 m) and has good capacity for degradation of organic material, due to large water masses and favourable water currents and water renewal.

Rogaland Research (RF) was contacted by Aker to perform an environmental impact assessment (EIA) of the disposal of marine growth to the recipient. This is a part of the EIA of the whole decommissioning process of the MA and ALC.

Two main subjects are of most important environmental concern:

- **The organic load to the recipient**
- **Possible content of harmful substances**

A total of approximately 570 tonnes of wet growth is expected to be exposed to air after refloat. The dry organic matter in this growth is estimated to be 10-20%, that is 57-114 tonnes. Approximate 60 tonnes are to be discharged in a new operation in 2002.

Depending on how dry the growth will be at removal time some part of it might float on the surface. A contingency boom should be used to prevent spreading of this material, and make it possible to collect.

A reasonable course of events will be that most of the mussels and other heavy parts will sink to the bottom close to the platform, and the rest of the material will be spread over a larger area. We believe that this will lead to spots on the seabed close to, and under, the platform that will be overloaded with organic material, causing temporary oxygen deficiency in the sediment. In the rest of the influenced area the growth will be a source of food supply and make less effect, but may cause some temporary changes in the benthic community. We do not suspect oxygen deficiency in the water column. Since the material has marine origin there is natural scavengers (e.g. bacteria, crustaceans, worms, fishes) which will digest and decompose the growth. We assume that most of the organic material will be decomposed within a year after disposal. The benthic community may need a year extra to resemble the original situation.

At this date there is not sufficient knowledge about the content of potential harmful substances in the growth on MA to make a good description of effect from this on the seabed environment. Nevertheless it can be assumed that the levels are not in a magnitude that would lead to detectable elevated levels in the sediment. The growth will also be spread over a large area.

Without knowledge about the benthic fauna in the area before, during or after the decommissioning it is not possible to be certain of the disposal effects of the marine growth.

Glossary of acronyms and terms

ALC	Articulated Loading Column, the structure for transferring crude oil from Maureen Alpha to shuttle tankers.
Aker–	Aker Offshore Partner, Aker Maritime Contractors and Aker Stord
Benthic	Associated with the seabed (usually flora and fauna)
Biomass	weight of biota
Biota	living organisms (plants and animals) i.e. marine growth
EIA	Environmental impact assessment
MA	Maureen Alpha oil platform
Marine growth	Marine organisms living attached to any structure in the sea,
NPD	Naphthalenes/Phenanthrene/Dibenzothiophene, low molecular weight aromatic hydrocarbon compounds, present in diesel and some low-toxicity based drilling muds.
PAH	Polycyclic Aromatic Hydrocarbons, hydrocarbon compounds that contain more than one benzene ring. Such compounds are present in low-toxcicity base fluids, diesel etc., but not in synthetic drilling muds.
RF	Rogaland Research
SFT	Norwegian pollution control authority

1 Introduction

The oil platform Maureen Alpha (MA) and the Articulated Loading Column (ALC) are to be decommissioned at Aker Stord, at the island Stord on the, western coast of Norway. After mooring the structures at Digernessundet, Aker is planning to discharge marine growth above sea level to the recipient. The platform is raised ca. 30 m offshore when it is elevated from the seabed and the construction is more or less covered with marine growth. The purpose of removing the biota inshore is mainly to avoid odour problems from decaying marine life. It will also make the construction clean and safer to work on (e.g. cut into parts) later.

Rogaland Research (RF) was contacted by Aker to perform an environmental impact assessment (EIA) of the disposal of marine growth to the recipient. This is a part of the EIA of the whole decommissioning procedure of Maureen Alpha (MA) and Articulated Loading Column (ALC). MA is an oil platform (approximately 110,000 tonnes) with a steel frame and jacket and three steel large oil storage tanks. ALC is primarily made of concrete and have a total height of 130 m.

The EIA is requested from the Norwegian pollution control authority (SFT), before they will give a prospective permission for the discharge of marine growth.

RF is an independent research institute with ca. 30 persons engaged in marine environment investigations-and research. For information, see http\\www.rf.no.

2 Environmental effect of disposal of marine growth

Our knowledge of the existing marine fauna and flora on MA and ALC is based on Cordah report 015/00 (Cordah 2000). The Cordah report is based on video film/pictures from different parts of the installation from –4 m depth to the bottom and also includes some data from metal and hydrocarbon analyses.

Two main subjects are of most important environmental concern:

- **The organic load to the recipient**
- **Possible content of harmful substances**

2.1 Organic load

2.1.1 Amount of biomass

Cordah estimates the total amount of growth on MA to be 1700 tonnes wet weight (including sea water) distributed over ca. 90 m depth from under the sea surface to the bottom. The quality and quantity of the fauna and flora are changing with depth. Seaweed and mussel (*Mytilus edulis*) are dominating in the first 5 meters, and below this anemones, soft corals, sea-squirts, bryozoans, hydroids, barnacles and tube-worms are dominating. Scientific names (Latin) on most of the species are not included.

As a rough estimate one could say that one third (570 tonnes) of this mass would be exposed to air when MA is lifted 30 m from the seabed during refloat. The organisms will then start to dry, and the amount of water loss will depend on species, weather condition and time before removal. Sea squirts will lose most of its water after a short time in air, but mussels will shut their shells and retain their internal moisture. Water content of the growth above sea surface will initially typical be 70-90 %, most water loss in the sea-squirts and least in the mussels. Assuming it will take at least one week after the refloat offshore until the removal starts at Digernessundet, the growth could lose 20-60 % of its weight. This results into between 230-450 tonnes of "half dried" growth which are to be removed and discharged.

A scientific assessment of the quality and quantity of the growth on ALC is not performed. It is reasonable to assume that it is similarly distributed as that on MA. Since it is a cylindrical structure and only elevated 15 m when it is moored at Eldøyane at Aker Stord the amount of growth that is to be removed is estimated to be around 10 tonnes wet weight.

Calculation of the organic content of the material could be done by percentage of the initial weight. One can assume that 10-20 % of the 570 tonnes is organic material, i.e. 57-114 tonnes.

Maureen is also elevated 25 m in March 2002 when the topside is removed. This will lead to a new cleaning process. The initial weight of the growth will probably be less than in June 2001, since the mussels and seaweed in the uppermost meters had less than a year to establish and grow. In addition, the animals that were elevated to a higher level in 2001 may die or thrive bad, as results of unfavourable living conditions. However this can be contradicted by arguing that the organisms may find the conditions in calm coastal waters to be favourable. Summing up: the load of organic material to the recipient from the cleaning process in 2002 could be expected to be 60 tonnes.

2.1.2 The recipient

MA is to be moored in Digernessundet (the Digernes sound) south of the island Stord (se map in Figure 1). Digernessundet is a deep and open sound and therefore a recipient with good capacity for breaking down organic material. In the west the area is restricted from Stokksundet by a deep sill of ca. 140 m depth but in the east there is no sill between Digernessundet and the huge Hardangerfjord (this part may also be named Bømlafjord or Sunnhordlandbassenget). In the mooring area for MA the water depth is 270-280 m. The ALC is moored closer to Eldøyane in an area with water depth around 300 m. Earlier current investigations shows that the current is mainly driven by the tide and the water moves forwards and backward (Sintef 1986, CMI 1987 & VHL 1975). The tidal amplitude in the area is about 1 m. Measurements at 22 m depth close to the MA mooring position, indicates currents in south-east and north-west direction but also some movement in north and south direction. In this depth the typical mean speed is 8-10 cm s^{-1}. The current velocity is reduced with increasing depth but typical around 6-8 cm s^{-1} at 60-110 m. The current direction in the deeper water is varying but is dominated by water movement towards north-west and south-east. This corresponds with the bottom topography of the sound. The maximum speed is high in all measured depths. We have not seen any data from the surface water layer in Digernessundet or close to the bottom (the latest is extrapolated in Sintef 1986). It is assumable that the direction in the surface is along the shore and with a mean velocity of 10-15 cm s^{-1}. The surface current will be highly dependent on the weather situation.

There has not been conducted any previous recipient investigations in the area. The nearest investigation is from Stokksundet, which have in general conclusion satisfactory environmental conditions and water renewal (SAM 2001). From general knowledge of the fjords in this area we can conclude that there is no problems with lowered oxygen levels in the bottom water.

The municipality of Stord has regulated Digernessundet as an industrial mooring area and there is no important fishery in the area. The nearest fish farm is at Klungervika, at the island Bømlo, 5 km from west of the MA mooring site into Stokksundet. A mussel farm at Digernes is the nearest aquaculture activity, however the activity remains low at the farm. Some part of the neighbouring shore is used for recreation in summer time, especially at the island Føyno. The nearest bird protection area is 3 km away, south on the island Otterøy.

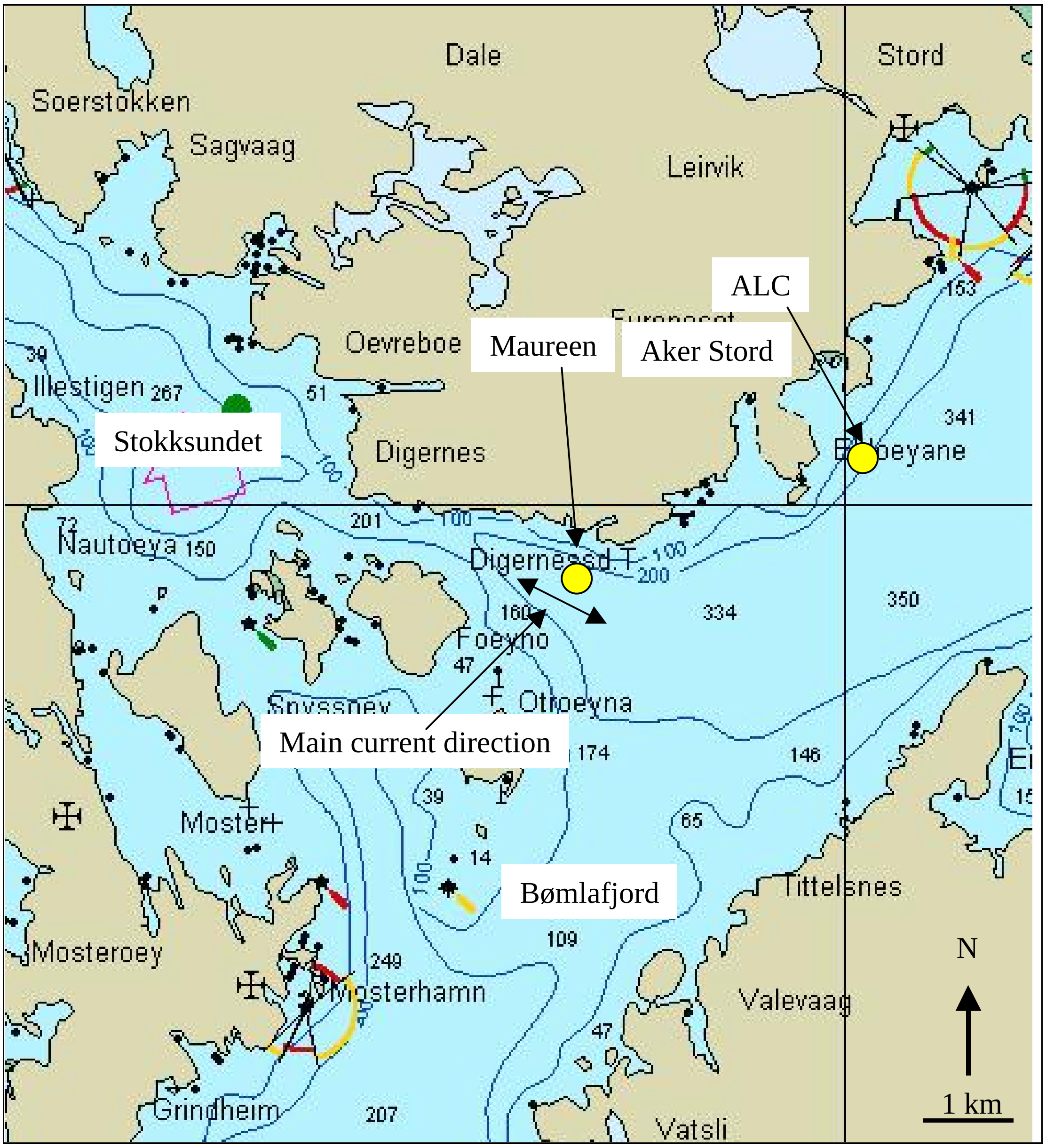

Figure 1. Map of the Digernessundet area, with mooring position of MA and ALC.

2.1.3 Effects on the recipient

2.1.3.1 Sea surface

Depending on how dry the growth will be at removal time some part of it might float on the surface. A contingency boom should be used to prevent spreading of this material, and make it possible to collect. This is because the material could cause unpleasant conditions in recreation areas if the amount or appearance differs from the natural content at the shore.

2.1.3.2 Water column

High quantity of organic load to the water could lead to reduced oxygen levels if the material was highly degradable and very slow sinking. The water velocity in Digernessundet is rather high and this will lead to a good dispersion of the growth and supply of new water with high oxygen content. In addition the major part of the material will sink to the bottom before significant degradation in the water. We therefore don't expect any oxygen deficiency in the water column. Larger free swimming organisms could easily avoid the plume of growth if they find it stressful. Some of the material can probably be a food source for fishes and other animals in the water column. It is thinkable that some particles will be collected in layers with increasing density (pycnocline), but still we don't think this could cause any significant oxygen deficiency.

2.1.3.3 Seabed

Decaying organic material on the seabed can lead to oxygen deficiency in the sediment, and affect benthic animals. Together with a smothering effect, this is the main stress on the benthic fauna. A secondary effect can also be changing the habitat e.g. hard shells on a silty-clayish soft bottom, leading to a different benthic community. If the organic load is moderate the effects will be a change in species composition, species biomass and diversity. Oxygen depletion can occur when the organic load is high and/or the water renewal is poor. In Digernessundet it can be assumed that the first issue is the most ruling factor since the water renewal seems satisfactory. In many benthic surveys close to effluents of organic material e.g. sewage this is a well-known effect.

An assumed spreading distance of the material can be calculated from current and sinking velocity. Both factors will probably be highly variable. Mean current speed is typical 6-10 cm s^{-1} and maximum speed 50 cm s^{-1}. The current direction is changing with low tide and high tide. Sinking velocity of marine growth will also be highly variable. One can think of a sinking mussel as compared with partly dried seaweed. Both weight and shape are of importance. The mussel may sink with a velocity of 50 cm s-1 and the seaweed 1 cm s-1. A reasonable overall sinking velocity to use in calculation is 5-10 cm s-1. If we use sinking the velocity of 5 cm s-1, a particle would need 90 minutes to reach the bottom (270 m). During this time a current velocity of 5 cm s-1 would transport the particle 270 m away from the platform. Doubling the current speed would also of course double the distance. Doubling the sinking velocity would reduce the spreading correspondingly.

The MA is 150 m in diameter. If we assume a sinking velocity of 5 cm s^{-1} and a current velocity of 10 m s^{-1} (both directions) this could lead to a deposition area of 250*1230 m (including 150 m of MA). An area of 307,500 m^2 would mean 0.19-0.37 kg dry organic matter per m^2. Doubling the sinking velocity and reducing current speed to 5 cm s^{-1} would make the area 250*420. An area of 105,000 m^2 would mean 0.54-1.1 kg dry organic matter per m^2.

Conclusions

A reasonable course of events will be that most of the mussels and other heavy parts will sink to the bottom close to the platform, and the rest of the material will be spread over a large area. We believe that this will lead to spots on the seabed close to, and under, the platform that will be overloaded with organic material, causing temporary oxygen deficiency in the sediment. In the rest of the influence area the growth will be a source of food supply and cause less effect. We do not suspect oxygen deficiency in the water column. Since the material has marine origin there is natural scavengers (e.g. bacteria, crustaceans, worms, fishes) which will digest and decompose the growth. We assume that most of the organic material will be decomposed within a year after disposal. The benthic community may need a year extra to resemble the original situation.

Without knowledge about the benthic fauna in the area before, during or after the decommissioning it is not possible to estimate the effects of the disposal of the biomass on the benthic diversity.

2.2 Harmful substances within the growth

MA is not coated with paint on the steel construction subsurface. This means that there is no paint sticked to the growth which could make it contain harmful substances. The other possible source of pollution is through absorption from the environment round the growth.

A study of the metal content in mussels on MA was conducted in October 1999 and hydrocarbon content in June 2000 (Cordah 2000). The results are presented in Appendix, together with some data from the Esso Odin platform decommissioned by Aker in 1997. New samples are going to be taken and analysed in the spring of 2001 and this will give updated information of a potential pollution level. It is estimated that growth on MA includes 12 tonnes (wet weight) of mussels.

The results from 1999 and 2000 can be compared to SFT guidelines for environmental classification of coastal waters (SFT 1997). Only four of SFT's classification metals were analysed. The Mercury and Nickel content were lower than the limit value for unpolluted environment, but Lead and Cadmium were higher. We don't know how the sampling were done, but feel that one analysis is not sufficient to estimate the load to the area. The result indicates that there may be elevated levels for some of the metals. In other surveys RF have discovered large difference in metal content between different species (RF-2000/259, RF-2001/034). The next sampling on MA should also include dominating species other than mussels and include analyses of all SFT's classification metals as a minimum.

The PAH content in mussels from the splash zone (-2 m) and –12 m were higher than SFT's levels for unpolluted environment. Corresponding to the level of the compounds Benzo(a)pyrene (28 and 4 $ng.g^{-1}$) and sum 16 EPA PAH's (560 and 390 $ng.g^{-1}$) the mussel samples could be classified as markedly or grossly polluted. There was also a significant level of NPD's (3000 and 2000 $ng.g^{-1}$) in the samples. The highest hydrocarbon levels were detected in the sample from the splash zone. The mussel samples were taken from a riser when this was elevated during shut-down operation. The samples may have been contaminated during sampling or as a result from the activity during the shut-down operation. Again two samples are little to rely on and the new investigation in the spring of 2001 will give more information on the hydrocarbon content. After a time with little exposure to hydrocarbons the mussel will release their hydrocarbon to the environment (Aune 2000) and this may be the case before the platforms is towed inshore. PAH in organism are normally slowly metabolised and released from the organisms when exposure terminates. The load of these components can therefore be difficult to estimate before the actual release to Digernessundet. The present situation offshore might not be totally valid since the refloat part of the decommissioning might itself cause a considerable load of pollutant to the biota. Source of pollutants may be both from resuspension of sediment and cutting piles (despite the efforts planned to avoid this) and from the operation itself with all the vessel activity.

Conclusions

There is not sufficient knowledge about the content of potential harmful substances in the biota on MA to make a good description of effect from this on the seabed environment. Nevertheless it can be assumed that the levels are not in a magnitude that would lead to detectable elevated levels in the sediment. The biomass will also be spread over a large area.

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Appendix

Results from analyses of metal and hydrocarbon content in mussels (numbers taken from Cordah 2000).

Appendix Table 1. Consentration of metals (mg.kg $^{-1}$ dry weight) in mussels from the MA platform in October 1999 and Esso Odin 1997. N.a. = not available. Classification of pollutant according to limit values in SFT 97:03. Metals in italic is not included in SFT 97:03.

Metal	**SFT Class I**	**Mussels from Esso Odin**		**Mussels from MA**		**Total weight of**
	Not polluted	**Average**	**St.dev.**	**Dry weight**	**Wet weight**	**heavy metals in mussels (kg)**
As (Arsenic)	<10	9,30	1,16	n.a.	n.a.	n.a.
Pb (Lead)	<3	1,89	0,09	83	15	0,09
Cd (Cadmium)	<2	5,43	0,77	2,5	0,45	0,003
Cu (Copper)	<10	5,04	0,43	n.a.	n.a.	n.a.
Cr (Chromium)	<3	0,99	0,13	n.a.	n.a.	n.a.
Hg (Mercury)	<0,2	<0,15		<0,11	<0.02	0,0001
Ni (Nickel)	<5	1,03	0,36	2,8	0,5	0,003
Zn (Zinc)	<200	134	33	n.a.	n.a.	n.a.
Ag (Silver)	<0,3	n.a.		n.a.	n.a.	n.a.
Ba (Barium)				*20*	*3,6*	*0,02*
Sr (Strontium)				*83*	*15*	*0,09*
V (Vanadium)				*1,9*	*0,34*	*0,002*

Appendix Table 2. Consentration og hydrocarbons (µg.kg [-1] dry weight) in mussels from the MA platform in June 2000. See details in Cordah 2000. Classification of pollutant according to limit values in SFT 97:03. Nd = not detectable.

Sample	**Splash zone (ca. 2- m)**	**(ca. -12 m)**
Naphthalene	49	55
C1-Naphthalenes	78	65
C2-Naphthalenes	130	140
C3-Naphthalenes	290	260
C4-Naphthalenes	340	270
Total Naphthalenes	**890**	**790**
Phenanthrene	79	85
C1-Phenanthrene	420	260
C2-Phenanthrene	680	370
C3-Phenanthrene	630	280
Total Phenanthrenes 1	**800**	**990**
Dibenzothiophene	13	8.4
C1-Dibenzothiophenes	67	45
C3-Dibenzothiophenes	140	66
C4-Dibenzothiophenes	130	70
Total Dibenzothiophenes	**350**	**190**
Total NPD	**3 000**	**2 000**
Acenaphthylene	Nd	Nd
Acenaphthene	25	Nd
Fluorene	23	32
Anthracene	*	3.6
Fluoranthene	87	64
Pyrene	71	49
Benzo(a)anthracene	82	43
Chrysene	58	29
Benzo(b)fluoranthene	48	19
Benzo(k)fluoranthene	#	#
Benzo(a)pyrene	28	4.7
Indeno(1,2,3-cd)pyrene	5.2	2.0
Dibenzo(a,h)anthracene	2.9	0.42
Benzo(ghi)perylene	6.4	2.3
Total EPA 16	**560**	**389**
4-6 Ring PAHs/NPD	0.1	0.1
SFT Class B(a)P		
SFT Class 1, not polluted	<1	<1
SFT Class 2, moderate polluted	1-3	1-3
SFT Class 3, markedly polluted	3-10	3-10
SFT Class SUM 16 EPA PAH		
SFT Class 1, not polluted	<50	<50
SFT Class 2, moderate polluted	50-200	50-200
SFT Class 3, markedly polluted	200-2000	200-2000