

# Ekofisk I disposal: Impact Assessment

Environmental and Societal Impacts



# **EKOFISK I DISPOSAL: IMPACT ASSESSMENT**

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# PREFACE

The Phillips Norway Group, A/S Norske Shell, and Norpipe Oil AS own, in whole or in part,<sup>1</sup> several offshore facilities, located in the Greater Ekofisk Area on the Norwegian Continental Shelf, that are redundant or will become redundant in the coming years (referred to in this Report as the «Ekofisk I facilities»).

This Impact Assessment Report presents the results of an assessment of the effects on the environment and society estimated to result from implementation of each of the relevant Disposal Alternatives for Ekofisk I topsides, sub-structures, pipelines, drill cuttings and seabed debris.

This Report also assesses the environmental and societal impacts of the owners' recommended Disposal Scenario for the Ekofisk I Entities (the combined solution recommended by the owners for the Ekofisk I topsides, sub-structures, pipelines, drill cuttings and seabed debris).

The impact assessments of the Disposal Alternatives and the recommended Disposal Scenario described in this Report were performed by personnel from Det Norske Veritas and Asplan Viak. The technical justification for the Recommended Disposal Scenario (Section 11.2 of this Report) was prepared by Phillips Petroleum Company Norway (PPCoN).

During the course of the Ekofisk Cessation Project, certain terms and abbreviations have been assigned specific meanings. Appendix A to this Impact Assessment Report provides a description of some of the most relevant terms and abbreviations used in this Report.

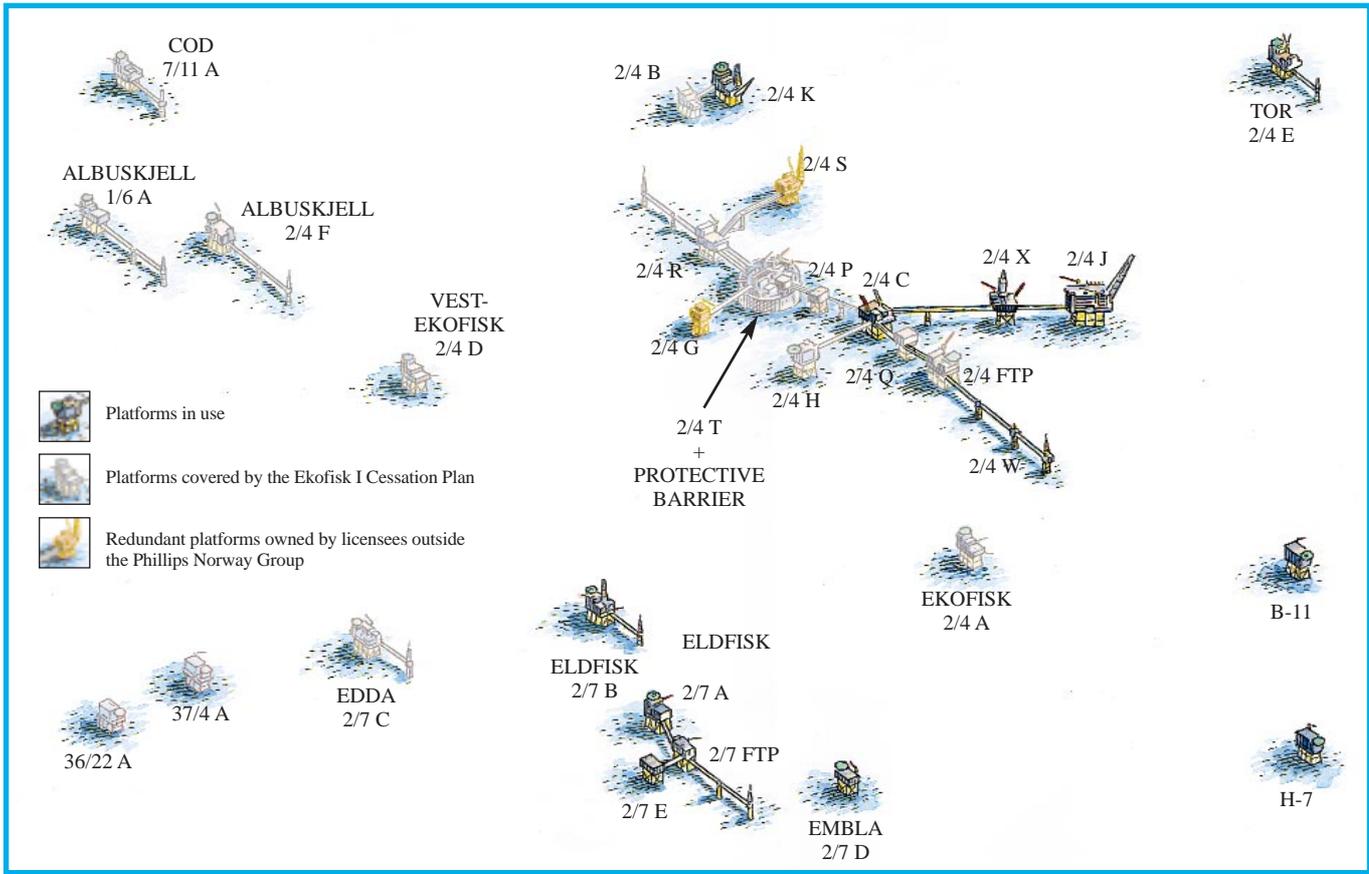
This is a translated version of the Report, which in its original form was written in Norwegian. In the case of any discrepancies, the Norwegian version prevails.

Stavanger, 22th October, 1999

*Lars Takla*  
Managing Director  
Phillips Petroleum Company Norway  
Scandinavian Division

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<sup>1</sup> The Phillips Norway Group owns eleven platforms and related facilities in the Ekofisk Area. The Phillips Norway Group also owns, together with A/S Norske Shell (50% each), two outlying platforms in the Ekofisk Area. Norpipe Oil AS owns two platforms on the Norpipe oil pipeline in the United Kingdom Sector of the North Sea.



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# SUMMARY

## Background

The Phillips Norway Group (PNG) discovered the Ekofisk Field in 1969. Development of Ekofisk and nearby fields transformed Norway into an oil and gas nation. The infrastructure in the Ekofisk Area has evolved continuously over the last twenty-five years, and today the Ekofisk Area has the highest concentration of offshore facilities and pipelines in the North Sea.

The development and operation of the Ekofisk Area fields, however, has not been without challenges. In the mid-1980's, the PNG observed that the seabed at Ekofisk was subsiding. To combat the effects of subsidence, the PNG elevated six platforms at the Ekofisk Center by six meters in 1987. In 1989 the PNG floated a concrete Protective Barrier Wall (PBW) in two parts to the field and installed it around the concrete Ekofisk 2/4 Tank to protect it against increased wave loads resulting from subsidence.

Despite the mitigating actions taken to combat subsidence, by the early 1990's the Ekofisk facilities were showing their age, operating costs were rising, and new safety requirements for continued use of the Ekofisk Tank facilities and continued seabed subsidence presented uncertainties about the future. As a result, the PNG, in consultation with the Norwegian Authorities, decided to redevelop the facilities at the Ekofisk Center. The new facilities – known as «Ekofisk II» – were completed and put into use in August 1998. Ekofisk II will allow production of the Ekofisk Area long into the next century to the benefit of the PNG and Norwegian society.

As a result of subsidence and the Ekofisk II development, and the fact that several outlying fields have reached the end of their economic life, thirteen platforms in the Ekofisk Area – twelve steel structures of varying sizes and the 2/4 Tank and its Protective Barrier Wall – are or will become redundant over the next fifteen years. Two additional steel platforms on the Norpipe Oil Pipeline are also redundant, and thus a total of fifteen redundant offshore structures require disposal solutions.

In 1994, the PNG established the Ekofisk Cessation Project (ECP) with the following objective:

*Final disposal of the Ekofisk I platforms will be performed in a safe, environmentally sound, and cost-effective manner. The goal is a solution acceptable to the Norwegian authorities, the Norwegian and international communities, and the Licensees.*

The ECP has spent five years and 100 million Norwegian kroner in fulfilment of its mission. The ECP has reviewed disposal options for the following five Entities:

- Topsides on all the redundant platforms
- Substructures comprising 14 steel jackets and the concrete Tank/PBW
- 235 km buried pipelines of various dimensions
- Seven drill cuttings piles
- Debris on the seabed

The ECP proceeded from a conceptual phase, in which 197 conceptual ideas for the redundant facilities were originally identified, through a feasibility stage, in which extensive technical, scientific and engineering screening studies reduced the number of viable alternatives, through a final, four-staged assessment stage to arrive at the PNG's recommended Disposal Scenario for the redundant Ekofisk I Entities. The short-listed Disposal Alternatives and the recommended Disposal Scenario were arrived at by conducting a comprehensive overall evaluation of the technical feasibility, safety risks, environmental effects, effects on society and public opinion, economic impacts, effects on fisheries, and impacts on other users of the sea.

## Purpose and Scope of the Impact Assessment

The purpose of this Impact Assessment is to provide an objective, well-documented assessment of the societal and environmental impacts of the short-listed Disposal Alternatives for all the Entities covered by the Ekofisk I Cessation Project. This information is also used to compile an Impact Assessment summary for the recommended Disposal Scenario.

The Impact Assessment is carried out in compliance with the Norwegian Petroleum Act and appurtenant regulations. This Impact Assessment, together with the Ekofisk I Cessation Plan, will form an important part of the information required by the Norwegian authorities to decide the final Disposal Scenario for Ekofisk I.

## Assessment Methodology

The methodology used in this Impact Assessment follows the main principles and guidelines provided by Norwegian legislation for such assessments. On a detailed level, the assessments cover the scope recommended by the Norwegian Oil Industry Association (OLF), with some supplements. The methodology and content of the Impact Assessment also complies with PPCoN's proposed «Programme for Impact Assessment», which was approved by the Ministry of Petroleum and Energy on October 20, 1998.

The environmental impacts of the Alternatives were assessed based on the following considerations:

- Energy (consumption and Total Energy Impact)<sup>2</sup>
- Emissions to the atmosphere
- Discharges to sea, water, or ground

<sup>2</sup> The Total Energy Impact is the sum of three different factors: (1) direct energy consumption for removal (e.g. fuels for vessels); (2) energy consumption required for processing and recycling of materials; and (3) indirect «replacement energy» i.e. the energy needed to produce new materials equal to the amount not being reused/recycled. See also section 2.3.1.

- Physical impacts/effects on habitat
- Aesthetic Effects: Noise, odors, visual pollution
- Waste/resource utilization
- Littering

The consequences to society and the community of each Alternative were assessed with respect to the following issues:

- Impacts on fisheries
- Impacts on free passage at sea
- Impacts on safety of personnel
- Costs and national goods and services
- Impact on employment

Cessation of Ekofisk I is much larger and more complex than cessation of any fields previously assessed in Norway. Accordingly, this Impact Assessment uses a slightly altered method of presentation and comparison of the impacts of the identified Disposal Alternatives than previous impact assessments in Norway. This process has sought to distinguish to a greater degree the important from the less important impacts. This was done by determining the importance of each issue in terms of the magnitude and range of its potential impact. Combined, these give the total impact. In this Report, the impact assessments, made in accordance with this methodology, are identified by the use of quotation marks (e.g. «Moderate negative»). The method is described in more detail in Section 2.3.

No attempt is made in the impact assessments to rank or weigh the different assessment issues against each other. However, this is done in a summary chapter for each entity. It is also done by the PNG in the form of an overall assessment of the recommended Disposal Scenario (see Chapter 11).

## Summary of Short-listed Disposal Alternatives

This Impact Assessment examines the effects and consequences of the identified Disposal Alternatives for the fifteen redundant Ekofisk I-installations and their associated pipelines. Fourteen of the installations are steel jacket structures and the fifteenth, the Ekofisk Tank with its surrounding concrete barrier wall, is a concrete gravity base structure (GBS). This Report also assesses the impacts of different ways of disposing the drill cuttings found under seven of the Ekofisk I installations which were used for drilling purposes, and the impacts of clearing debris from the seabed.

For each type of Entity investigated one (1) to five (5) Disposal Alternatives have been assessed. The short-listed Disposal Alternatives for each Entity are summarised as follows:

Entity	Alternatives Assessed				
<p><b>I Topsides</b></p>	<p><b>A</b></p>  <p><i>Jacket topsides:</i> Lift and Transport to shore for recycling</p> <p><i>Tank Topsides</i> Remove offshore and transport to shore for recycling</p>		<p><b>B</b></p>  <p><i>Jacket Topsides:</i> Lift and transport to shore for recycling</p> <p><i>Tank topsides:</i> Remove at shore &amp; recycle after tow to shore on substructure</p>		
<p><b>II Substructures</b></p>	<p><b>A</b></p>  <p><i>Jackets:</i> Reef in-place</p> <p><i>Tank:</i> Reef in-place</p>	<p><b>B</b></p>  <p><i>Jackets:</i> Reef at Tank</p> <p><i>Tank:</i> Reef in-place</p>	<p><b>C</b></p>  <p><i>Jackets:</i> Remove for onshore recycling</p> <p><i>Tank:</i> Leave in-place</p>	<p><b>D</b></p>  <p><i>Jackets:</i> Remove for onshore recycling</p> <p><i>Tank:</i> Refloat and Deposit deep water</p>	<p><b>E</b></p>  <p><i>Jackets:</i> Remove for onshore recycling</p> <p><i>Tank:</i> Refloat and recycle onshore</p>
<p><b>III Pipelines</b></p>	<p><b>A</b></p>  <p>Remove to shore for recycling of materials</p>		<p><b>B</b></p>  <p>Leave buried in-place</p>		
<p><b>IV Drill Cuttings</b></p>	<p><b>A</b></p>  <p>Remove, slurrify and reinject</p>	<p><b>B</b></p>  <p>Removal to shore for disposal</p>	<p><b>C</b></p>  <p>Leave in-place</p>	<p><b>D</b></p>  <p>Cover with gravel</p>	
<p><b>V Seabed</b></p>	<p>Remove debris</p>				

## Summary of the Impact Assessments of the Toppides Disposal Alternatives

### Description of the Toppides Disposal Alternatives

Toppides Disposal Alternatives	
<p><b>Alternative IA</b></p> <p><i>Jacket Toppides:</i> Lift and Transport to shore for recycling</p> <p><i>Tank Toppides:</i> Remove offshore and transport to shore for recycling</p> <hr/> <p>Estimated cost: 4.7 billion kroner*</p>	<p><b>Alternative IB</b></p> <p><i>Jacket Toppides:</i> Lift and Transport to shore for recycling</p> <p><i>Tank Toppides:</i> Remove at shore &amp; recycle after tow to shore on substructure</p> <hr/> <p>Estimated cost: 4.1 billion kroner</p>

\* All cost estimates in this impact assessment are calculated in 1998 Norwegian kroner.

Both topsides Disposal Alternatives require that all Ekofisk I topsides be removed. For the topsides on the steel jackets, the premised method of removal for both Alternatives is by reverse installation using semi-submersible crane vessels (SSCV). For the 82 modules on the Ekofisk Tank, however, there are two different locations for reverse installation: removal offshore (Alternative IA), or inshore removal after refloating and towing the Tank substructure and topsides to shore (Alternative IB).

### Environmental Impacts of the Toppides Disposal Alternatives

#### Energy, Emissions and Discharges

Removal of the topsides will require a massive effort in the form of marine operations, demanding high energy consumption and thus producing considerable atmospheric emissions. Likewise, demolition and recycling will result in energy consumption and atmospheric emissions. Alternative IA has a higher energy consumption (5.1 million GJ) than Alternative IB (4.4 million GJ). To put these figures in perspective, 5 million GJ is equivalent to the energy consumption for the town of Stavanger – a city with about 100,000 citizens – for more than 6 months. Alternative IA will also result in higher emissions (390,000 tonnes CO<sub>2</sub>) than Alternative IB (330,000 tonnes CO<sub>2</sub>). Since both Alternatives involve recycling of the topsides materials, the Total Energy Impact of each Alternative is the same as its energy consumption.

Alternative IB's lower energy consumption and resultant lower atmospheric emissions are attributable to savings achieved by removing the topsides inshore instead of offshore. However, to achieve the savings in energy and emissions the Tank substructure must be refloated and towed ashore, which, overall, would result in much higher energy consumption and atmospheric emissions than alternative IA. An attempt to refloat and move the Tank substructure also entails considerable risks (see discussion of substructure Disposal Alternatives below).

Neither of the two topsides Disposal Alternatives are expected to result in any discharges to sea, water or ground of significance.

### **Physical Impacts, Aesthetics and Waste**

None of the topsides Alternatives are expected to result in any physical environmental impacts of any significance.

Both topsides Alternatives will have negative aesthetic effects due to onshore demolition and recycling operations. Demolition operations generate noise, and depending on the location of these operations, would result in either a «moderate negative» impact or a «large negative» impact. Therefore it will be important to mitigate the negative impacts on the surroundings by appropriate choice of demolition site and implementation of noise-reduction measures.

The topsides are made largely of steel, which can be recycled, plus a range of other materials that must be disposed of as waste. Demolition activities will therefore generate considerable volumes of waste in addition to recyclable materials.

### **Societal Impacts of the Topsides Disposal Alternatives**

#### **Fisheries and Other Users of the Sea**

Removal of the topsides to shore will have no impact on either fisheries or free passage of shipping.

#### **Personnel Safety**

The actual removal operations and subsequent onshore demolition involve some 6.5 million man-hours and thus represent a certain risk to personnel. The estimated probability of loss of life (PLL) for the two operations is 22 per cent if the topsides on the Ekofisk Tank are removed inshore (Alternative IB), and 29 per cent if all the topsides are removed offshore (Alternative IA). The PLL for the inshore removal of the Tank topsides, however, must be considered in conjunction with the increased PLL caused by an attempt to refloat and move the Tank substructure onshore (see discussion of Substructure Alternatives below).

#### **Employment and Cost**

The total estimated cost of the two topsides Disposal Alternatives is 4.7 billion kroner for Alternative IA and 4.1 billion kroner for Alternative IB. While some cost savings would be achieved by removing the topsides inshore (Alternative IB), these would be far outweighed by the increased costs to refloat and tow the Tank substructure to shore (see discussion of Substructure Alternatives below).

The «Norwegian content» of the work, provided demolition takes place in Norway, is an estimated 65 per cent. If the demolition operation takes place abroad, the Norwegian content would fall to 55 per cent. Norwegian supplies (from service contractors) will give direct and indirect employment effects of some 4700 man-years if demolition takes place in Norway.

#### **Activity levels**

In combination with disposal of the Ekofisk I steel jackets, both topsides Alternatives would monopolize significant parts of the marine services fleet if the removal operations were concentrated over a relatively short time period. To leave capacity for other operations in the coming years and avoid over-activating the market, it is therefore preferable to spread the removal operation over several years. An optimal planning of the removal will also have economic benefits.

## Summary of the Impacts of the Substructure (Steel Jackets and Ekofisk Tank) Disposal Alternatives

### Description of the Substructure Disposal Alternatives

The Disposal Alternatives short-listed for the Ekofisk I substructures (steel jackets and concrete Tank with its Protective Barrier Wall) are summarised below:

Disposal Alternative	IIA	IIB	IIC	IID	IIE
	<i>Jackets:</i> Reef in-place	<i>Jackets:</i> Reef at Tank	<i>Jackets:</i> Remove for onshore recycling	<i>Jackets:</i> Remove for onshore recycling	<i>Jackets:</i> Remove for onshore recycling
	<i>Tank:</i> Reef in-place	<i>Tank:</i> Reef in-place	<i>Tank:</i> Leave in-place	<i>Tank:</i> Refloat, deposit in deep water	<i>Tank:</i> Refloat and recycle onshore
<b>Estimated Cost</b>	0.7 billion kroner	2.0 billion kroner	3.2 billion kroner	5.8 billion kroner	6.5 billion kroner

\* All cost estimates in this impact assessment are calculated in 1998 Norwegian kroner.

The steel jackets will either be toppled in-place to form reefs (Alternative IIA), will be placed around the Tank to form a cluster reef (Alternative IIB), or will be transported to shore for recycling (Alternatives IIC, IID, and IIE). With respect to the steel jackets, all of these Alternatives are based on use of proven methods.

The concrete Tank and its Protective Barrier Wall will either be left in-place as a reef (Alternative IIA or IIB), be deposited in-place (Alternative IIC), be refloated and deposited in deep water (Alternative IID), or be refloated and brought to shore for recycling to the extent practicable (Alt IIE). The reef and leave in-place options (Alternatives IIA, IIB, IIC) would involve equipping the concrete Tank with navigation aids in accordance with prevailing international requirements to ensure safety of navigation. An attempt to refloat and move the Tank (Alternatives IID and IIE), would require development and application of new and unproven methods having high technical risks.

### Environmental Impacts of the Substructure Disposal Alternatives

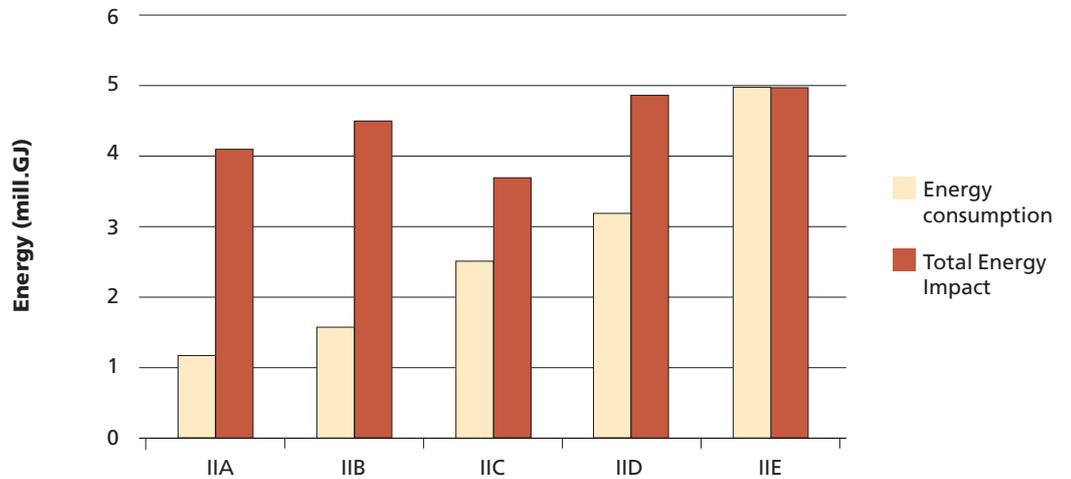
#### Energy

All the substructure Disposal Alternatives demand significant energy consumption and have high Total Energy Impacts. The Total Energy Impact is highest for Alternative IIE (remove all substructures – steel jackets and Ekofisk Tank – and dismantle and recycle onshore), see Figure 1. Alternative IIC (remove and recycle steel jackets, leave Tank in-place) has the lowest Total Energy Impact, approximately 25% lower than that of Alternative IIE.

The differences in direct energy consumption between the Alternatives are more significant, with the reef solutions (Alternatives IIA, IIB) requiring significantly lower energy consumption than the removal Alternatives (Alternatives IID, IIE). The direct energy consumption of Alternative IIC would be higher than that of the reef Alternatives (due to the energy required

to remove and recycle the steel jackets) but significantly less than the total removal and recycle Alternative.

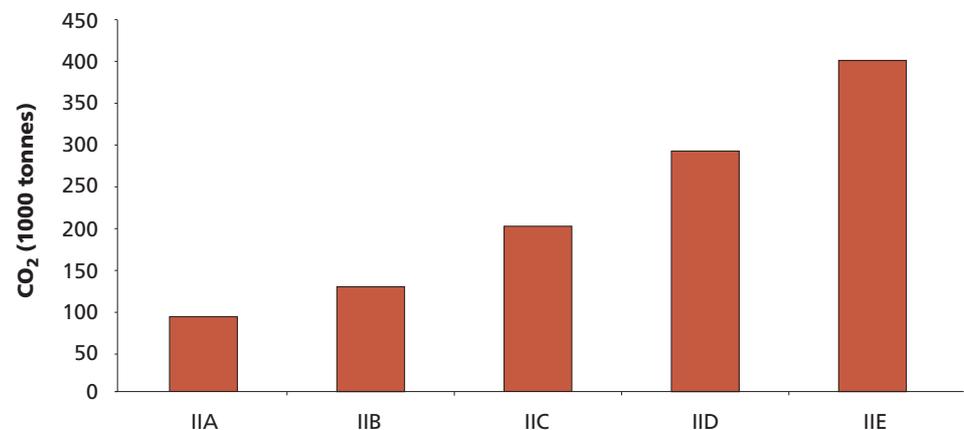
**Figure 1**  
*Energy consumption and Total Energy Impact for disposal Substructure Alternatives*



**Emissions to Atmosphere**

Emissions to the atmosphere caused by the Substructure Disposal Alternatives largely follow the same pattern as energy. Only direct CO<sub>2</sub> atmospheric emissions are considered in this summary. The direct «carbon» (CO<sub>2</sub>) releases, for instance, will vary from approximately 90,000 tonnes for Alternative IIA to 390,000 tonnes for Alternative IIE (see Figure 2 below). The maximum predicted is about 1 per cent of Norwegian annual emissions (Statistics Norway, SSB, 1998), released over several years. The reef Alternatives (IIA, IIB) result in least atmospheric emissions, approximately 70–75% less than the complete removal Alternatives (IID, IIE). Alternative IIC (removal and recycling of the steel jackets and leaving the Tank in-place) results in approximately 40–60% more emissions than the reef Alternatives, but 25–50% less emissions than the refloat Alternatives (Alternatives IID, IIE), as shown in the following figure:

**Figure 2**  
*Atmospheric emissions from substructure Disposal Alternatives*



### **Discharges**

None of the Substructure Disposal Alternatives are expected to cause discharges into the sea that would cause negative environmental impacts of any significance.

### **Physical Impacts, Aesthetics, Waste and Littering**

To remove the Ekofisk Tank, ballast (sand and gravel) must be removed at the field. This may be released to the seabed in the area, which would have impacts on the seabed and organisms living there. This was assessed to represent a «moderate negative» impact. Lesser impacts can also be expected in connection with toppling the jackets to create artificial reefs, and in connection with deep water disposal of the Tank.

Significant aesthetic effects on health and the local environment are generally related to noise and the generation and spread of dust. The dust problem is only significant with respect to the recycle Alternative for the Ekofisk Tank (Alternative IIE), whereas noise is a relevant concern for all substructure recycle Alternatives (with respect to dismantling and recycling operations both for the steel jacket and for the concrete Tank). The choice of demolition yard, coupled with monitoring and perhaps implementation of countermeasures, will therefore be very important for mitigating any such impacts.

The volumes of waste generated during recycling operations depend largely on the fouling (marine growth) on the installations. There is also some uncertainty regarding whether the Ekofisk Tank concrete can actually be entirely recycled or reused as filler material (Alternative IIE), or whether it has to be disposed of as waste. The leave-in-place Alternatives (IIA, IIB, IIC) and the deep-sea Disposal Alternative (IID) would not generate much waste.

The resource utilization for each Alternative was also studied. Reuse of the installations as artificial fish reefs (Alternatives IIA, IIB) was found to be positive but not optimal. Demolition and recycling of the Tank (Alternative IIE) was found to be both resource and energy intensive. Leaving the Tank in-place means discarding materials that are not considered to represent a valuable resource (concrete, whose main recycling potential is as filler). Thus, from a resource utilization point of view, recycling the Tank is relatively less positive than recycling the steel substructures, even if the concrete reinforcement steel is taken into account.

In this Impact Assessment, «littering» was defined as leaving something behind that was not originally present in the environment, and/or dispersal of materials that could potentially litter other areas. Using this definition, «littering» impacts were identified mainly in connection with the fish reef Alternatives, which after a very long time will eventually degrade and end up as «litter».

## **Societal Impacts of the Substructure Disposal Alternatives**

### **Impact on Fisheries**

The Ekofisk Area is described as an area that is not very important for Norwegian and international fishing activities. Still, some fishing does take place, generally with trawls or purse seine gear.

Evaluating the consequences to fishing of the various Disposal Alternatives for the Ekofisk I substructures presents some challenges, in part due to the

differing interests of different parts of the North Sea fishing industry, and in part due to the lack of data regarding the effects of reefs in the North Sea. In relation to existing fishing operations in the area (mainly trawling and purse seine), Alternatives involving removal of possible obstructions will be considered positive. However, the magnitude of the benefit is difficult to estimate. On the other hand, construction of artificial fish reefs would to a certain extent have positive effects for those parts of the fishing industry which use passive implements – mainly nets and possibly lines. The extent of this positive reef effect in the North Sea is, again, difficult to quantify. Scientists at the Institute of Marine Research have tried to quantify the effects of artificial reefs in the North Sea, but many questions remain unanswered. This Report approaches the problem by according greatest weight to the main existing fishing activities on the Ekofisk Area, which means greatest emphasis on removal of obstacles to seine and trawl fishing, and less focus on reef benefits.

Reefs are successfully used in other areas of the world, but generally close to shore and with more support from various interest groups. Accordingly, the following impacts on fishing were identified for each substructure Disposal Alternative:

	<b>IIA</b>	<b>IIB</b>	<b>IIC</b>	<b>IID</b>	<b>IIE</b>
	<i>Jackets:</i> Reef in-place	<i>Jackets:</i> Reef at Tank	<i>Jackets:</i> Remove for onshore recycling	<i>Jackets:</i> Remove for onshore recycling	<i>Jackets:</i> Remove for onshore recycling
	<i>Tank:</i> Reef in-place	<i>Tank:</i> Reef in-place	<i>Tank:</i> Leave in-place	<i>Tank:</i> Refloat, deposit in deep water	<i>Tank:</i> Refloat and recycle onshore
Area released (km <sup>2</sup> )	0	21–23	22.5	24	24
Number of areas with obstacles	8	1	1	0	0
Reef-effect	1–3 boats	1–3 boats (after 2028)	None	None	None

**Other Users of the Sea**

The Ekofisk Area is considered of moderate importance to shipping, as a variety of shipping lanes pass through the area. Thus the situation today represents some risk that collisions between ships and installations may occur. All Alternatives will necessarily improve this situation, since they all represent some degree of removal of the installations from the zone where surface vessels operate.

The construction of a reef in-place would (depending on the final configuration) uphold a risk to shipping, since some of the toppled jackets and the Tank would be tall enough to extend into the zone where large surface vessels operate. A reef at the Tank or simply leaving the Tank in-place would considerably reduce the risk to shipping, since all the substructure Entities would then be gathered in one small area, and thus these Alternatives (IIB, IIC) have «small positive» impacts on free passage of shipping.

Disposal Alternatives whereby all jackets and the Tank are removed are considered to provide a «large positive» impact on free passage of shipping.

### Personnel Safety

The scope of the work operations will be different for the five Substructure Alternatives. The Table below shows the estimated Potential Loss of Life (PLL) values for each alternative. The PLL figure represents the risk of fatality during an operation (e.g. a PLL at 0.08 means 8 per cent probability for a fatal accident).

	<b>IIA</b>	<b>IIB</b>	<b>IIC</b>	<b>IID</b>	<b>IIE</b>
	<i>Jackets:</i> Reef in-place	<i>Jackets:</i> Reef at Tank	<i>Jackets:</i> Remove for onshore recycling	<i>Jackets:</i> Remove for onshore recycling	<i>Jackets:</i> Remove for onshore recycling
	<i>Tank:</i> Reef in-place	<i>Tank:</i> Reef in-place	<i>Tank:</i> Leave in-place	<i>Tank:</i> Refloat, deposit in deep water	<i>Tank:</i> Refloat and recycle onshore
<b>PLL</b>	0.08	0.13	0.16	0.27	0.29

As this Table shows, the two reef Alternatives have the lowest risks of loss of life (8% and 13%). Leaving the Tank in place but bringing the steel jackets ashore (Alternative IIC) increases the PLL to 16%, but that Alternative has a considerably lower PLL than the two Alternatives involving refloat of the Tank (Alternatives IID and IIE), which nearly double the risk of loss of life to 27–29%.

### Employment and Cost

The cost of each Alternative is presented below, including an indication of the estimated «Norwegian content» (goods and services) and national employment effects of each.

	<b>IIA</b>	<b>IIB</b>	<b>IIC</b>	<b>IID</b>	<b>IIE</b>
	<i>Jackets:</i> Reef in-place	<i>Jackets:</i> Reef at Tank	<i>Jackets:</i> Remove for onshore recycling	<i>Jackets:</i> Remove for onshore recycling	<i>Jackets:</i> Remove for onshore recycling
	<i>Tank:</i> Reef in-place	<i>Tank:</i> Reef in-place	<i>Tank:</i> Leave in-place	<i>Tank:</i> Refloat, deposit in deep water	<i>Tank:</i> Refloat and recycle onshore
Costs (kroner)* (BL)	0.7	2.0	3.2	5.8	6.5
Norwegian content (%)	15–19	19–21	20–23	43–44	36–52
Man-years	190	640	1000	3500	4700

\* In 1998 terms

### Activity levels

As described in the case of the topsides, removal of the substructures will tie up much of the heavy-lift capacity available in the North Sea if the operations are executed on a tight schedule. Any spread in time will therefore be helpful

as it will relieve pressure on the market and spread the societal effects over a longer period. A later removal of the jackets also permits removal technology to advance and less energy-intensive and less costly equipment to be developed (e.g. equipment for cutting of foundation piles).

## Summary of Assessments of the Pipeline Disposal Alternatives

### Description of Pipeline Disposal Alternatives

There are two short-listed Alternatives for redundant Ekofisk I pipelines: remove to shore for recycling of materials (Alt. IIIA), or leave buried in-place (Alt. IIIB).

Pipelines Disposal Alternatives	
<b>Alternative IIIA</b>	<b>Alternative IIIB</b>
Remove to shore for recycling of materials	Leave buried in-place
Estimated cost*: 2.6 billion kroner	Estimated cost: 30 million kroner

\* in 1998 terms

### Environmental Impacts of Pipeline Disposal Alternatives

#### Energy

Removal and demolition of the pipelines would require considerable energy consumption. Leaving in-place requires almost no energy, but still constitutes a slightly negative Total Energy Impact due to the recyclable resources that are left in-place. Nevertheless, leaving the pipelines in-place (Alternative IIIB) has a 40% less Total Energy Impact than removing them (Alternative IIIA): 1.6 million GJ for removal and 0.9 GJ for leaving in place.

#### Emissions and Discharges

Emissions to the atmosphere follow the same pattern as energy consumption: direct carbon dioxide releases will be about 120,000 tonnes for removal (Alternative IIIA), but only 1,000 tonnes for leaving in-place (Alternative IIIB). The corresponding figures for nitrogen oxides (NO<sub>x</sub>) are 1,700 for removal and 20 tonnes for leave-in-place.

None of the Disposal Alternatives would result in any direct discharges into the sea. However, removal of the pipelines would disturb bottom sediment, and if contaminants are present in the sediments, this «re-suspension» process could have adverse environmental effects. All told, this was assessed as representing a «small negative» impact for Alternative IIIB. Leaving pipelines in place will result in a very gradual release of metals to the ground over time as the pipelines disintegrate, but this was found to result in an «insignificant» impact.

#### Physical Damage, Aesthetics and Waste

The physical effects on the seabed are related to recovery of the pipelines, and those effects would be local. For a total recovered pipeline length of about 235 km, the impact assessment results in a «small negative» rating. On the other

hand, leaving in-place preserves habitat and the benthic organisms which have come to reside there.

Onshore demolition of the pipelines also involves the potential for negative aesthetic impacts due to noise. Since experience with pipeline demolition is limited, the magnitude of this consequence remains rather uncertain. The potential is, however, negative.

Apart from the steel, which is recyclable, pipelines are coated with considerable volumes of concrete and also lesser quantities of other materials. The volume of the concrete and other material could be very large: about 50.000 tonnes. Some of the concrete could possibly serve as construction fill material, while the rest would have to be disposed of as waste (e.g. in a landfill).

Leaving the pipelines in-place has no environmental impacts of significance. One key reason for this is that they are cleaned and buried to a depth of between 0.8–2.5m.

## Societal Impacts of the Pipeline Disposal Alternatives

### **Fisheries and Other Users of the Sea**

Since the pipelines are cleaned and buried or covered they have no negative impacts on fisheries or passage of shipping. Measures are proposed for monitoring and also for action if parts of the pipelines become exposed within the subsidence area around the Ekofisk Center, for as long as production continues from Ekofisk II. Thus, neither of the two pipeline alternatives is expected to affect fisheries or passage in any way.

### **Personnel Safety**

The safety aspects are very different for the two Alternatives. Alternative IIIB (leave buried in-place) represents no safety risks. Removing the pipelines (Alternative IIIA), on the other hand, would pose risks in the same range as normal offshore operations, with an estimated loss of life of 10%.

Onshore demolition of pipelines and separation of their various materials have a certain potential for negative health effects. Knowledge of these aspects is, however, limited.

### **Employment and Cost**

The work operations for removal and demolition of the pipelines will require about 1.6 million man-hours. By contrast, measures for leaving in-place only requires about 1 to 3 per cent of this total.

The cost estimates for the short-listed Disposal Alternatives are 2.6 billion kroner and 0.03 billion kroner, respectively, for removal and leave in-place. The estimated Norwegian content is some 32 and 50 per cent respectively for these Alternatives, provided the demolition contractor is in Norway. Norwegian services will offer direct and indirect production effects totalling some 1500 man-years provided demolition takes place in Norway, and 50 man-years for leaving the pipelines in-place.

## Summary of the Impacts of Alternatives for the Drill Cuttings Piles

### Description of Disposal Alternatives for the Drill Cuttings Piles

Accumulations of drill cuttings, the stone fragments that are generated as the drill bit cuts through rock, are found below seven Ekofisk I drilling installations. The cuttings piles at Ekofisk are relatively small by North Sea standards, but contain some hydrocarbons and also some heavy metals associated with the bante.

Disposal alternatives	IVA	IVB	IVC	IVD
	Remove, slurrify and reinject	Removal to shore for disposal	Leave in-place	Cover with gravel
Estimated cost*	710 mill. kroner**	669 mill. kroner**	0	22 mill. kroner

\* in 1998 terms (\*\* indicative cost estimates, since acceptable removal methods have not been identified).

### Environmental Assessment of Cutting Piles Disposal Alternatives

#### Energy and Atmosphere Emissions

No quantifications of energy consumption for the different Alternatives have been made. Nevertheless, it is clear that the Alternatives that require removal will require higher energy consumption than those that involve leaving in place. Leaving in place with no cover (Alternative IVC) will not require energy consumption.

Atmospheric emissions will have the same relative proportions as direct energy consumption.

#### Discharges to sea

Knowledge regarding different Disposal Alternatives for drill cuttings remains limited. Nevertheless, an assessment has been made in respect of the marine environment based on the available information.

Both Disposal Alternatives that involve removal the cuttings piles (Alternatives IVA and IVB) have significant potential for release and distribution of any pollutants present. There are, however, large differences between the different technical methods.

Cuttings left in-place (Alternatives IVC and IVD) might be affected by removal of the associated steel jackets. This could lead to the swirling up of sediment and the spread of any contaminants that might be present. A later removal of the jackets would thus have a positive effect on the cuttings piles, which measurements show are diminishing with time. The environmental impact of erosion at Ekofisk I platforms is evaluated to be less than any physical disturbance of the cuttings piles, since natural erosion involves a small and very gradual release of any contaminants. Although no release can be said to be positive in itself, particularly in regard to bioaccumulation, a gradual process will reduce the chance of acute impacts. It will also allow a natural decomposition of hydrocarbons over time.

Covering the piles (Alternative IVD), an option available when the jackets are removed, could potentially disturb them and cause re-suspension of sediment with release of contaminants from the piles in the short-term. In the long-term, however, covering the piles would not have any significant environmental impacts.

### **Physical Impacts, Aesthetics and Waste**

Removal of the cuttings piles (Alternatives IVA and IVB) will cause a change to the local environment. Disturbance of sediment in connection with a removal would cause fine particles to precipitate on the sea bed in the area, covering marine bottom fauna.

Leaving in place (Alternative IVC) will preserve habitat and the bottom dwelling organisms that are established there.

Covering the piles (Alternative IVD), would give a small positive effect in the form of a new, uncontaminated surface, but would at the same time disturb the established habitat. The impact is assessed as «insignificant».

Negative aesthetic effects will mainly be associated with Alternative IVB – removal for disposal on land. These will be associated with effects on the local environment from temporary storage, handling, and final deposition.

Treatment and disposal on land (Alternative IVB) would create a quantity of waste which would have to be disposed. Leaving in-place (Alternative IVC) would neither generate waste nor consume resources. Covering (Alternative IVD) would involve a certain consumption of resources (gravel), but in limited quantities.

## **Societal Impacts of the Disposal Alternatives for the Drill Cuttings Piles**

### **Fisheries and Other Users of the Sea**

Accumulations of cuttings on the seabed may represent a slight contamination risk to trawls and catches. A later removal of the steel jackets, allowing time for natural erosion to slowly disperse the cuttings, would mitigate this effect.

Drill cuttings which are either covered or removed will have no negative effect on fisheries.

The drill cuttings piles have no effect on ship passage.

### **Personnel Safety**

Operations for removal do not involve intense activity, and are not particularly risky in relation to other offshore operations. The PLL estimate for the removal Alternatives (IVA and IVB) is on the order of 1%. Other Alternatives have no (Alternative IVC) or insignificant (Alternative IVD) PLL.

### **Employment and Cost**

The estimated cost of removing the cuttings piles is in the region of 700 million kroner. These estimates are only indicative, as application of available technology for this purpose is untried. Operations to cover the piles would cost about 20 million kroner. The Norwegian content of the alternatives is 23–50 per cent, for an employment effect of between 30 and 300 man-years.

## **Summary of Impacts of the Seabed Debris Disposal Alternative**

### **Description of the Seabed Debris Disposal Alternative**

The only short-listed Alternative for the seabed is to remove the debris.

### **Environmental Impacts of the Debris Disposal Alternative**

Any removal of objects from the seabed would have a very positive effect with respect to the littering issue. Except for a small consumption of energy, no other environmental impacts are expected.

### **Societal Impacts of the Debris Disposal Alternative**

Removal of debris from the seabed after removal of the installations would have a positive effect on bottom fishing (trawling, nets, lines). The cost estimate is about 70 million kroner, and thus these operations are not expected to have any social consequences of significance.

## **The Owners' Recommended Disposal Scenario**

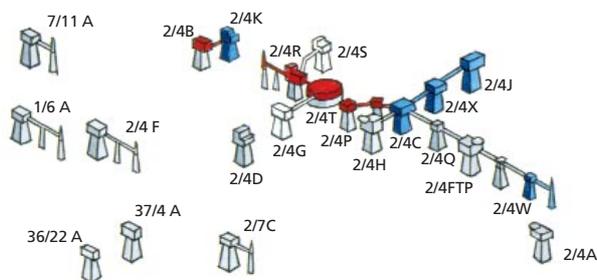
The PNG arrived at its recommended Disposal Scenario by conducting an overall assessment of all relevant factors connected with shutdown and disposal of Ekofisk I in accordance with the criteria laid down in the Norwegian Petroleum Act.

In this process, Phillips, on behalf of the owners of the Ekofisk I facilities (Phillips Norway Group, A/S Norske Shell, and Norpipe Oil AS), has conducted an overall assessment of the topics covered in this Report (natural resources, environment, safety, society, fisheries, marine operations), as well as the technical, logistical, economic, and public opinion aspects of the various Disposal Alternatives, to arrive at the optimum Ekofisk I Disposal Scenario. The PNG's resultant recommended Disposal Alternatives for the Ekofisk I Entities are shown in colour below (see Chapter 11 for a summary of the justifications for this Scenario):

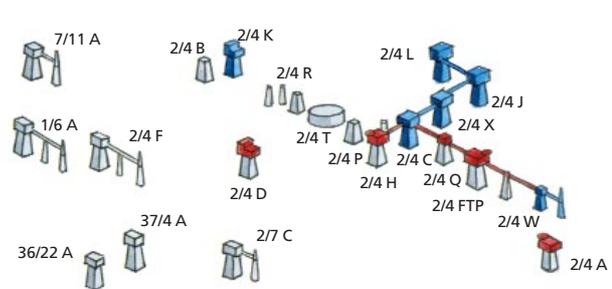
Entities		Alternatives Assessed (recommended alternatives in colour)				
I Topsides	<b>A</b> Jacket Topsides: Lift and Transport to shore for recycling  Tank Topsides: Lift and transport to shore for recycling			<b>B</b> Jacket Topsides: Lift and transport to shore recycling  Tank Topsides: Remove at shore & recycle after tow to shore on substructure		
	<b>A</b> Jackets: Reef in-place  Tank: Reef in-place	<b>B</b> Jackets: Reef at Tank  Tank: Reef in-place	<b>C</b> Jackets: Remove for onshore recycling  Tank: Leave in-place	<b>D</b> Jackets: Remove for onshore recycling  Tank: Refloat and Deposit deep water	<b>E</b> Jackets: Remove for onshore recycling  Tank: Refloat and recycle	
II Substructures	<b>A</b> Remove to shore for recycling of materials		<b>B</b> Leave buried in-place			
III Pipelines	<b>A</b> Remove, slurrify and reinject in waste well	<b>B</b> Removal to shore for disposal	<b>C</b> Leave in-place	<b>D</b> Cover with gravel		
IV Cutting Piles	Remove Debris					
V Seabed	Remove Debris					

The timetable proposed by the PNG for disposal work is split into four separate and successive removal campaigns. Campaigns 1–3 cover removal of the topsides, while Campaign 4 covers jacket removals, as depicted in Figure 3 below:

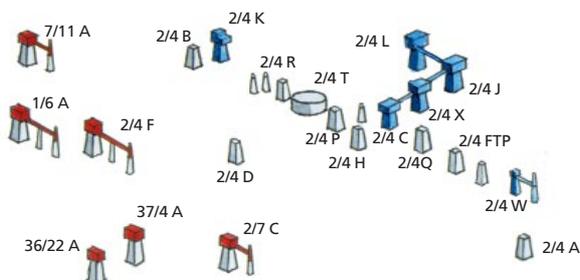
**CAMPAIGN 1: 2003–2008**



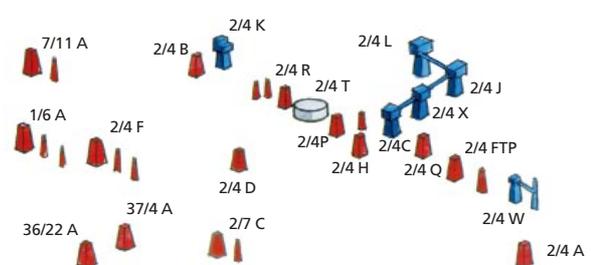
**CAMPAIGN 2: 2008–2013**



**CAMPAIGN 3: 2013–2015**



**CAMPAIGN 4: 2015–2018**



**Figure 3**

Removal Campaigns: Components marked in red are removed in each campaign. Installations marked in blue represent Ekofisk II installations. The disposal timing for 2/4 A and 2/4 B is indicative. The 2/4 G installation, owned by the BP Amoco Group, and the 2/4 S installation, owned by Statpipe, are outside the scope of this impact assessment.

Campaign 1 is given priority due to safety concerns (increased wave loads due to increased water depth resulting from subsidence of the seabed). This campaign will remove the topsides on the Ekofisk Center North and Ekofisk 2/4 B.

In Campaign 2, additional topsides affected by subsidence will be removed: topsides on Ekofisk Center South, Ekofisk 2/4 D and Ekofisk 2/4 A. Most of the topsides at Ekofisk Center South cannot be removed before 2012 because they provide important access to some of the Ekofisk II installations.

Campaign 3 involves the removal of the remaining topsides, those on the outlying installations which are not affected by seabed subsidence.

Campaign 4 covers completion of the disposal work including removal of the steel jackets, covering of pipeline ends and removal of seabed debris.

The impacts of the recommended Disposal Scenario are summarised in brief below.

## **Summary of Impacts for the Owners' Recommended Disposal Scenario**

### **Environmental impacts, Recommended Disposal Scenario**

#### **Energy**

The recommended Disposal Scenario is estimated to have a total energy consumption of some 7.6 million GJ, which is 35 per cent more than the energy-optimal solution (which would involve creation of artificial reefs instead of recycling the steel jackets), and 35 per cent less than the most energy-intensive solution (which would include removing and recycling the Ekofisk Tank and redundant pipelines).

The Total Energy Impact of the recommended Disposal Scenario, 9.7 million GJ, is the lowest Total Energy Impact among all the Disposal Scenarios, about 17 per cent below the Scenario with the highest Total Energy Impact (which would include removing and recycling the Tank and redundant pipelines).

#### **Emissions and Discharges to Sea**

The total emissions of CO<sub>2</sub> are about 580,000 tonnes spread over a period of about 15 years. This is 36 per cent less than corresponding emissions from the Scenario with the highest emissions.

The corresponding figures for NO<sub>x</sub> are 9,100 tonnes, which is 30% less than the Scenario with the highest emissions. For sulphur dioxide, SO<sub>2</sub>, the solution means the release of 970 tonnes, 35% less than the Scenario with the highest emissions.

The recommended Alternatives will not have any impacts of significance with respect to discharges into the sea.

#### **Physical impacts, aesthetic effects, waste and littering**

Any effects on the habitat or other physical impacts of the Recommended Alternatives are marginal.

Aesthetic effects are mainly connected with noise from the onshore demolition of the steel jackets and topsides. Relative to other Disposal Alternatives dust will not be an issue, and even the extent of noisy operations is less relative to most of the Alternatives.

The solution will result in the recycling of about 160,000 tonnes of steel, whereas about 15,000 tonnes of waste will have to be disposed of, about half being marine growth.

Leaving the buried pipelines in-place is not expected to cause a genuine littering effect as they are buried beneath the seabed. Disintegration of the Ekofisk Tank will take hundreds of years, and is not expected to result in any littering of significance. In the future, the possibility of accelerating the disintegration process by the employment of explosives or other means may be exercised, providing any environmental impacts arising therefrom can be acceptably mitigated.

The seabed will be cleared of debris in one operation when the disposal operations are completed.

## Societal Impacts, Recommended Disposal Scenario

### Fisheries and Other Users of the Sea

For fisheries, the recommended Disposal Scenario will ultimately open significant areas for fishing. The only remaining obstacle from Ekofisk I will be the Ekofisk Tank.<sup>3</sup> Overall, this is considered a good solution for fishing interests.

In relation to marine activities the left-in-place Ekofisk Tank will represent the sole risk. The risk is very small and the installation will be marked with navigation aids to secure safety of navigation.

### Personnel Safety

The total Potential Loss of Life (PLL) for the recommended Disposal Scenario is 0.45, which means that there is a 45% probability for loss of life in the activities connected with implementation of the Scenario. Other Scenarios have PLLs ranging from 68% for Scenario IA-III-III A-IVA-VA, to 37% for Scenario IA-IIA-IIIB-IVC-VA.

### Employment and Cost

The overall cost of the recommended solution is 8 billion kroner, which is 3 billion more than the least costly Scenario (Alternatives IA-IIA-IIIB-IVC-VA), and 6.6 billion less than the most expensive Scenario (Alternatives IA-III-III A-IVA-VA).

The recommended Scenario has a Norwegian content (value credited) for the work of about 41–50 per cent. In fact, all the Disposal Scenarios have relative Norwegian contents in the region of 50 per cent.

In total, the solution will require 5700 man-years of direct and indirect employment. Spread over the four disposal phases, this means an average annual employment increment of 200–500 jobs each year.

## Legal considerations

The fate of redundant offshore installations is to be decided by the Norwegian Authorities in accordance with applicable Norwegian legislation, primarily the Petroleum Act of 1996. The Petroleum Act requires the licensees to submit a Cessation Plan (including an Impact Assessment) that will

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<sup>3</sup> Disposal of Ekofisk II installations is not considered in this evaluation.

provide the information, evaluations and recommendations necessary for the authorities' decision. The Petroleum Act mandates that the decision shall be based on a broad-based evaluation of all relevant factors, including technical, safety, environmental and economic aspects as well as consideration for other users of the sea. The final Disposal Alternatives may include further use in petroleum activities, new uses (including use as an artificial reef), complete or partial removal, or deposit in-place. The Norwegian regime is consistent with all relevant international guidelines and conventions.

The owners of the Ekofisk I, the Phillips Norway Group, A/S Norske Shell and Norpipe Oil AS, arrived at the recommended Disposal Scenario in accordance with the assessment criteria laid down in the Norwegian Petroleum Act of 1996. The recommended Disposal Alternatives are consistent with applicable Norwegian petroleum legislation. They are also consistent with certain international guidelines and conventions – OSPAR decision 98/3 and the 1989 IMO Guidelines – which will be considered by the Norwegian Authorities when making its decision on Ekofisk I disposal. After an overall evaluation, the licensees recommend that the Ekofisk Tank and its Protective Barrier Wall be adequately marked for navigation purposes and left in-place. This is consistent with both the IMO Guidelines and OSPAR Decision 98/3, which allow certain redundant offshore facilities – including concrete structures – to be left in-place when the Authorities find that such a result is preferable to re-use, recycling or final disposal on land.

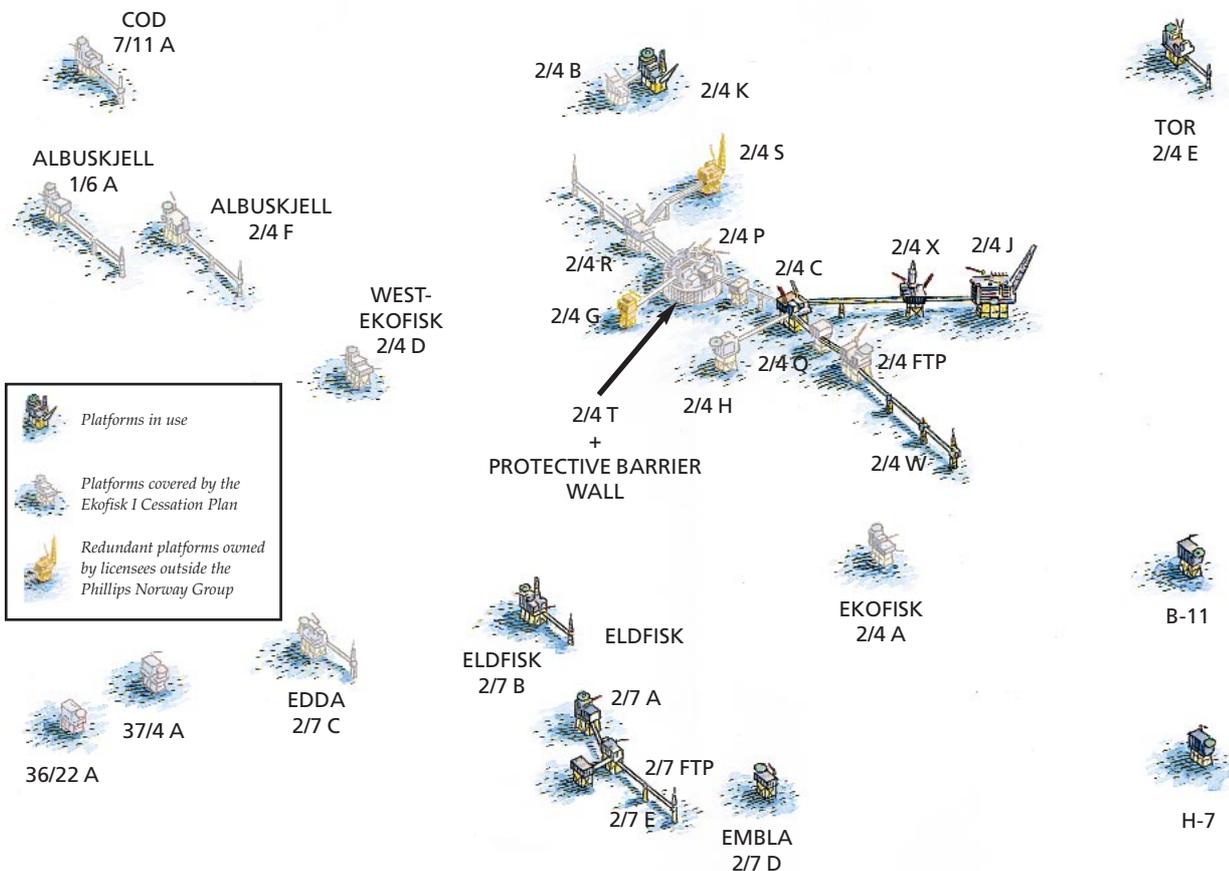
# 1 INTRODUCTION

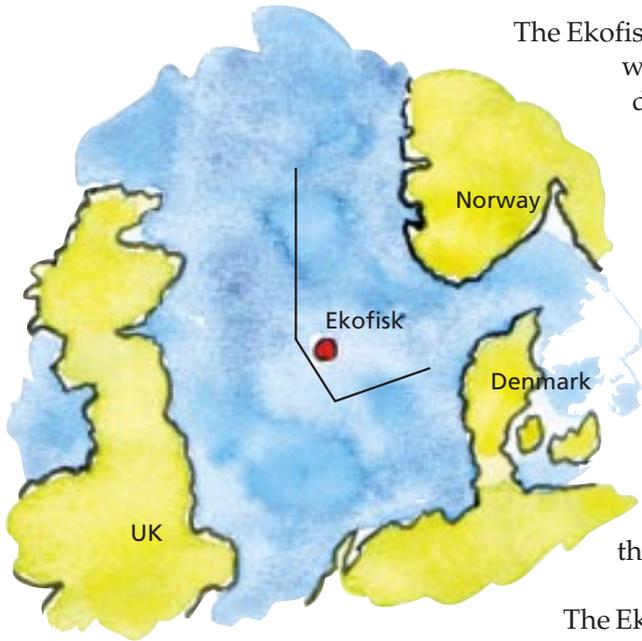
## 1.1 Brief Description of the Ekofisk I Facilities

The Ekofisk field was discovered in 1969 and was the first field in the North Sea to commence production of crude oil. From first production in 1971 until 1999, over 350 million standard cubic metres of oil and condensate, plus 215 billion standard cubic metres of natural gas, were produced from the Ekofisk Area fields. Figure 4 provides an illustration of the fixed installations in the Greater Ekofisk Area.

**Figure 4**

*Ekofisk I and II installations. Distances on diagram are not true to scale.*





The Ekofisk Area is situated in the central part of the North Sea where water depths range from 66 to 78 metres. It was developed in phases and now hosts a total of 30 fixed installations (see Figure 4). The Ekofisk II Plan for Development and Operation was approved by the Norwegian Parliament in the spring of 1994. As a result of the Ekofisk II development, two new platforms have been installed at the Ekofisk Center: Ekofisk 2/4 X, a drilling and wellhead platform, and Ekofisk 2/4 J, a process and transport platform. As a consequence, several existing installations became redundant and were shut down. Thus there are now twelve platforms at the Ekofisk Center, some redundant, and others providing field center functions for Ekofisk as well as being the node for the process and export of oil and gas from outlying fields and from other Norwegian fields.

The Ekofisk Center has a northern and a southern part. The northern Center consists of the installations Ekofisk 2/4 P, 2/4 R and 2/4 T, plus platforms 2/4 G and 2/4 S, which are owned by other licencees and hence are not part of this Impact Assessment. The southern part of the Center consists of Ekofisk 2/4 H, 2/4 C, 2/4 Q, 2/4 FTP, and 2/4 W, plus the two new installations, 2/4 X and 2/4 J. Plans to replace the present 2/4 Hotel platform with a new Living Quarters platform at the Center, Ekofisk 2/4 L, are under consideration, and a decision will be dependant upon future subsidence rates. A few miles to the south and north of the Center lie platforms 2/4 A, 2/4 B and 2/4 K.

Apart from the Ekofisk Center the Ekofisk Area also embraces the «outlying» fields: the Cod, Albuskjell, West Ekofisk, Tor, Edda, Eldfisk, and Embla fields.

This Report also considers two decommissioned booster platforms in the UK Sector of the North Sea, along the Norpipe oil pipeline to Teesside.

*Ocean Viking:  
Testing of the first discovery  
well in 1970*



The installations examined in this Report are all described in more detail in Chapter 3.

## 1.2 Ownership of Ekofisk I Facilities

The Licensees in the PNG Production Licence 018, with the participants' respective percentage interests before and after the Ekofisk II development, were/are:

### PL 018 License (Ekofisk I) (31.12.98)

Phillips Petroleum Company Norway	36.960 %
Fina Exploration S.C.A	30.000 %
Norsk Agip A/S	13.040 %
Elf Petroleum Norge AS	8.449 %
Norsk Hydro Produksjon AS	6.700 %
TOTAL Norge AS	3.547 %
Den norske stats oljeselskap a.s	1.000 %
Saga Petroleum ASA	0.304 %

### PL 018 License (Ekofisk II) (01.01.99)

Phillips Petroleum Company Norway	35.112%
Fina Exploration S.C.A	28.500%
Norsk Agip AS	12.388%
Elf Petroleum Norge AS	8.026%
Norsk Hydro Produksjon AS	6.365%
Den norske stats oljeselskap a.s	5.950%
TOTAL Norge AS	3.370%
Saga Petroleum ASA	0.289%

Originally, the Albuskjell field was divided between PL011<sup>4</sup> (50%) and PL018 (50%). Effective 25 August 1995, PL011 relinquished its area of the Albuskjell field, and this area was awarded to the PL018 Licensees pursuant to a new license designated «PL018B». Norske Shell, however, retains its ownership of 50% of the Albuskjell facilities as far as abandonment obligations are concerned.

The Norpipe oil pipeline from Ekofisk to Teesside in the UK with its two booster platforms is owned by Norpipe Oil AS, a Norwegian corporation.

## 1.3 The Ekofisk Cessation Project

Early in the 1990's, it became clear that the Ekofisk Center was due for a major overhaul if it were to withstand and overcome the effects of the subsiding seabed and mounting maintenance costs, and preserve adequate safety levels on the Ekofisk Tank Facilities. At the same time, the economic lives of several of the satellite fields were approaching a close. As a result a major field re-development was undertaken, and operations continued throughout the platforms associated with Ekofisk II. With the implementation of Ekofisk II,

<sup>4</sup> The Production license 011 is 100% owned by A/S Norske Shell.

thirteen platforms are now or will soon be redundant, in addition to the two decommissioned booster platforms on the Norpipe Oil pipeline.

Since initiation of the Ekofisk I Cessation Project in 1994, a major effort has been made to examine all potential disposal solutions and to recommend the best overall disposal solution for all the Ekofisk I Entities.

The first of the Ekofisk I platforms was shut down in 1983. Most of them, however, were recently shut-down in 1998 as a result of Ekofisk II start-up. Depending on future subsidence and economic lifetime calculations, the last of the Ekofisk I installation is at present due to come out of service in 2004.

The PNG made an assessment of the optimal time to dispose of the platforms, based on an overall technical, safety, environmental and economic evaluation. The following considerations were taken into account in these evaluations:

- Seabed subsidence at the Ekofisk Center and some neighbouring installations
- Structural integrity of disused platforms during the «cold phase»
- Development of new methods for removal
- Bridge access to installations
- Proximity to Ekofisk II installations
- Market conditions for removal of installations

A flexible removal operation will allow development of new, safer and more environmentally friendly technology. This is also generally advantageous from an economic point of view, and the benefits accrue to the owners and the State alike. Technical constraints and market conditions within the industry can also influence the removal date. Removal is phased in four main campaigns, the timing of which is given below. However, it is emphasised that the time of removal depends on the solution chosen in each case, and a solution for one installation may affect the procedure for other installations (see Chapter 3). Therefore this schedule is indicative:

Campaign	Action	Timetable
1	Remove topsides of Ekofisk Center North installations, and 2/4 B	2003–2008
2	Remove topsides of Ekofisk Center South installations including 2/4 H, 2/4 D and 2/4 A	2008–2013
3	Remove topsides on Cod, Albuskjell, Edda and Norpipe Oil booster installations in UK sector	2013–2015
4	Remove steel jackets, cover pipeline ends with gravel, and remove seabed debris	2015–2018

### 1.4 Legal Considerations

The Norwegian Ministry of Petroleum and Energy will make the decisions concerning disposal of the Ekofisk facilities in accordance with the Norwegian Petroleum Act of 1996<sup>5</sup>.

According to the Petroleum Act, disposal decisions are to be made based on a broad-based evaluation in each individual case, with emphasis placed on

<sup>5</sup> It is assumed that the application of the new petroleum legislation to PL018 will be clarified between the Norwegian authorities and the licensees.

technical, safety, environmental and economic aspects, as well as to consideration for other users of the sea. The Act envisages a socio-economic evaluation where the costs and safety risks associated with the various Disposal Alternatives are weighed against environmental, fisheries and other users' interests. The final disposal solution may consist of, inter alia, further use in petroleum activities, other uses, full or partial removal or leave in-place.

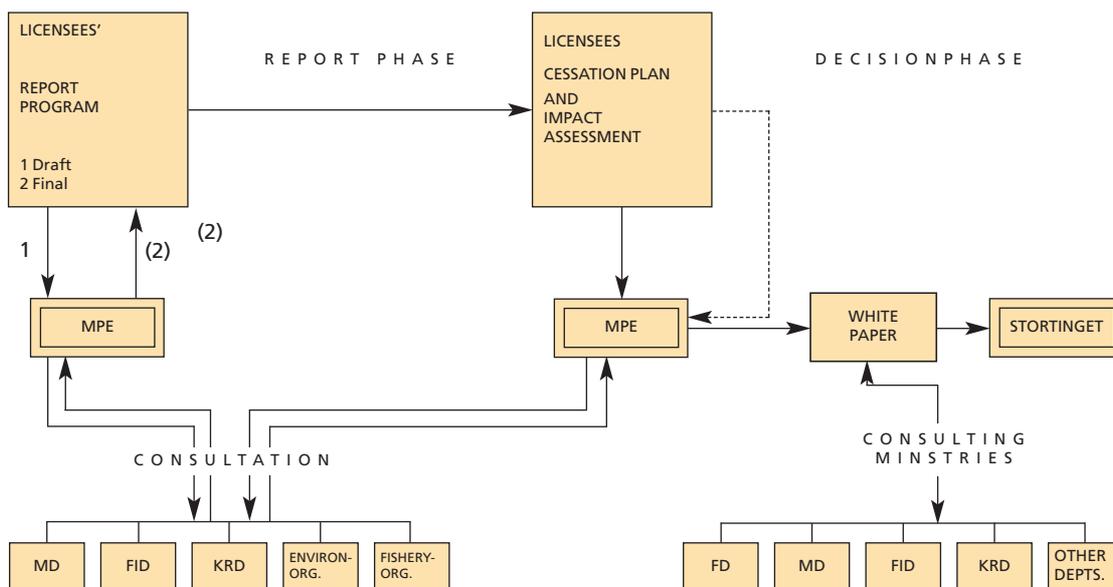
According to the Petroleum Act, the Norwegian Ministry of Petroleum and Energy will decide how redundant offshore petroleum installations will ultimately be disposed. The licensees owning the facilities are responsible for submitting a Cessation Plan well in advance (2–5 years) of the anticipated expiry of the license or termination of use of the facility to aid the authorities in their decision-making.<sup>6</sup>

The Regulations to the Petroleum Act specify that the Cessation Plan shall contain a Disposal Report and an Impact Assessment. The Impact Assessment must contain a description of the effects each of the relevant Disposal Alternatives is expected to have on industry and the environment, and an account of the steps that can be done to reduce discharges and emissions in connection with disposal and to remedy any damage or convenience. The licensees should clarify the scope of the Impact Assessment with the Ministry in advance. The proposal shall give a short description of the relevant disposal solutions and, on the basis of available information, the expected impacts on the environment and society. The proposal shall also clarify the need for documentation. For Ekofisk I the Programme for Impact Assessment was set by the Ministry of Petroleum and Energy 20 October 1998.

The full decision process concluding with the Storting Resolution is shown in Figure 5:

**Figure 5**

*Overall decision process ending with Storting resolution*



<sup>6</sup> The Norwegian Authorities have given the operator acceptance to deviate from this paragraph, by letter from MPE dated 28 October 1998.

In addition to the Petroleum Act, other Norwegian legislation – such as the Pollution Control Act, the Harbours and Navigation Act and the Working Environment Act – will have relevance for the Ekofisk Cessation Project. United Kingdom legislation may also be applicable to disposal involving the booster platforms on the Norpipe oil pipeline (see below).

In making decisions regarding disposal of the Ekofisk facilities, the Norwegian authorities will also consider certain international conventions (and decisions made pursuant thereto) and guidelines: the 1992 OSPAR Convention (and OSPAR Decision 98/3 taken pursuant thereto), and the IMO Guidelines of 1989.

The OSPAR Decision provides a general prohibition against dumping or abandonment in-place of redundant offshore installations that are not serving another purpose. The Decision allows exemptions for certain categories of installations (including concrete substructures) if the Norwegian authorities determine that an exemption is justified on technical, safety, environmental and economic grounds.

In 1989, the International Maritime Organization (IMO) adopted Guidelines and Standards for the Removal of Offshore Installations («the IMO Guidelines») for the purpose of promoting safety of navigation. The IMO Guidelines are not formally binding and thus are advisory in nature. The IMO Guidelines recommend a case-by-case evaluation to determine whether a redundant offshore installation should be left wholly or partly on the sea-bed, considering i.a. the effects on navigation, costs, risks, safety and technical feasibility.

According to the IMO Guidelines, if the coastal State determines that an installation shall be partly removed to below the sea surface and will not be re-used (e.g. as an artificial reef), then an unobstructed water column of at least 55 meters to the sea surface should be provided. None of the recommended Disposal Alternatives involve a partial removal and an assessment of this is therefore not relevant.

The IMO Guidelines recommend that the coastal State ensure that installations which are not entirely removed are indicated on nautical charts and are properly marked with navigation aids. Any disused installation that projects above the sea surface should be adequately maintained to prevent structural collapse. The main purpose of the IMO's maintenance recommendation is to ensure preservation of the navigation aids and thereby promote maritime safety.

### **United Kingdom Legislation**

The Norpipe pipeline is addressed in a treaty between Norway and the United Kingdom. According to that treaty, the Norwegian Authorities shall ensure the removal of any part of the pipeline which is no longer in use and which both Governments agree shall be removed. The treaty also provides that Norwegian law will govern the pipeline and incidents pertaining thereto, it being understood, however, that this shall not preclude the concurrent application of United Kingdom law to the pipeline, subject to the United Kingdom law governing the conflict of laws.

British law may thus have some application to decisions on disposal of the Norpipe booster platforms. It is assumed that the application of British law to Norpipe will be clarified between the two Governments. A summary of potentially relevant British law thus follows:

The British legal framework regarding offshore cessation is presented in a Guidance note on Decommissioning under the Petroleum Act 1998 (UK DTI 1999). Similar to the Norwegian legal framework, the UK Petroleum Act requires a cessation plan before disposal can be executed. Additionally, some other information is required, where the following could be appropriate for the booster platforms:

- acceptance of an Abandonment Safety Case under the Offshore Installations (Safety Case) Regulations 1992 (installations only);
- confirmation that the requirements of the Coast Protection Act 1949 have been satisfied;
- fulfilment of notification requirements to HSE under regulation 22 of the Pipeline Safety Regulations 1996.

If a disposal solution involves leaving installations in-place on or below the seabed, a permit according to Part II of the Food and Environment Protection Act 1985 will be required. In addition, there are potentially many Acts and regulations of relevance if installations or parts thereof are taken to shore in the UK.

# 2 THE IMPACT ASSESSMENT PREMISES

## 2.1 Purpose

The Petroleum Act describes alternatives that should be addressed when planning for cessation. The Impact Assessment should contain an objective assessment of all relevant Disposal Alternatives.

The purpose of an Impact Assessment is to clarify the effects of measures that may have significant consequences for the environment, natural resources, and society. The Impact Assessment shall ensure that these effects are taken into account when the measure is planned and when decisions are reached regarding whether, and on what conditions, the measure may be carried out.

The Regulations to the Petroleum Act further specify that, in connection with termination of petroleum operations, the assessment shall contain information about what can be done to reduce the emissions and discharges associated with removal, and give proposals for how to mitigate any damage or nuisance.

Accordingly, the purposes of this Impact Assessment are:

- To clarify the effects of the relevant alternatives for disposing the Ekofisk I installations which seriously affect the environment, natural resources, and society
- To present information about these effects in a manner that can form a basis for a decision on the removal options
- To present proposals for mitigating any damage and nuisance caused by implementation of the chosen solution, to serve as a basis for formulating conditions for implementation.

## 2.2 Scope

This Impact Assessment examines the effects of activities and circumstances connected with disposal of the Ekofisk I Entities, as well as the long term effects of the Disposal Alternatives on the environment, natural resources, and society, where knowledge about these factors exist.

Circumstances and activities relating to the termination of operations and decommissioning of the installations are discussed in the Ekofisk Cessation Plan. These activities are controlled by separate end-of-production regulations, and thus are not assessed in this Report. Nevertheless, since certain decommissioning activities are considered important for the subsequent disposal activities, these are described in Chapter 4.

The Disposal Alternatives which have been the subject of impact assessments in this Report are presented in Chapter 3. The total impacts of the PNG's recommended Disposal Alternatives are summarised in Chapter 11, which also outlines the technical reasons for selecting the recommended Disposal Scenario.

The technical issues that are discussed for each Alternative were presented in the Proposal for Impact Assessment Program for disposal of Ekofisk I (Anon. 1997-a). The Proposal has been circulated for external comments and comments were received from many quarters. The Ministry of Petroleum and Energy confirmed the program on 20 October 1998.

The comments that were received in response to the Proposal for the Ekofisk I Impact Assessment Program, including a discussion of how the operator plans to accommodate them, are presented in an annex to document (Anon. 1997-a).

The topics examined relate to operations and final disposal for all Disposal Alternatives, and embrace both the short-term and long-term effects. Typical operations are marine operations, demolition, transport, and melting down for scrap. «Final disposal» can cover anything from various forms of sea disposal, sale of parts and equipment, recycling and reuse, to simple disposal at a waste facility.

Based on the Proposal for the Ekofisk I Impact Assessment Program and the comments received from interested parties, this Report examines the following issues for each of the Disposal Alternatives:

#### **Environmental issues**

- Energy (Consumption and Total Energy Impact)
- Emissions to atmosphere
- Discharges to sea, water, or ground
- Physical impacts/effects on habitat
- Aesthetic effects, noise, odors, visual effects
- Waste/resource utilization
- Littering

#### **Societal/community issues**

- Impacts on Fisheries
- Impacts on free passage at sea
- Safety of Personnel
- Costs and national goods and services
- Impact on Employment

Emissions and other effects are quantified and discussed where the available documentation so allows. In other cases, qualitative assessments are made, also with discussions of the possible impacts and potential mitigating actions that could avert negative effects and promote positive benefits.

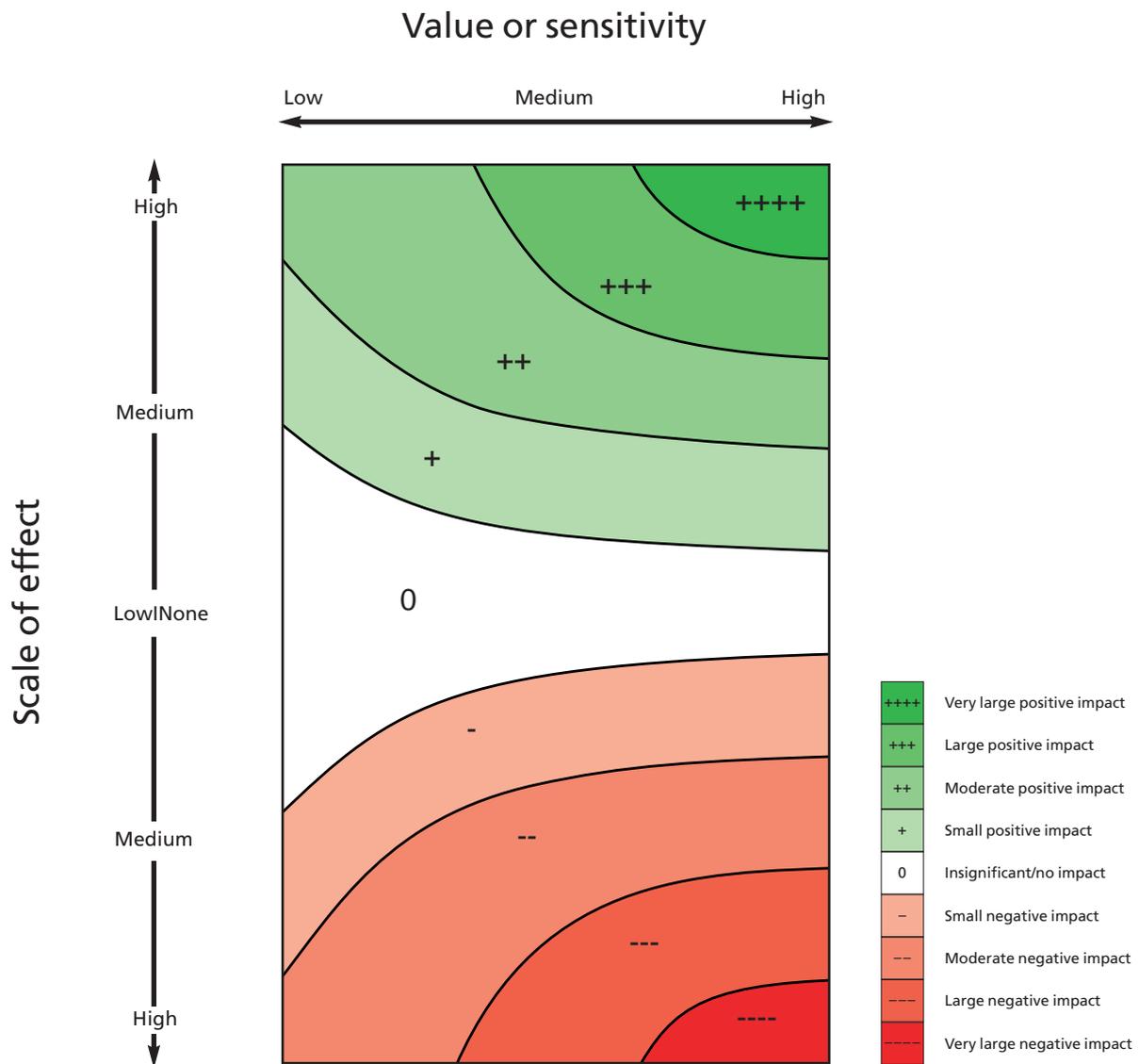
## **2.3 Methodology**

The methodology used in this Report generally follows the principles set out in the Norwegian Oil Industry Association's Methodology Study for Decommissioning Impact Assessments (OLF 1996).

The methodology involves the quantification of quantifiable impacts on the environment, fisheries and society, including, but not limited to, cost figures for estimated employment benefits in various industries, and the «Norwegian content» of the added jobs created.

Factors that cannot be quantified are described and subject to a technical evaluation of the type of effect, its scope, and its consequences.

Since the Ekofisk I Cessation Project is far more complex than cessation of any Norwegian fields previously assessed, this Report employs a slightly altered method of presentation and comparison of the Disposal Alternatives and their impacts. This process has sought to distinguish the important impacts from those that are less important. This was done by considering the effect of an impact in the area in which it is felt («value» or «sensitivity») combined with the scope of the effect, to arrive at the total impact. The method is outlined in Figure 6.



**Figure 6**  
Methodology for assessment of non-quantifiable impacts

In this Report, impacts assessed in accordance with this methodology are presented with quotation marks (e.g. «Moderate negative»).

The Impact Assessments in this report do not attempt to rank or weigh the factors against each other. However, this is done in a summary chapter for each entity, and is also done by the PNG in the form of an overall assessment for each Entity (see Chapter 11).

### 2.3.1 Environmental impact assessment methodology

The methods employed to study the environmental impacts in this Report follow in all essentials the principles given in the Norwegian Oil Industry Association Methodology Study (OLF, 1996). However, methods have developed to some extent since 1996, and the focus has shifted to new concerns and issues, and thus this Report supplements the OLF principles accordingly. A brief review of the methods employed and the presumptions underlying the conduct of this work is therefore presented below.

#### Energy

Energy issues are considered important factors in evaluation of the environmental impacts of shutdown, decommissioning and disposal of redundant offshore installations. There are various ways of accounting for energy effects, and a wide range in the input data which is used. The method used in this Report is recommended as an international standard by the Institute of Petroleum in London (IoP, 1999).

In an assessment of the energy impacts of alternative disposal solutions, two factors predominate:

1. Actual direct consumption of energy (fuel and electricity) for vessel operations and for melting down metals
2. Theoretical energy consumption for virgin production of materials in amounts corresponding to those not being recycled (represents potential energy savings by recycling).

This Report uses the following definition:

*Total Energy Impact* ( $E_{TOT}$ ) for an Alternative (in a global perspective) is represented by the formula

$$E_{TOT} = E_{DIR} + E_{REC} + E_{REP}$$

where

- $E_{TOT}$  = the Total Energy Impact in a global perspective
- $E_{DIR}$  = the direct energy consumption (fuel, electricity)
- $E_{REC}$  = the energy consumed by recycling/melting down metal
- $E_{REP}$  = a theoretical quantity of energy equivalent to the amount of energy required to produce a quantity of material equivalent to the quantities of material disposed and not recycled/re-used.

*Energy consumption* is the sum of the direct energy used for disposal and for recycling ( $E_{DIR} + E_{RES}$ ). In evaluating energy consumption, the focus is on the actual energy consumption for implementing the Disposal Alternative, not on the global energy balance.

The Ekofisk I installations, except for the concrete Tank and its Protective Barrier Wall, are constructed mainly of steel, which is thus the predominant material in any recycling program. The Tank and its Barrier is constructed of concrete but also contain considerable amounts of reinforcement steel and prestressed cables. Other materials, like aluminium and copper, have little effect on the overall equation. The actual cutting operations offshore have little impact since they use little fuel or electricity. The key factors in the energy analysis are thus the quantity of steel in the installations and the activities of the marine vessels involved in the disposal process.

Estimates have been made of the energy consumption and Total Energy Impact for each Disposal Alternative. It must be stressed that there are uncertainties associated with these calculations. Normally the uncertainty simply in the reference data can amount to 30–40 per cent (ERT 1997). In addition, there is uncertainty regarding the duration of the marine operations. The estimated values are thus approximate, and the total is rounded off. The estimates and reference data are reproduced in a separate report (DNV 1999-c).

**Emissions to atmosphere**

Atmospheric emissions are also included in the proposed international guidelines (IoP, 1999). As for the energy assessments, the focus of atmospheric emissions is both on actual emissions as well as emissions associated with replacement of materials (see definition under energy above). They are quantified on the basis of the Institute of Petroleum’s data and method. In the summaries, most weight is placed on actual emissions for the sake of simplicity.

The emission components CO<sub>2</sub>, NO<sub>x</sub> and SO<sub>2</sub> were assessed.

The harmful effects may be summarised as follows:

<b>Emission component:</b>	<b>Harmful effect:</b>
CO <sub>2</sub> (Carbon dioxide)	Increases greenhouse effect
NO <sub>x</sub> (Nitrogen oxides)	Causes respiratory complaints (particularly NO <sub>2</sub> ). Tends to form ground-level ozone, and cause acidification and corrosion of materials
SO <sub>2</sub> (Sulphur dioxide)	Heightens risk of respiratory complaints in conjunction with other components. Acidifies soil and water courses and corrodes materials.

As described above, carbon dioxide, CO<sub>2</sub>, is a global ecological problem and the exact location of the release is not greatly significant. For nitrogen oxides, NO<sub>x</sub>, and sulphur oxides, SO<sub>2</sub>, the effects are regional and local in nature. Notwithstanding this, no assessment has been made of their effects on the local environment. The reason is the uncertainty regarding where the disposal will take place, in particular relating to the location of the scrap furnace and production of steel. Only quantitative considerations of these emission components are therefore given. Even so, this offers an opportunity to look at relative differences between Alternatives, independent of the location where the emission actually occurs.

**Discharges to sea, water or ground**

Discharges into the sea, water or ground were assessed on a scientific basis in the Impact Assessment. The focus is on:

- Type and amount of discharge
- Time and duration
- Location of discharge
- Presence of natural resources, if any
- Effects on natural resources, their nature and how they can be mitigated

Detailed assessments of these factors have been made for operations in the Ekofisk Area. For other areas, where the exact locality is not known, more general assessments were made. It is worth bearing in mind that most of the Disposal Alternatives involve minimal discharges into the sea, water, or ground.

Leaching of metals into the sea is part of this topic and is explored in detail.

#### **Physical impacts/effects on habitat**

This topic is included to cover any potential impacts that are largely physical in nature, for instance damage caused by underwater explosions to fish or the seabed, various operations that might have a physical impact on the seabed, reef-like effects, etc. «Reef effects» involve the structures forming a firm substrate for organisms to grow on, and which will in turn constitute part of the ecological system in the area.

These factors are considered in relation to type, scale and impact.

#### **Aesthetic impacts**

This topic covers issues largely related to health and the local environment (noise, dust, odours). Where relevant, assessments are also made of any «visual pollution».

#### **Waste and resource recycling**

Sound utilization of resources, with re-use and recycling as the most favourable options, is the starting point for this topic. Therefore, this assessment makes a scientific evaluation of the materials in each installation to assess the potential for re-use and recycling, and to quantify volumes of substances that need to be disposed of as waste.

#### **Littering**

«Littering» in this assessment relates to the sea, since waste taken to land will be handled in accordance with detailed regulations aimed to prevent littering. «Littering» in this impact assessment is therefore defined as leaving things in the sea that were not originally present.

To examine this line of thought more technically in an ecological perspective, an assessment was also made of whether leaving a structure in-place could have consequences in the form of littering and dispersal problems. In a long term perspective, the litter topic is considered to be among the most important environmental issues. In cases where litter is deemed to potentially constitute a problem, this is therefore emphasised.

### **2.3.2 Societal impacts' methodology**

#### **Fisheries**

In an overall assessment of the effects on the fisheries of Disposal Alternatives for the Ekofisk I Entities, one has to have in mind that the Ekofisk Area is of

limited interest as a fishing ground for Norwegian (Valdemarsen 1994; Soldal *et al.* 1998) and other nations' (see Chapter 5.4) fisheries. This limits the impacts that may occur to the fishing industry as a whole. The effects on local operations may nevertheless be of some significance.

Marine operations and marine transport activities will occur in connection with most of the Disposal Alternatives. Marine operations related to Disposal Alternatives for platforms will take place within safety zones.<sup>7</sup> Thus will not affect fisheries, and are not considered further in this Assessment. The marine operations for removal of pipelines, by contrast, would sometimes be outside a safety zone, and therefore the potential impacts on the fisheries are considered in that case.

Transport operations in connection with the different Disposal Alternatives will mean limited and increases in ship activity in some areas for short periods. Fishing vessels will have to exercise some caution in respect of this, but the transport operations are not expected to impede fishing.

The different Alternatives presented for the Ekofisk I Entities have different potential consequences on fisheries conducted in the Ekofisk and surrounding areas. The option to create a reef for fish in the Ekofisk Area presents major challenges for assessing the impacts on the fishing industry. On the one hand, such a reef will present an obstacle to present fishing operations in the area, and on the other it may create a new – albeit somewhat limited – branch of the industry.

According to the Norwegian Oil Industry Association (OLF) investigative method for impact assessments, the impacts on the fisheries are assessed by calculating the obstructed area and comparing with the statistics for catches in the vicinity. One problem with this approach is that the effects then appear to be very small, and thus by itself it is unsuitable for describing the overall impact experienced. The factors that have been identified as most important and therefore the subject of analysis here are as follows:

- Effect of new reefs on fisheries
- Area excluded for fisheries
- Direct hindrance to fishing (damaged harvest and gear)

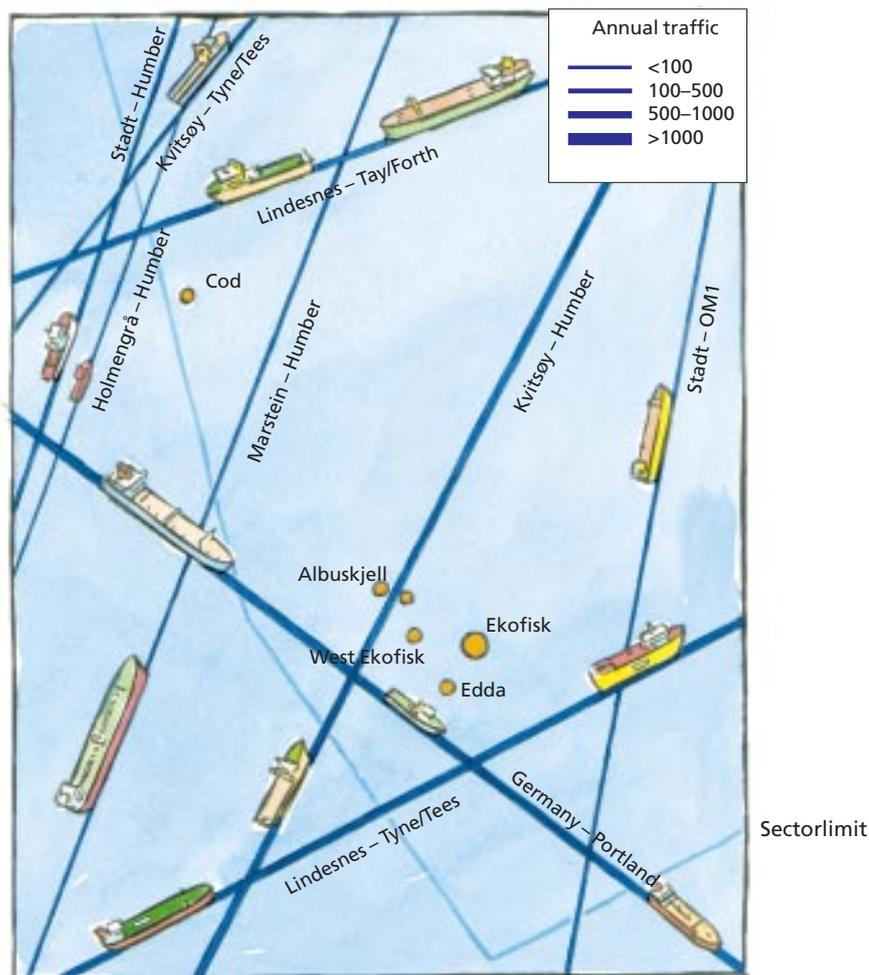
#### **Free passage at sea**

Offshore installations represent a risk to shipping. How large this risk is will depend mainly on the extent of the shipping activities and the measures and systems used to identify the installation and avoid contact.

The North Sea is a heavily trafficked area, and some important shipping lanes pass the Ekofisk Area (Figure 7)). In addition, some fishing vessels operate in the area (see Section 5.4). The total transits of commercial ships past the map section below is about 5,000 per year, or 10–15 each day. According to Dovre (1997), about 560 of these transits will pass less than 10 nautical miles from the Ekofisk Center. The number of fishing craft in the area will depend on the season and vary from year to year. Based on a study done by Technica (1987), it is believed that there is a density of 2.6 craft per 10,000 sq.km, which means five vessels in the map section below. The importance of the area to free passage is thus assessed as being of moderate value.

In connection with removal of the Ekofisk I installations, extra vessel operations will be conducted during short time periods.

<sup>7</sup> In this report, safety zones include fishing exclusion zones.



**Figure 7**  
Annual traffic along shipping lanes in the Ekofisk Area (according to Siktec 1989). Note that lines denote main lanes and that some traffic may be off-centre of the nominal lane.

Some Disposal Alternatives will also result in a more extended or permanent hindrance to shipping.

There is less maritime activity in the vicinity of the two Norpipe booster platforms in the UK sector. The most important lane near booster platform 36/22A is the Lindesnes-Tyne/Tees lane, with about 320 annual passages. There is about twice that amount of traffic near booster platform 37/4A.

### Personnel safety

The estimated risks to personnel of the various proposed Disposal Alternatives were calculated in a separate project (DNV 1998-e). The project based its safety studies on a review of the feasibility studies for the various Disposal Alternatives. The risks of given operations were calculated based on historical track-records (accident frequencies, «FAR») and individual exposure coefficients (man-hours).

The risks are presented as the Potential Loss of Life (PLL), an expression of the chance that life will be lost during a given operation. For example, an operation with a PLL equal to 0.5 means that there is a 50 per cent chance that life will be lost.

### Costs and national supplies (goods and services)

National supplies were estimated based on the cost estimates for the respective Alternatives.

The «Norwegian content» of goods and services connected with the Ekofisk I Disposal Alternatives is based on general knowledge of petroleum-related industries and information obtained from the field operator and the supplier industry.

The results of the employment estimates are subject to some uncertainties. The main sources of uncertainty are:

- *Uncertainties in cost estimates for supplies.* There is considerable uncertainty regarding these estimated costs, deriving from technology, weather conditions, installation condition, and so on.
- *Evaluation of suppliers.* Contracts may go to suppliers in other regions or countries, not those assumed in the calculation. This results in uncertainty regarding the Norwegian content of supplies and consequent employment effects.

### Employment effects

This Impact Assessment employed a model for assessing the employment effects of each Alternative within different categories of trade and industry.

The assessment model bases itself on the estimated goods and service deliveries broken down by industry and year, and calculates – from that basis – the total *production value* created in industry as a result of these deliveries, not only within the supplier firms, but also within their sub-contractors. The production value is then converted into employment (jobs) calculated on a man-year basis, using the statistical production per man-year quoted for different industries (Statistics Norway, SSB, 1997). The result of these modelling calculations is the estimated *direct employment effect* within vendor/supplier companies, and the estimated *indirect employment effects* within subvendors/subcontractors (vendors and subcontractors to the main vendors and contractors). The total is the project's *production effects*.

The term «ripple effects» (direct and indirect effects) denotes the phenomenon whereby purchases of goods and services in one segment spreads impulses in industry and commerce which in sum enhance the total value added. The basis is that supplies for the primary purchase instigate a chain of new supplies «upstream» in industry. The overall effects are the sum of the direct supplies, the indirect supplies, and derived activities due to increased private consumption.

## 2.4 Future Activity Levels

This topic addresses only the activity level in the Ekofisk I disposal period.

The activities related to cessation and disposal of the Ekofisk I Entities will be extensive, and are expected to be spread over a period of 15 years. The activities in this period will utilize a large portion of the available marine vessel capacity, particularly with respect to heavy-lift vessels.

To put these activities in perspective in relation to other field disposal activities in the same period, an approximate estimate of such activity has been made. This is based on Kværner's 1996 study performed for the European Union (Kværner John Brown 1996). The EU Report provides an overview of the number of fields and installations found or planned to be constructed in Western Europe. The information is given on an aggregate level, and it is difficult to trace to individual installations. The information is

from 1996, but nevertheless gives a certain perspective on the overall situation.

There are 297 fields in production, plus 62 under development (1996). This gives a total of 359 fields, including Ekofisk.

The number of platforms is as follows (status as of 1999):

Denmark	Germany	Greece	Netherl.	Ireland	Italy	Norway	Spain	UK	TOTAL
39	2	4	117	2	110	77	2	238	591

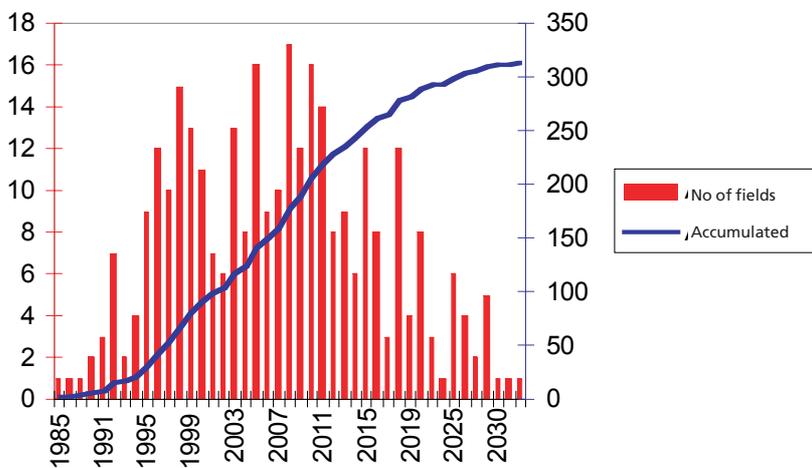
The following table shows an apportionment by type of installation:

Floating concrete platform	Floating production platform	FPSO (ship)	Jack-up	Tension leg platform	GBS*	Steel platform
1	11	13	11	3	28	524

\* Gravity based platforms: All but one constructed of concrete

The steel platforms have a total weight of 3.2 million tonnes. Of this, the Ekofisk installations make up approximately 160,000 tones (5%), while they constitute less than 3% of the number of steel installations.

Figure 8 below gives the estimated field shut-down dates:



**Figure 8**  
 Number of fields shut-down per year and accumulated over the period. «Shut-down» based on the filed's expected date of termination of production (as of 1996), which is subject to change.

When planning Ekofisk I disposal operations, the overall market situation regarding cessation activities will be taken into account. The plan will place weight on utilizing potentive flexibilities on timing that may exist in the market, to avoid creating pressure in the market and consequent cost increases. This will be a part of the PNG's contract strategy regardless of choice of Disposal Alternative.

# 3 DESCRIPTION OF ENTITIES AND DISPOSAL ALTERNATIVES

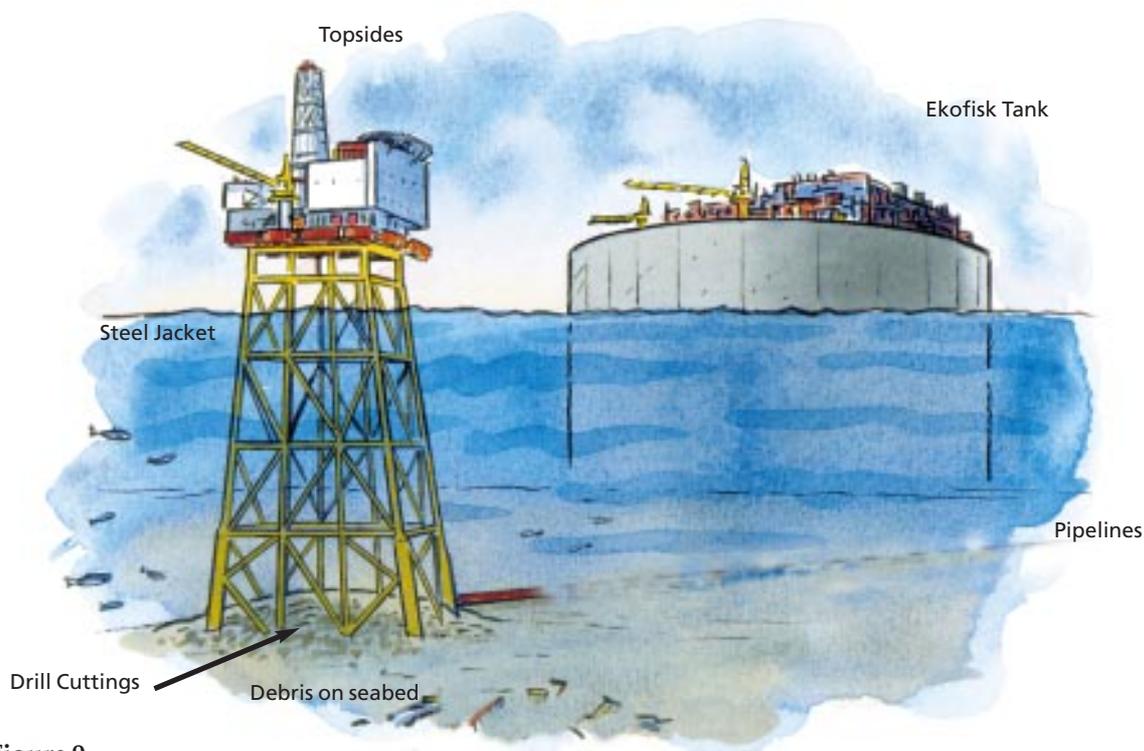
## 3.1 Description of Ekofisk I Entities

### 3.1.1 Introduction

The Ekofisk I Impact Assessment addresses five types of Entities:

- Topsides
- Substructures (steel jackets and the Tank with surrounding Protective Barrier Wall)
- Pipelines
- Drill Cuttings Piles on the seabed
- Seabed Debris

A simplified representation of these is shown in Figure 9.



**Figure 9**  
*A simplified representation of the Ekofisk I Entities*

### 3.1.2 Topsides and Substructures

The installations that this Impact Assessment addresses can be grouped into four different geographical areas as shown earlier in Figure 4:

- Outlying platforms
- Ekofisk Center North installations
- Ekofisk Center South installations
- Norpipe Booster platforms in the UK Sector

There are also redundant pipelines running between some of the installations, as well as flare stacks, bridges and bridge supports at the Ekofisk Center and on outlying installations. The installations found in each of these areas are briefly described in the following subsections.

#### Outlying platforms

These are installations in the Ekofisk Area which lie outside the Field Center (Ekofisk Center), see Figure 4. Brief descriptions of these outlying platforms are given in Table 1.

#### The Ekofisk Center

The Ekofisk Center area is divided into a northern and southern part. The redundant installations in these two parts (north and south of the Field Center) are described briefly in Tables 2 and 3 below:

**Table 1**  
*Outlying platforms, basic data*

Installation	Function	Date installed on field	Date of shut down	Weight Topsides and decks (tonnes)	Weight Jacket and bridges (t)	Water depth (m)
Ekofisk 2/4 A	Production, quarters	1972	2004*	4300	3900	74
Ekofisk 2/4 B	Production	1972	2003*	4900	4950	74
Albuskjell 2/4 F	Production, quarters	1977	1990	11300	8200	71
Cod 7/11 A	Production, quarters	1975	1998	5050	5400	75
Albuskjell 1/6 A	Production, quarters	1976	1998	11500	8200	70
West Ekofisk 2/4 D	Production, quarters	1973	1998	5300	3300	73
Edda 2/7 C	Production, quarters	1976/78**	1998	12300	7800	71



\* Timing of shut-down is uncertain

\*\* Jacket installed 1976, topside in 1978

**Table 2** *Ekofisk Center North installations*

Installation	Function	Date installed on field	Date of shut down	Weight Top-sides and decks (tonnes)	Weight Jacket and bridges (t)	Water depth (m)
Ekofisk 2/4 R	Riser platform	1975	1998	4300	6100	78
Ekofisk 2/4 T	Process and storage	1973	1998	36.860	290.000	78
Protective Barrier Wall (PBW)	Wave Barrier for 2/4 T	1989	1998	-	900.000	78
Ekofisk 2/4 P	Booster Platform	1974	1998	1600	2850	78



**Table 3** *Ekofisk Center South Installations*

Installation	Function	Date installed on field	Date of shut down	Weight Top-sides and decks (tonnes)	Weight Jacket and bridges (t)	Water depth (m)
Ekofisk 2/4 Q	Quarters	1973	2000	3000	1700	78
Ekofisk 2/4 FTP	Processing, Riser	1972	2004*	7300	5800	78
Ekofisk 2/4 H	Quarters	1977	2009*	7700	3500	78



\* Estimated: The Date of shutdown is very dependent upon the future subsidence rate at Ekofisk Center.

### Norpipe Booster Platforms

Along the crude oil pipeline to Teesside in England are two installations that were originally intended to maintain the pressure in the pipeline. These oil booster platforms were taken out of service in 1983 (36/22A) and 1987 (37/4A) and the Norpipe oil pipeline to Teesside was routed around them in 1991 (36/22A) and 1994 (37/4A).

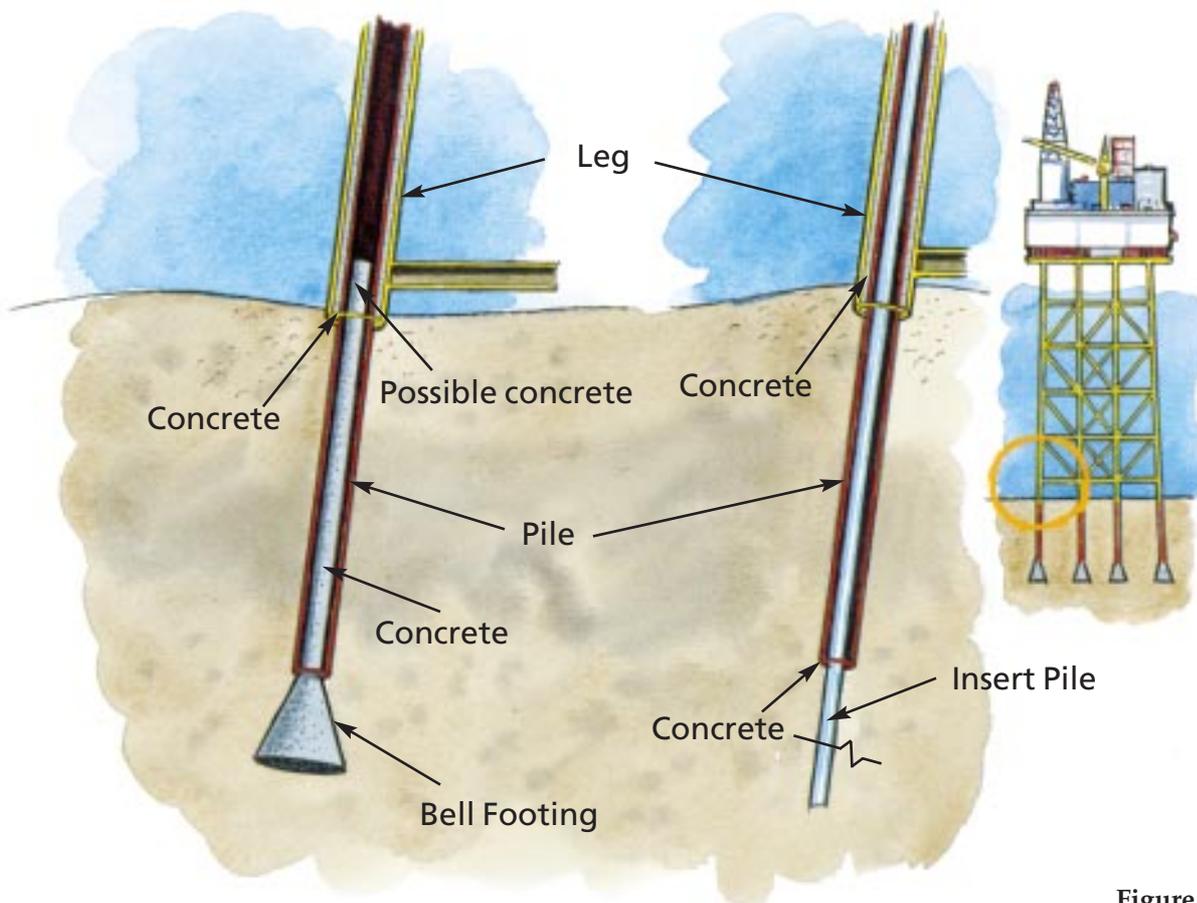
**Table 4** *Booster platforms on UK sector*

Installation	Function	Date installed	Date of shut down	Weight Top-sides and decks (tonnes)	Weight Jacket and bridges (t)	Water depth (m)
Norpipe 36/22 A	Booster	1974	1983	5400	4400	81
Norpipe 37/4 A	Booster	1974	1987	5600	5000	80



### Steel Jacket foundation piles

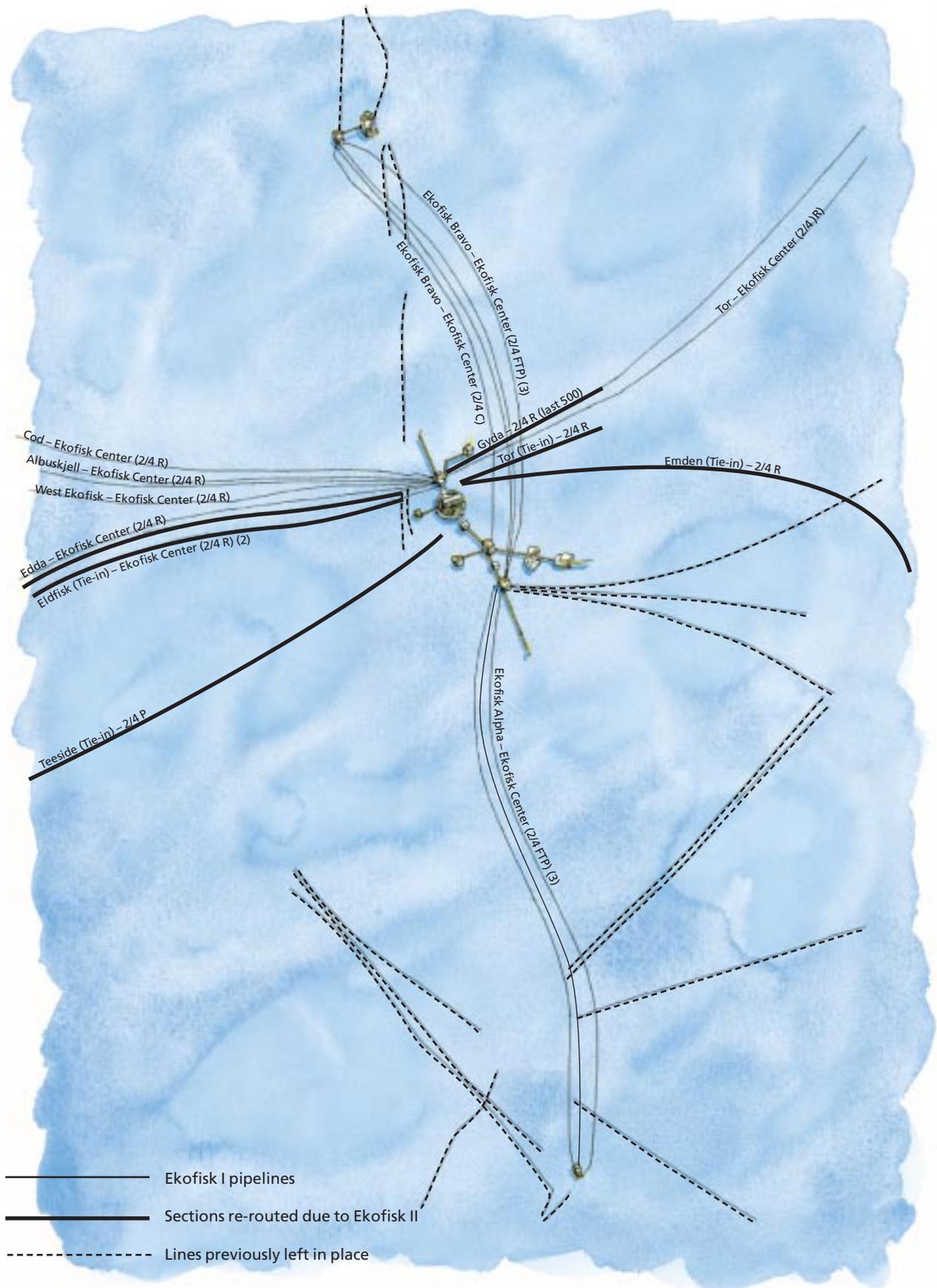
Some of the evaluations in this Report consider detailed technical operations. Among these are operations to cut the jacket piles which hold the steel jacket to the seabed. On the Ekofisk I jackets, the piles were placed inside the jacket legs. After the pile was driven into the seabed, a cement plug was installed to increase the end-bearing capacity, or alternatively, an insert pile was placed inside the pile. Uncertainty concerning the amount of cement in the piles complicates the planning for removal of the steel jackets. The as-built configuration of the cement grout will be investigated after removal of the topsides. An illustration of a pile and its configuration is given in Figure 10.



**Figure 10**  
*Configuration of cement grouted piles in Ekofisk I jacket legs*

### 3.1.3 Pipelines

There are a total of 40 redundant Ekofisk I pipelines or pipeline remains on the seabed in the Ekofisk Area. Among these are several smaller field flow-lines that became redundant in the 1970's when Ekofisk converted from offshore buoy-loading of oil tankers to oil export via pipeline. Others became redundant more recently with the changeover to Ekofisk II in 1998. The various lines have very different dimensions and are of different types, varying from 4.5 to 34 inches in diameter, and from a few hundred metres to 75 kilometres in length. The «pipelines» topic also includes five hydraulic hoses and a cable between the Ekofisk Center and Ekofisk 2/4 A. The cable lies within the 10" pipeline and thus is not exposed to the environment.



**Figure 11**  
Diagram of Redundant pipelines covered by the cessation plan

**Table 5**  
*Redundant pipelines*

<b>From and to</b>	<b>Number of lines</b>	<b>Length of each in km</b>
Ekofisk I-pipelines:		
Cod – Ekofisk Center (2/4 R)	1	75
Edda – Ekofisk Center (2/4 R)	2	13
Albuskjell 2/4 F – Ekofisk Center (2/4 R)	2	13
Albuskjell 1/6 A – Albuskjell 2/4 F	2	8
Ekofisk 2/4 A – Ekofisk Center (2/4 FTP)	3	2.9
Vest Ekofisk – Ekofisk Center (2/4 R)	1	8
Ekofisk 2/4 B – Ekofisk Center (2/4 FTP og C)	4	2.6
Tor – Ekofisk Center (2/4 R)	1	13.6
Gyda – Ekofisk Center (2/4 R) (del)	1	0.5
Sections re-routed due to Ekofisk II	6	2.9–7.8
Lines previously left in-place:	12 steel-pipelines 5 hydraulic hoses	0.9–3.3 0.6–1.8
<b>Total</b>	<b>40</b>	<b>≈ 235*</b>

\*Pipelines that are buried comprise 99% of the total length; the remainder are covered with gravel.

### 3.1.4 Drill Cuttings and Seabed Debris

In planning the disposal of Ekofisk I facilities, certain Entities have been identified as potentially having important influence on the decision-making process, since they may affect the technical solutions, costs, safety, or the environment.

The Entities in question include drill cuttings from earlier drilling operations found on the seabed under seven Ekofisk I installations, and any debris left in the vicinity of the Ekofisk I facilities.

Chapters 9 and 10 discuss these in more detail.

### 3.1.5 Materials and Substances in the Installations

Offshore installations are made mainly of structural materials, like steel and concrete, in addition to a range of other materials and substances in smaller quantities. Table 6 gives the main materials in each Entity examined in this Report. All told, it is estimated that the installations and pipelines comprise approximately 1.3 million tonnes of materials. Over 1 million tonnes come from the Ekofisk Tank and its Protective Barrier Wall, and half of this in turn is ballast (gravel). The column «Remainder» in the table includes various construction and insulation materials, plus paint, marine growth, and other substances. The substances are discussed more fully later in this Report under the heading «Waste/Resource utilization» for each Entity.

Any chemical or oil residues on the installations will be removed and dealt with in connection with shutdown of the installations. Procedures will also be developed for identification and handling of any other substances harmful to health or the environment during shutdown and final disposal. They are therefore not included in this summary.

**Table 6**  
*Materials in the various components (tonnes)*

<b>Component</b>	<b>Steel</b>	<b>Concrete and ballast</b>	<b>Copper in wiring</b>	<b>Anode materials</b>	<b>Remainder</b>
Topsides	92.000	770	2900		8000
Steel Jackets, bridges, flare stacks etc.	63.000	7200		920	7500
Tank base and Protective Barrier Wall*	46.000	1 mill.		94	3700
Pipelines	35.000	50.000	2	600	4500

\* In this assessment the two decks on the Ekofisk Tank are considered as part of the substructure.

A more detailed presentation of the distribution of materials is given in Chapters 6, 7, and 8 (sections on «waste/resource utilization») as well as in a separate report (DNV 1999-c). The information is based on several studies done by Kværner (1998 a, b, c, d, e) and DNV (1999-b).

### 3.2 The Ekofisk Cessation Project Short-listing and Selection Process

#### 3.2.1 Initiation and Concept Phases

The Ekofisk I Cessation Project (ECP) was initiated in 1994. In the period from 1995 to 1996, PPCoN commissioned a major conceptual study (REL, 1996) to identify and assess the health, environment and safety (HES) and cost impacts of all possible options for disposal of the Ekofisk I installations and pipelines. 197 possible disposal methods were sorted under the following categories:

- Continued use in-place
- Other use in-place
- Removal (complete or partial) for subsequent further use, recycle or deposit
- Leave in-place (complete or partial)

Approximately half of the options considered were either discarded or combined for further consideration in the continued work.

#### 3.2.2 Feasibility Phase

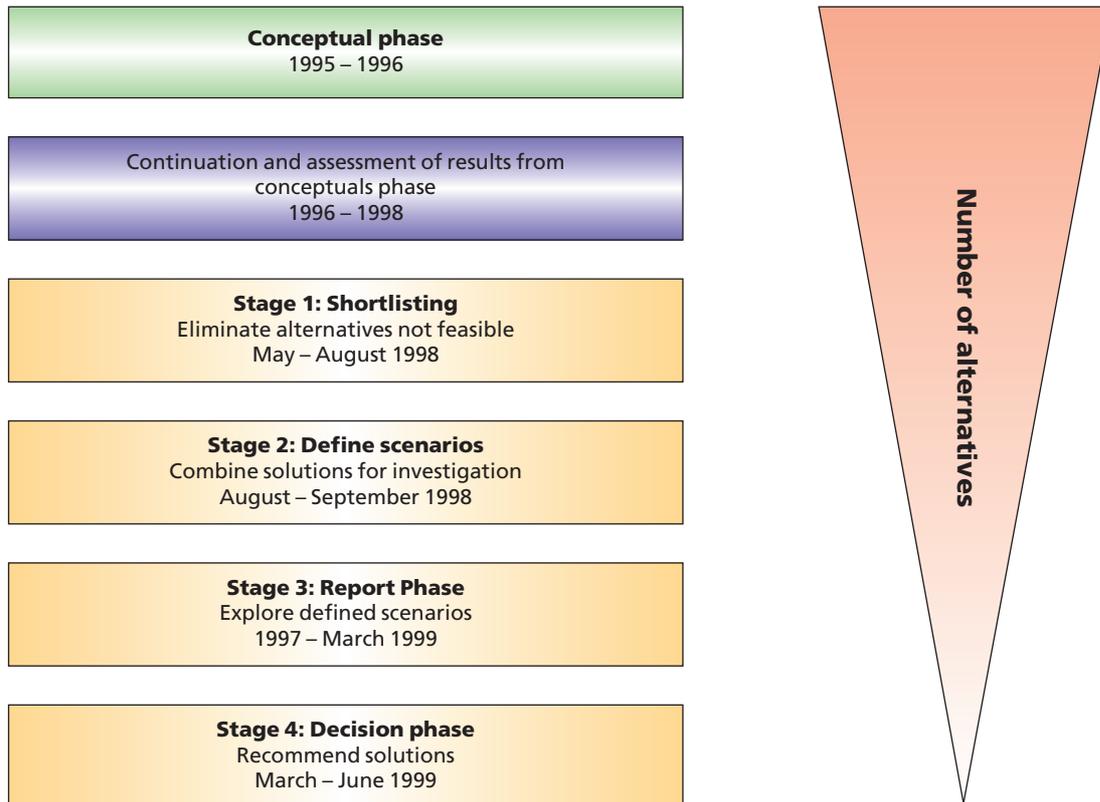
Early in 1998, the Cessation Project defined the final process to identify a recommended Disposal Scenario for the Ekofisk 1 Entities, designing it to include a close dialogue between the licensees and the Authorities. The scope of the Cessation Plan was extended and six disposal Entities were identified: the topsides, the substructures, pipelines, drill cuttings, storage tank contents and the sea bed. Cleaning of the Ekofisk Tank storage cells was subsequently included as a decommissioning activity, and is described in Chapter 4. The subsequent process of selecting one Disposal Alternative for each of these Entities was divided into four stages with the following goals:

- Stage 1: Discard untenable Disposal Alternatives  
 Stage 2: Compile Disposal Scenarios (short-list of Alternatives for each Entity)  
 Stage 3: Extend decision basis for the selected Alternatives  
 Stage 4: Recommend optimum Disposal Scenario for disposal of Ekofisk 1

The internal planning process is illustrated in Figure 12 and is described more fully below.

**Figure 12**

*Internal decision process from ideas to Cessation Plan*



### Stage 1

In Stage 1, which started with 92 Disposal Alternatives (Stage 1 in Figure 12), a range of selection assessment issues were established for each technical discipline (environment, safety, technical feasibility, etc) (PPCoN 1998-a).

Various alternatives under consideration were eliminated from further consideration because the licensees determined they were impossible to implement, were not practicable or feasible, or were deemed to have an unacceptable environmental impact. Among the alternatives discarded at this stage of the analysis were disposal of the topsides in deep water.

Of the 92 initial alternatives, 27 were carried forward to Stage 2.

### Stage 2

During Stage 2, dependencies between the various Disposal Alternatives for each Entity were studied, thereby eliminating Alternatives that were not feasible collectively – although they might be individually.

The final short-list of Disposal Alternatives for the Ekofisk I Entities where thereby defined as a total of five combined Alternatives for the steel jackets

and Tank, while the other Entities were considered on an individual basis (see Table 7).

### Stage 3

The objective of Stage 3 of the selection process was to strengthen the basis for decision-making. The emphasis in Stage 3 was on documentation of technical feasibility of the Alternatives, and on assessing and documenting the effects on safety, the environment, and other users of the sea, as well as developing better cost estimates. Stage 3 was extremely comprehensive and extended over a long period. A range of feasibility studies were completed, including studies of the following:

- Removal of the Ekofisk Tank and Barrier
- Leaving the Ekofisk Tank and Barrier in-place
- Removal of the pipelines
- Leaving the pipelines in-place
- Converting substructures to artificial fish reefs
- Removal of topsides and jackets
- Structural reliability analyses for subsidence affected installations
- Alternative methods of dealing with drill cuttings
- Windmill park at Ekofisk
- Gas power plant at Ekofisk

The results of these studies form the basis for this Impact Assessment.

### Stage 4

In Stage 4, the goal was to identify the recommended Disposal Scenario after a thorough, overall evaluation, meeting the following project objective:

*Final disposal of the Ekofisk I platforms will be performed in a safe, environmentally sound, and cost-effective manner. The goal is a solution acceptable to the Norwegian authorities, the Norwegian and the international communities, and the licensees.*

To meet this goal, PPCoN developed a methodology where options were assessed based on the following factors: safety, environment, economics, public opinion, fishing industry, shipping, and other users of the sea.

The methodology is designed to enable the best possible comparison across very different assessment factors – and the magnitude of their impacts. The comparison data includes:

- safety evaluations based on scientific methods for risk assessments
- environmental assessments, including many and varied factors assessed through independent consulting reports
- data on the fishing industry based on both scientific studies and statements from industry organizations
- independent expert evaluations concerning shipping
- opinion surveys based on statements from the Authorities and important interest organizations
- cost estimates based on established cost estimation methods.

### 3.2.3 Assessment criteria

The assessment criteria employed in the final shortlisting phases (Stages 1–4) are described below:

#### **Safety:**

- No activities shall be performed that result in personnel injury, harm to personnel's health or damage to property.
- Results from qualitative and quantitative assessments of total risk of all Alternatives shall form the basis for the evaluation of the Alternatives.
- The assessment of the activities shall identify and document relevant risks which may be encountered during the operations for each Alternative, and preventive measures to reduce identified risks to an acceptable level shall be identified.

#### **Environment:**

The total, overall evaluation shall be based on a thorough evaluation of environmental risks and consequences. Qualitative and/or qualitative evaluations of the following factors shall be applied:

- Energy (energy consumption and Total Energy Impact<sup>8</sup>)
- Atmospheric emissions
- Discharges to sea, water or ground
- Physical impact/effects on habitat
- Aesthetic impacts (noise, dust and visual impacts)
- Waste/resource utilization
- Littering

In the process to find the best Disposal Alternative for these installations, both the short and long-term impacts on the environment were considered.

#### **Cost:**

- One shall, in a long term perspective, strive to minimize the costs associated with the final disposal of the Ekofisk I Entities.
- An optimized economic solution will be identified for all Disposal Alternatives based on technical and logistical constraints, risk, timing of operations and other parameters considered important for minimizing the cost.

#### **Public opinion:**

- An acceptable solution must meet international guidelines, be environmentally aware, meet expectations among major stakeholders both in Norway and Europe, and project the companies' roles as responsible world citizens.
- The recommended solution must build on healthy socio-economics, make common sense and be easy to communicate widely.

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<sup>8</sup> Total Energy Impact is defined in Section 2.3.1. It consists of three different elements: (1) Direct energy consumption (e.g. fuels); (2) energy for recycling/smelting; and (3) Indirect «Replacement Energy» – the indirect energy required to produce new material corresponding to the material not reused/recycled.

The evaluation of public opinion was based on an in-depth opinion-maker survey of 30 non-governmental organizations in the UK, Holland, Germany, Denmark and Norway. The majority of the organizations represent the environment and the fishing industry. The representatives from the organizations were asked about their view on all Disposal Alternatives. These answers were discussed with independent consultants – and all the different information was combined with knowledge of public opinion regarding the oil industry in general and environment related issues in particular.

**Fishing industry:**

- Improved efficiency / reef effect
- Risk of damage to equipment
- Area occupied / hindrances

The evaluation sought to identify positive and negative impacts on all participants in the fishing industry.

**Shipping/transport and other users of the sea**

- Evaluated based on whether an Alternative represents a hindrance to free passage.

In Stage 4, the PNG conducted an overall assessment of all the assessment criteria to arrive at its recommended Disposal Scenario. A summary of the considerations underpinning the recommended Disposal Scenario and a summary of its consequences is presented in Chapter 11.

### 3.3 Further Use of Facilities and Equipment

Recommissioning, or re-use of whole installations, preferably in-place but alternatively elsewhere, remains a priority alternative for the licensees. Several possibilities, internal as well as external, have been explored, and new possibilities will be explored as the Ekofisk Cessation Project progresses. To optimise the work with identifying future re-use of the installations, PNG has developed a strategy. In this strategy possibilities and limitations are discussed and an action plan for marketing and sale is described.

All installations have been advertised for sale, and a number of potential buyers have expressed an interest. One factor that is extremely important for recommissioning or re-use is the time aspect relative to the demands of a given project, as this might also influence the planned date of removal of the installation. Therefore the sale must compensate for any economic aspects in relation to the planned removal and the maintenance costs.

The steel jackets and Ekofisk Tank have been evaluated as potential foundations for windmills. The study concluded that this option is technically feasible, but the gains were not proportionate to the investment (HUB 1998). Therefore it was not recommended.

Similarly, the PNG evaluated use of some installations as foundations for gas power plants, with reinjection of the CO<sub>2</sub> into the reservoir. Modifications of this kind require an extended production stoppage on Ekofisk, which is extremely costly. Further, the technology is not fully developed. Thus this option was also not found worthy of recommendation (PPCoN 1998-b).

The potential to exploit geothermal energy by circulating water through old reservoirs was also studied (NTNU, 1996). However, the temperature gain was found to be less than 1 °C, which meant the idea was both technically and economically not feasible.

Until now, no firm re-use options – apart from fishing reefs – have been identified, and a hypothetical study concerning further or other use on a general basis was not thought very useful. If realistic re-use projects are identified, they will be thoroughly evaluated against the recommended Disposal Alternative(s), and if of interest will be discussed with the relevant authorities.

Load-bearing structures will be subject to regular monitoring and maintenance as necessary to maintain structural integrity. This will also have a positive effect on future re-use possibilities. Selected components will also be preserved for possible later re-use. Six pipelines have already been preserved for possible later use. Some smaller units or parts and equipment will likely be re-used regardless of the Alternatives selected, although deterioration of equipment over time should be expected. Attempts will also be made to re-use modules and equipment according to PNG's re-use strategy before the platforms are put into a «cold phase».

It is also important to note some of the technical challenges and operational restrictions that might reduce the potential for re-use, for instance re-use of steel jackets at other locations. Some of the jackets must be cut into several parts in order to move them. That means that recommissioning or re-use of steel jackets at other sites is unlikely given the state of current technology. New technology in the future might, on the other hand, make this option more feasible.

Likewise, removal of entire installations or topsides for re-use at other locations would only be possible with as yet unproven technology. At present, installations must be partitioned in order to remove them, which tends to undermine the technical and economic feasibility for re-use.

### 3.4 The Short-listed Disposal Alternatives

The relevant Disposal Alternatives for Ekofisk I, identified in Stage 2 of the selection process (Figure 12) are listed in the Table 7 below. One key principle of the work of compiling the most relevant Alternatives was to consider whether installations and components were inter-dependent. If not, they could be assessed individually. Dependent components have to be assessed collectively to find the actual and total effects. Based on this approach, the project concluded that the Ekofisk Tank and steel jackets were the main installations with any significant inter-dependence. The inshore removal Alternative for the Tank topsides (IB) is also dependant upon choosing a refloat Alternative (IID/IIE) for the Tank substructure. In addition, the drill cuttings piles below some installations can also influence the options for disposal of the steel jackets. This is discussed further in this Report.

Details of the methods and activities assumed for each Disposal Alternative are described in detail in Chapter 6 (Topsides), Chapter 7 (Substructures), Chapter 8 (Pipelines), Chapter 9 (Drill Cuttings), and Chapter 10 (Seabed Debris).

**Table 7**

*Matrix of Entities and Short-listed Disposal Alternatives for Impact Assessment*

Entities	Alternatives Assessed				
<b>I Topsides</b>	<b>A</b>		<b>B</b>		
	<i>Jacket Topsides:</i> Lift and Transport to shore for recycling  <i>Tank Topsides:</i> Lift and transport to shore for recycling		<i>Jacket Topsides:</i> Lift and transport to shore recycling  <i>Tank Topsides:</i> Remove at shore & recycle after tow to shore on substructure		
<b>II Substructures</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
	<i>Jackets:</i> Reef in-place  <i>Tank:</i> Reef in-place	<i>Jackets:</i> Reef at Tank  <i>Tank:</i> Reef in-place	<i>Jackets:</i> Remove for onshore recycling  <i>Tank:</i> Leave in-place	<i>Jackets:</i> Remove for onshore recycling  <i>Tank:</i> Refloat and Deposit deep sea	<i>Jackets:</i> Remove for onshore recycling  <i>Tank:</i> Refloat and recycle
<b>III Pipelines</b>	<b>A</b>		<b>B</b>		
	Remove to shore for recycling of materials		Leave buried in-place		
<b>IV Cutting Piles</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	
	Remove, slurrify and reinject in waste well	Removal to shore for disposal	Leave in-place	Cover with gravel	
<b>V Seabed</b>	Remove Debris				

\* «Tank» includes both the Ekofisk Tank and the PBW.

# 4 DECOMMISSIONING ACTIVITIES

## 4.1 Cleaning in connection with shutdown

All relevant systems in the topsides will be cleaned before final removal. The pipelines will also be cleaned and purged. This will include cleaning and purging systems containing hydrocarbons and chemicals, as well as removal of substances that can represent a health or environment hazard. The results will ensure safety and environmentally acceptable conditions for activities connected with shutdown, decommissioning and final disposal.

Shutdown and cleaning are divided into two distinct phases, separated by a phase where wells on certain installations are plugged and abandoned (see Section 4.2).

Phase 1 covers steam-cleaning of the process trains in accordance with specially formulated purge criteria. Generally, cleaning continues to a standard where the gas content meets the working environment criteria. Oily water is reinjected or is dispatched to the Ekofisk Tank for treatment before discharge. This work also includes cleaning and preserving pipelines and flowlines, as well as removal from the installations of substances harmful to the environment. Cleaning relies on pressurised steam and thus avoids use of chemicals.

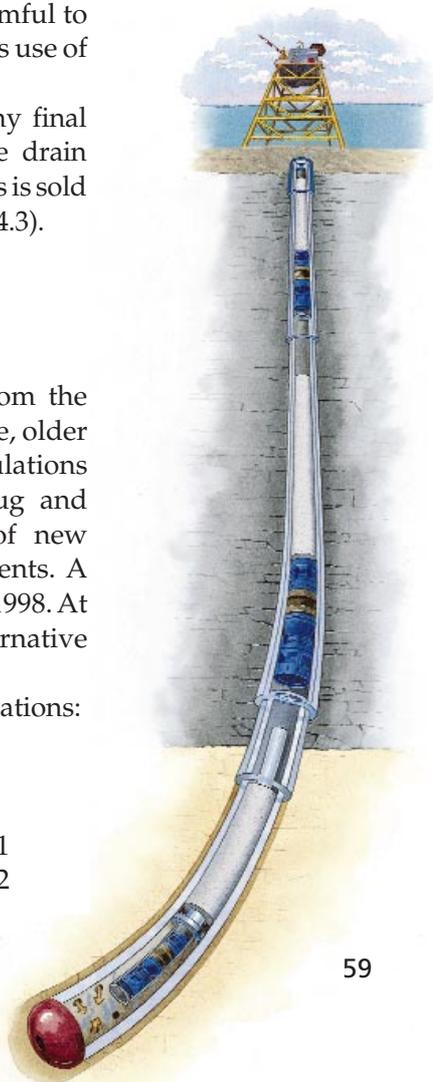
Phase 2 covers the shutdown of the utility and safety systems. Any final residues of hydrocarbons and fire-fighting agents are removed. The drain systems are flushed and any equipment for which a re-use potential exists is sold or preserved. Preparations are then made for the cold phase (see Section 4.3).

## 4.2 Plugging and abandonment of wells

Over the past 30 years, more than 100 wells have been drilled from the installations covered by this Report. Over this extended period of time, older equipment gradually deteriorated while Norwegian governing regulations for drilling operations became more stringent. The Ekofisk I plug and abandon («P & A») operations therefore required installation of new equipment that meets the new safety and environmental requirements. A specially built rig has been hired, and the work to plug Cod started in 1998. At the same time, PPCoN has commenced a process to examine alternative methods of plugging the various wells.

The following tentative time schedule applies for well plugging operations:

- |                                 |           |
|---------------------------------|-----------|
| • Cod 7/11 A (9 wells)          | 1998/99   |
| • Albuskjell 2/4 F (16 wells)   | 2000      |
| • West Ekofisk 2/4 D (15 wells) | 2000/2001 |
| • Albuskjell 1/6 A (16 wells)   | 2001/2002 |



- Ekofisk 2/4 B (23 wells) 2004/2005
- Ekofisk 2/4 A (23 wells) 2005/2006
- Edda 2/7 C (10 wells) 2002/2003

The overriding goal is to plug and abandon the Ekofisk I wells in a safe and environmentally sound manner.

The total costs associated with this process, including planning costs, are estimated at 13–20 million kroner for each well. The PNG has an objective to reduce the costs by development of new methodology. All told, the work is expected to have a direct employment effect of about 625 man-years.

### 4.3 The Cold Phase



Once the systems have been cleaned and purged and the wells plugged and abandoned (see Sections 4.1 and 4.2), the installations are said to be in a «cold phase».

In preparation for the cold phase the installations will be equipped with necessary systems for navigational markings (e.g. lights, foghorn, radar reflector).

During the cold phase the only work performed will be necessary inspection and maintenance of the navigation aids and load-bearing structures that are important for personnel safety during the cold phase and in connection with final removal. Certain areas will be marked and closed.

Only a small number of regulated substances will be permitted onboard during the cold phase. Examples are low specific activity scale (LSA) from isotopes in closed process systems, asbestos, smoke detectors, and fluorescent light tubes, where removal is complicated.

This is not considered to represent any risk to the environment or personnel. The materials will be removed and disposed in connection with the final removal of the topsides.

### 4.4 Decommissioning the Ekofisk Tank Substructure

Recovery of the sediments and cleaning the water in the Ekofisk Tank storage cells is a decommissioning activity, and thus outside the scope of the Cessation Plan, which deals with final disposal of the installations. However, this activity is considered to be extremely important (and was emphasised in the hearing rounds to the Impact Assessment Program). It was therefore decided to describe this operation – which will be carried out offshore as described below, regardless of which Alternative is chosen – in this Impact Assessment Report.

After its commissioning in 1974 the Ekofisk Tank functioned as a temporary oil storage facility until 1975. It was later modified for use as a final stage separator for produced oily water, until shut-down in 1998. The storage volume is about 160,000m<sup>3</sup> (1 million barrels), divided into 9 interconnecting cells.

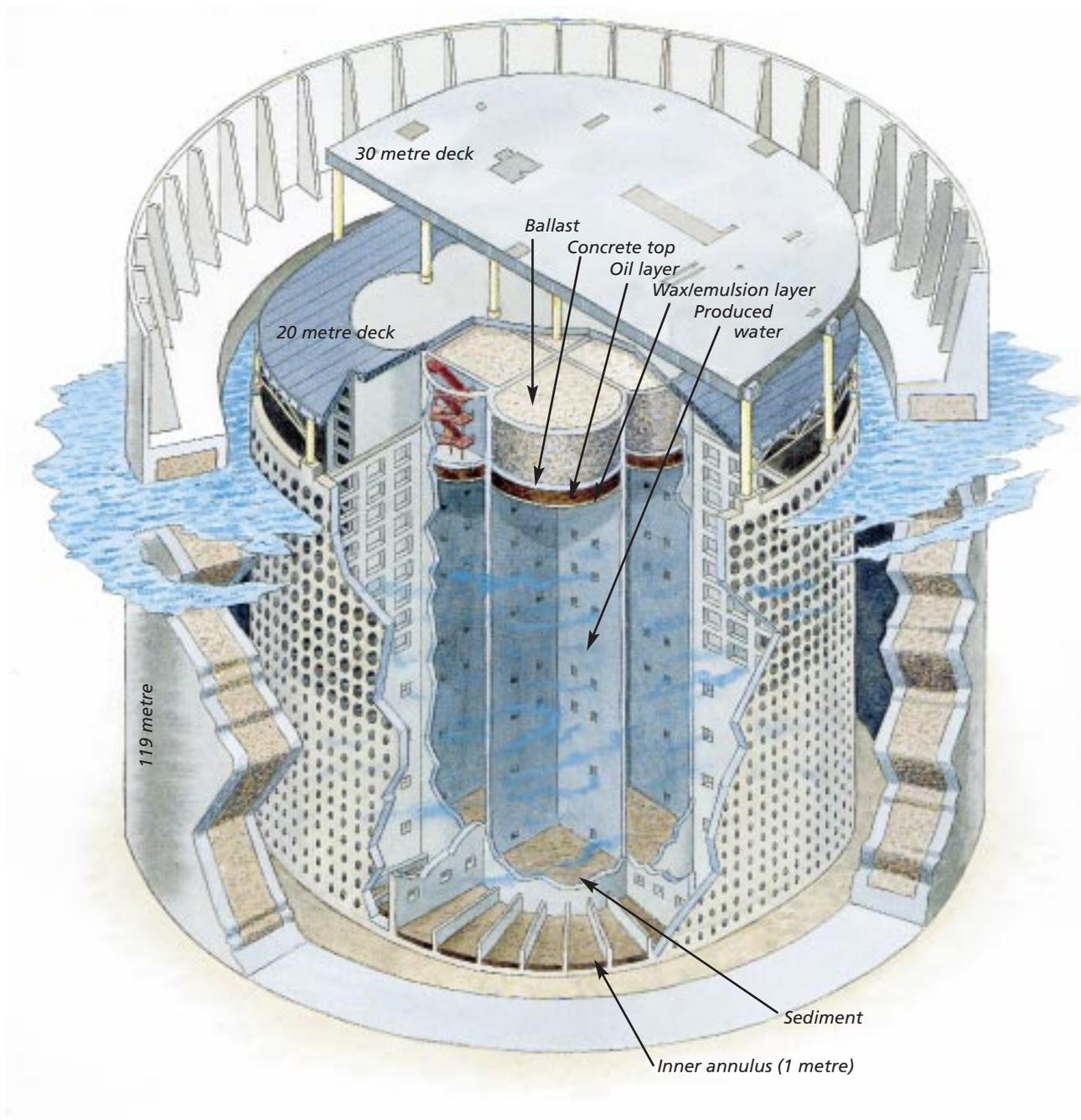
After shut-down, the PNG conducted extensive surveys of the contents of the Tank cells in autumn 1998. The results from the surveys indicated a far smaller magnitude of residual substances in the cells than previously anticipated.

The cells are not all identical, but generally they contain:

- A layer of crude oil, 4.5 metres thick, at the top
- About 0.5–1 metre of wax and emulsion
- A 63 metre column of produced water
- About 1–3 metres soft sludge on the bottom of four of the five cells examined, and a more solid layer of sludge/sediment in the fifth.

A diagram of the different cells and typical liquid layers is given in Figure 13.

**Figure 13**  
Structure and contents of Ekofisk Tank



The quality of the crude in the top oil layer is similar to regular Ekofisk crude. All of it, about 10,300 cubic metres, will be pumped to Ekofisk 2/4 J for export via pipeline to Teesside for normal handling and sale.

The oil content in the water phase is in the region 5–15 mg/l. The content of hydrogen sulphide, H<sub>2</sub>S, is very high, about 350–400 mg/l at the surface, and 25–60 mg/l at the bottom. This is a highly toxic gas and therefore special measures must be instituted along with strict precautions for treatment and cleansing of this water. The content of heavy metals in the aqueous phase is generally similar to produced water (E&P Forum 1994), while the concentration in the sludge is somewhat higher. The only organic acid detected in any significant amount is acetic acid, with concentrations equivalent to average-to-high values found in produced water in the North Sea (E&P Forum 1994).

The wax/emulsion layer, about 1,200 cubic metres in volume, will be recovered by pump and either be reinjected in a disposal well or be treated and disposed of onshore.

The water phase is equivalent to ordinary produced water and therefore a discharge permit will be sought for its disposal. In volume (approx 144,000 m<sup>3</sup>) it corresponds to about 10–15 days' discharge of produced water from normal operation of Ekofisk II (PPCoN 1999-c). The water level will be drained as far as technically acceptable to ease the cleaning and sediment removal operations in the cells. The sediment or sludge has a volume of about 2,300 m<sup>3</sup> and will be disposed of by reinjection or treatment and disposal onshore. The remaining water in the cells will be circulated through a filter for cleaning. Thereafter, the Tank cells will again be filled with fresh seawater. Measures to avert subsequent problems with hydrogen sulphide will be instituted.

In addition to the cleaning operations in the Tank cells, there exist some sediments in the inner annulus, the space between the Tank storage cells and the perforated Tank breakwater wall. Depth measurements performed indicate a volume of 6,000m<sup>3</sup> of sediment. Samples of these were taken in summer 1999. The result of analyses of these samples, and further evaluation thereof, are expected in fall 1999.

In brief, then, there is very little solid matter in the tank cells. What there is in the way of sediment can be pumped out and separated from the water in the tank cells before disposal. The waste residues can be washed out, taken to shore, and treated correctly and disposed of as special waste, or reinjected into a disposal well offshore.

In the case of onshore treatment, no exact plans have been laid for cleansing the sediment, but a tentative solution has been proposed using existing treatment facilities in Norway. They are regularly used for such purposes as cleaning contaminated soil.

# 5 THE PHYSICAL ENVIRONMENT AND NATURAL RESOURCES

To conduct an environmental impact assessment, it is important to document the existing environmental conditions in the area where activities are expected to be carried out. The following description of natural resources and environment therefore focuses mainly on the Ekofisk Area. Additional descriptions are given with respect to the Norpipe oil booster platforms located in the UK Sector.

## 5.1 Meteorology and oceanography

For removal of the installations at the Ekofisk Center to be conducted safely, good and stable weather conditions for lifting and transportation is required. Poor weather can result in delays in the removal process. The climate in this part of the North Sea is described as «highly variable», but there is none the less a clear annual temperature cycle. The wind velocity in the central part of the North Sea is around  $8.0 \pm 4.5$  m/s (Børresen 1987), with the strongest winds from October to March, inclusive. The wind is given as stronger than 18 m/s for about 3 per cent of the year. The annual winds are predominately from the south and northwest. The strongest winds in the winter come from the west-northwest to north-northwest, but also winds from the east-southeast to south-southeast sector prevail in the six winter months. In summer, the prevailing winds are northwest and north-northwest (Børresen 1987).



**Storm at Ekofisk**  
Photo: Husmo-foto

Reliable historical measurements of wave conditions at Ekofisk are available. These will be factored into plans for lifting operations.

The Ekofisk Area lies outside the major current systems in the North Sea (Turell *et al.* 1992). The predominant current vector is from North and West, and consists of the inflowing Atlantic stream known as the «Faeroes Current». This gives typical salinity values of between 34.75–35.00‰. Current direction and salinity are also valid for the booster platform locations. Surface currents are strongly influenced by winds and vary a great deal. Generally the current sets at 0.15 m/s in summer and 0.3 m/s in winter (Amoco 1988).

The temperature of the surface water is about 3–8 °C in winter, rising to 14–16 °C in summer (Otto *et al.* 1990; Becker and Wegner 1993). The water masses are layered in the summer, with a boundary layer at 20–40 metres. This is very significant for passive transport of fry and fish larvae, which generally in this period occur above the boundary layer. In the winter, the water layers are intermixed from seabed to seasurface.

## 5.2 Bottom conditions

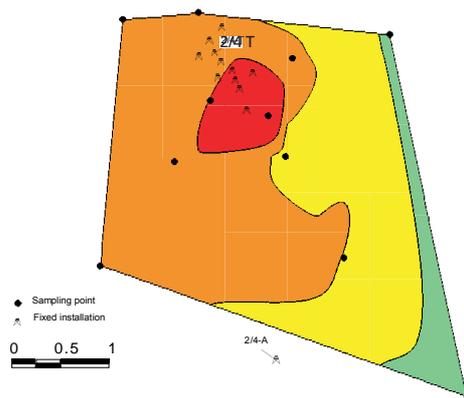
### 5.2.1 Seabed in the area

The water depth in the Ekofisk Area is in the order of 66–79 meters. The depth increases westwards to the first booster platform 37/4A (80 m), but decreases towards the UK coast. The water depth is about 81 meters at booster platform 36/22 A.

The bottom sediments in the Ekofisk Area consist generally of olive-grey coloured fine sand (88–94 per cent) with some silt and clay present. The content of organic matter in these sediments is in the region 0.65–1.29 per cent.

The total volume of cuttings released from drilling operations at the Ekofisk Center is very roughly 18,500 m<sup>3</sup> (from 2/4 C and 2/4 W). The total in the Ekofisk Area must be more than 240,000 m<sup>3</sup> cuttings (Dames & Moore 1999). Moreover, drilling mud was released with the cuttings. The total volume of all this has therefore been estimated at 500,000–640,000 tonnes, of which about half is associated with the installations which are the subject of this Report. Drilling mud used on Ekofisk was largely water-based, with some sections drilled using mud based on esters, ether, or poly-alphaolefins.

The total hydrocarbons (THC) in the sediments, measured in environmental monitoring studies (Mannvik *et al.* 1997), are in the region 8–25 mg/kg by dry weight (see Figure 14). Generally there seems to have been an increase in hydrocarbon content in the local sediments over the past 4–5 years. Most observation stations (sampling points) have in 1996 reported values above 15.3 mg/kg. The reference station used by Mannvik *et al.* (1997) for Region I shows a hydrocarbon concentration (THC) of 5.3 mg/kg. Compared with the reference station, all sampling points at the Ekofisk Center can be said to be contaminated. A «rule of thumb» states that the effects on biota can be expected to occur at values of twice the reference station. Most stations have values that are three times as high as the reference for Region I. Warwick and Clark (1991) concluded that a hydrocarbon content in sediment of between 10–100 mg/kg will moderately disturb the benthic community. Thus the Ekofisk Area is designated as one of «slight pollution» due to the THC value.



**Figure 14**  
Total hydrocarbon content (oil) around Ekofisk Complex. Red indicates values above 21 mg/kg, orange 16–21 mg/kg, yellow 11–16 mg/kg, and green 6–11 mg/kg (from RF and

Compared with the reference station for Region I, all sampling points at the Ekofisk Center are contaminated by heavy metals/metals like cadmium (Cd), lead (Pb), iron (Fe), zinc (Zn), copper (Cu) and barium (Ba). But the values are clearly within a range designated «insignificant to slight contamination» for sediments in coastal waters (SFT 1997). The area around the booster platforms is to a much lesser extent influenced by drilling production and it is expected that the level of hydrocarbon in the sediments is below 2 mg/kg (of NSTF 1993-c). It is assumed that the levels of metals in the sediments would be similar to other less influenced areas with open sea in the North Sea (NSTF 1993-c), which are low levels.

## 5.3 Natural resources

### 5.3.1 Plankton

Plankton are small plants and animals that move little in relation to the water mass in which they live. Phytoplankton are microscopic, freely suspended, normally single-celled algae. They exist mainly in the upper layers of the sea, where light supports photosynthesis. In the winter only small amounts of phytoplankton occur in the water, but in spring a bloom occurs with the increasing sunlight, higher nutrient values in the water, and formation of a stable surface layer. The spring bloom starts in March-April and lasts until the end of June. During the summer the amounts of vegetable plankton decrease as grazing by zooplankton accelerates and nutrient salts become in short supply. Between August-September-October a new bloom occurs, but the autumn bloom is usually smaller than its spring counterpart (Colebrook & Robinson 1965). Joint & Pomeroy (1992) estimate primary production in the central North Sea Area to be 100–150 gr. C/m<sup>2</sup>/year.

Zooplankton belong to different fauna groups, including single-cell animals, crustaceans (copepods), jelly fish, and fish. They consist of two groups, those organisms that live as plankton their entire life (holozooplankton), and those that pass through a plankton stage during parts of their life cycle (merozooplankton). Small crustaceans dominate the first category, and can make up 70–80 per cent of the



biomass of animal plankton (NSTF 1993A). Spawn and larvae of fish constitute an important part of the other category. Our knowledge of the breakdown of animal plankton in the North Sea is very limited. In general it can be said that the volume of animal plankton follows the bloom of vegetable plankton, with a lag of a couple of weeks. In the North Sea, copepods predominate (Fransz *et al.* 1991). Particularly numerous are the copepod, *Calanus finmarchicus*, which are carried with the current from the North Atlantic and drift with the upper water layers from March until August (Colebrook & Robinson 1965). This creature spends its winters in deep water, rising to the surface in February-March. The largest volumes occur in the upper layers from March to August. Generally large numbers of copepods occur for much of the year in the middle North Sea region, except during the winter months December, January, February and part of March (Colebrook & Robinson 1965). Simultaneously with the culmination of the biomass of the copepods, there are also large volumes of pelagic larvae and fry from many species of fish in the water. The copepods are a key food for them all. The copepod is also the key food source for adult herring. Krause & Martens (1990) estimated the production of zooplankton biomass to be greater than 10 grams dry weight per square metre of water in the period 2 May–13 June 1986.

### 5.3.2 Fish

The North Sea is one of the most richly stocked fisheries in the world. About 5 per cent of the total fish harvest in the world comes from the North Sea. The main pelagic species are herring, mackerel and sprat (Anon 1997-b). Of demersal species the significant fish are cod, saithe, haddock, whiting, plaice and sole, sandeel and Norway pout (Anon 1997-b).

Most populations of bottom-dwellers in the North Sea have now been reduced to very low levels due to over-fishing. The spawning population of herring has been very much reduced for many years, although its prospects are reported as improving (Toresen, 1998). For cod the spawning population remains very low and recruitment is generally poor. The mackerel stock has gone through a historical low point, but the Institute of Marine Research now reports that the decline has ceased. Also the stocks of haddock, whiting and saithe (coal fish) are generally low compared with previously, but at least an increase is predicted for haddock and whiting (Toresen, 1998).

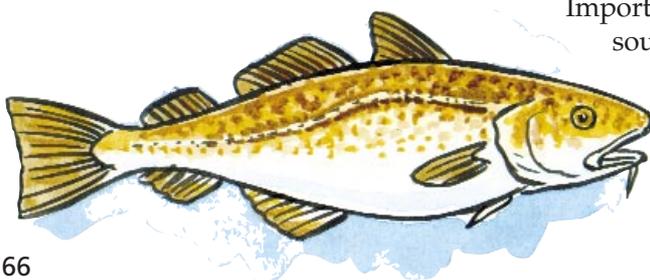
In this section of the North Sea occur eggs and larvae of many fish species. Mackerel, Norway pout and sandeel all have important spawning grounds here, and large volumes of spawn from the North Sea herring drift into the area. There are also larval stages of plaice, cod and sprat.

#### Cod

Cod spawns all over the North Sea. The highest egg concentrations are normally in the English Channel, Dogger Bank, and along the Scottish coast.

Important growth areas are the German Bight and south-eastern part of the North Sea.

Until the sixties the annual harvest of cod in the North Sea was 50,000–100,000 tonnes. From then on the harvest increased to a peak of 350,000 tonnes in 1972. This volume was far more than the population can withstand, and

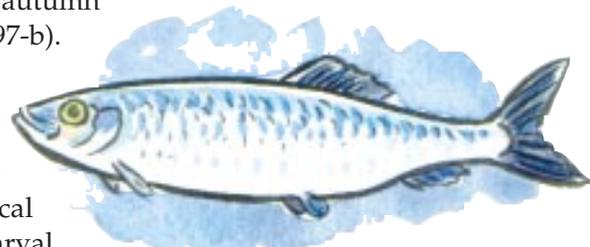


in recent years catches have been significantly less (approx 100,000 tonnes). The Norwegian catch is very modest indeed: in 1997 Norway took some 6,500 tonnes of a 9,850 tonne quota.

The status of cod in the North Sea is described as «worrying» (Anon. 1997-b).

**Herring**

Herring in the North Sea belong to several stocks, the autumn spawning stock being the largest in size (Anon 1997-b). Spawning takes place on the fishing banks east of the UK and Shetland/Orkneys in August (Table 8). The herring larvae drift with the currents into the North Sea and Skagerrak, staying normally within the top 30-40 metres of water, and making diurnal vertical migrations through the water column. Normally larval stages of autumn herring will drift across the whole North Sea to Skagerrak and German Bight. They will therefore encounter the Ekofisk area in the autumn and winter. Spring-spawning herring spawns, among other places, in the western parts of the North Sea and in the Skagerrak and Kattegat (Pethon 1989, Anon 1997-B).



The spawning population of North Sea herring has shrunk from an estimated 5 million tonnes after the second world war to less than 500.000 tonnes estimated in 1997. Extensive over-fishing is the culprit causing this collapse, and today the North Sea herring stock is considered fairly vulnerable (Toresen 1997).

**Mackerel**

The North Sea stock of mackerel has its primary spawning grounds in the central areas of the North Sea (Bakke *et al.* 1987, Anon. 1978), but also spawns northward along the Norwegian coast. Mackerel spawns between the middle of May and end of July (Table 8), with a maximum occurring in mid-June. Eggs and larvae disperse with the current systems in the area (Bjørke *et al.* 1990). The eggs generally occupy the top 10 metres, and hatch after 3-7 days. Newly hatched larvae drift with the surface water, most being found between 10 and 20 metres down.



**Sandeel**

This industrial fish is found over much of the North Sea. It occurs mainly in shallower parts where the bottom is sand or gravel. The primary areas are from the Viking Bank across to the Danish coast along the Egga Edge, across Dogger Bank, and in the coastal areas of Shetland, England, and Denmark (Lahn-Johannesen 1987). Sandeel likes to spawn on a sandy bottom, and spawning and hatching occur during much of the year depending on variety and population. Spawning occupies a large area in the central and southern parts of the North Sea. The larvae live freely in the water column before ultimately diving for the bottom. The spawning grounds for sandeel in the Norwegian sector are not well known, despite the industrial significance of this fish (Anon 1997-B). Spawning has been recorded in the Ekofisk Area (Figure 14).



**Table 8**

*Spawning period (colour) for selected fish populations in the North Sea (after Pethon 1989, for herring also Anon 1997-B).*

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mackerel												
Sandeel												
Herring												
Plaice												
Cod												
Norway pout												
Sprat												
Saithe												
Haddock												
Whiting												
Sole												

### 5.3.3 Seabirds

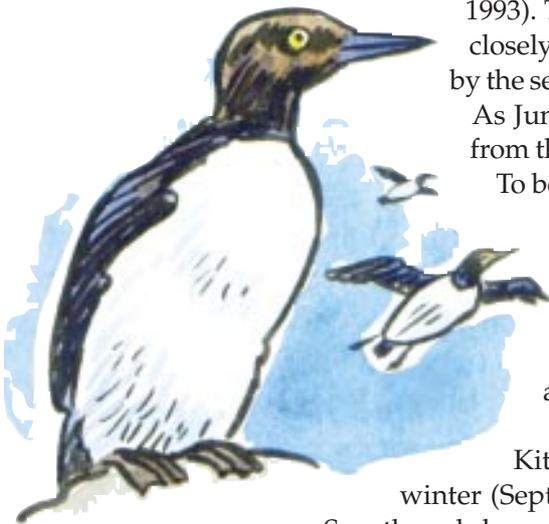
The Ekofisk Area lies outside the places in the North Sea where the greatest concentrations of seabirds are observed (NSTF 1993-a, Carter et al. 1993). The variations in occurrence of seabirds in the open sea are closely connected with their activities, which are controlled in turn by the seasons (Table 9).

As June turns into July an immense number of seabirds migrate from their nesting sites and into the central parts of the North Sea.

To begin with the young of the auks are unable to fly, and therefore they migrate on the surface. In company with moulting adults they therefore swim across the North Sea to their winter quarters in Skagerrak and Kattegat. From July to September a large number of birds will be found in the central parts of the North Sea. The auks (guillemots, auks, little auks, puffins) are the most numerous.

Other species too, like Fulmars, Skuas, Gannets and Kittiwakes occur in large numbers. As autumn draws on into winter (September-February) these types remain in the central North Sea, though large numbers have also moved further east to Skagerrak and Kattegat or the southern parts of the North Sea.

Seafowl are not expected to suffer in any way from the offshore removal processes. If underwater blasting is carried out, individual birds may be hit.

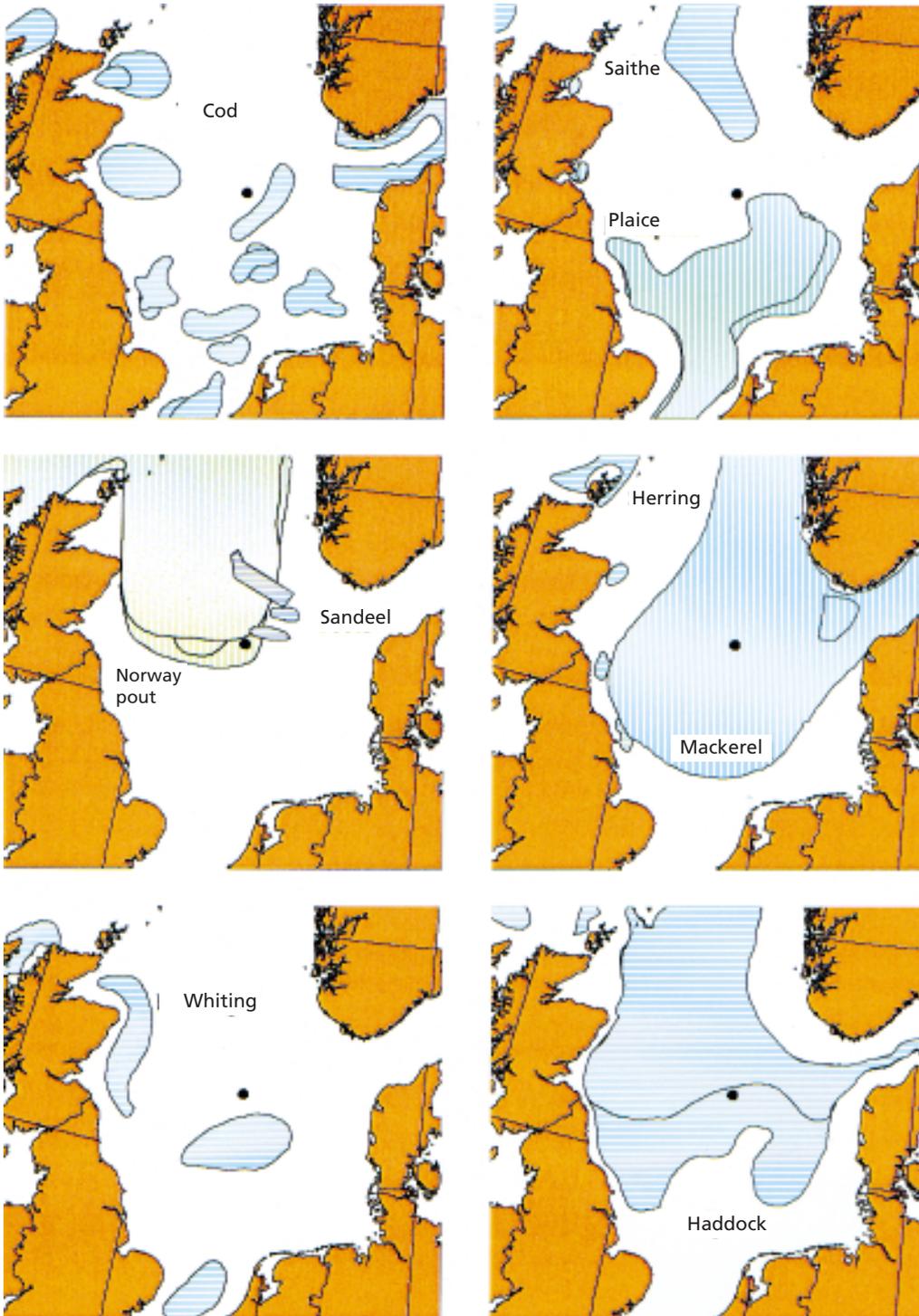


**Table 9**

*Key periods in life cycle of seabirds (after NSTF 1993B) (colour)*

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Nesting												
Swimming migration (auks)												
Moulting												
Migration (flying)												
Wintering												

**Figure 15**  
*Spawning areas for selected fish species in the North Sea. Ekofisk is marked with a dot (•).  
Data taken from MRDB®.*



### 5.3.4 Marine mammals

Several types of whale are seen regularly in the North Sea, but most observations are sporadic and the migration patterns and sizes of the stocks are not well known (Reijnders & Lankester 1990). The predominant species in the North Sea are the Minke whale and Pilot whale. The former is mainly observed north-west of Ekofisk. Observations of Minke have also been made within the Ekofisk Area (Øien 1990). The whales that occur in the North Sea are believed to make up a tiny portion of the total stock, which largely comes from southern parts of the North Atlantic and follows the North Sea up to the Barents Sea. The smaller whales (like the porpoise) largely stay close to shore, although they also occur in the North Sea and can therefore be expected to visit Ekofisk. Seals are also occasional guests, occurring individually in the area. Marine mammals are not expected to suffer from any of the operations associated with cessation.

### 5.4 Fishing resources

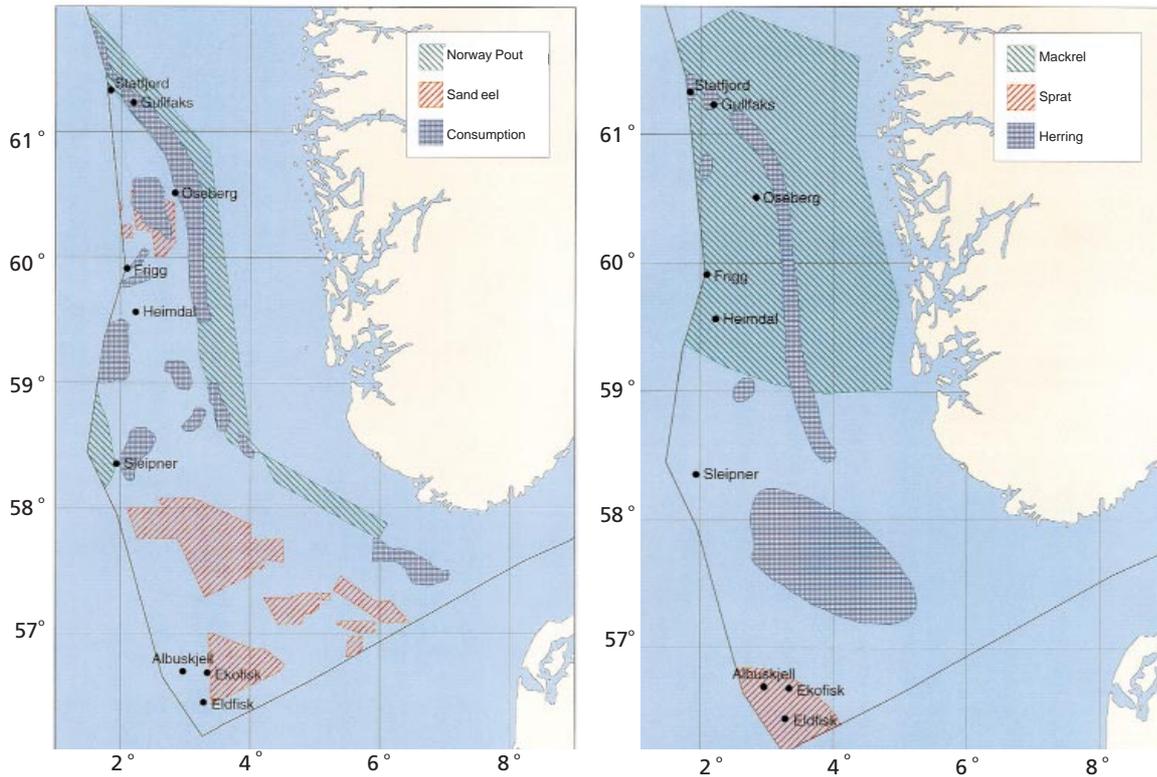
The North Sea is an internationally significant area for spawning, growth and feeding of fish, and its importance is reflected in the size of the catches. The volume of fish in the North Sea makes up about 5 per cent of the total world catch (Anon. 1997). Fishing in the North Sea can be divided into three main categories: trawling for human consumption (mainly cod, haddock and whiting); trawling for industrial fish (generally Norway pout, sandeel, blue whiting, sprat); and pelagic trawling and purse seine fishing (mainly for herring, mackerel and horse mackerel) (Soldal 1996). In the Ekofisk Area the various fishing operations are conducted to different extents by a range of countries. To the Norwegian fisheries the Ekofisk Area is mostly used for purse seining and trawling for industrial fish (Figure 16).

There are no detailed records of fishing activities within the Norwegian sector of the North Sea. The Directorate of Fisheries catch register does, however, contain information on harvest quantities of different fish types in the various areas of the Norwegian fishery zone. This information is based on reported catches at Norwegian sales co-operatives. A similar reporting system exists in other countries with a fishing fleet working in the North Sea.

#### 5.4.1 Ekofisk Area

Regarding international fishing activities in the Ekofisk Area, the Danish and Scottish fishing operations are of interest. Norwegian, Danish and Scottish fishing statistics from the Directorates of Fisheries in Norway and Denmark, and the Marine Laboratory in Aberdeen, form the basis for evaluating the significance of the Ekofisk Area and neighbouring vicinities as fishing banks in the North Sea.

The Norwegian fishing statistics refer to a division by «main areas», where main area number 41 covers central parts of the North Sea, including the Ekofisk Area. Area 41 is subdivided into numbered «locations» of 0.5 °N-S and 1 °E-W, representing an area of about 4.000 square kilometres. Compared with the oil industry's division into blocks in the Norwegian sector, this is about the size of six oil blocks.



**Figure 16**  
*Areas of Norwegian purse seine fishing (right) and trawling (left) off coast of Southern Norway.*  
 Map by Directorate of Fisheries

Scottish and Danish fishery statistics are based on a different system of rectangles drawn up by the International Council for Exploration of the Sea (ICES). These rectangles, for their part, are equal in size and position with the locations under the Norwegian system. To simplify the presentation in this Report, the Scottish and Danish statistics have therefore been converted and cited in accordance with the Norwegian location designators.

Norwegian statistics at the main area level are reasonably reliable, but the statistics at the location level conceal large potential reporting errors. The problem is greatest for trawling, where the total catch is reported for the location where the trawl is lifted, even though the fish may have been caught in several locations. The statistics at the location level are therefore a rather shaky background for estimating the actual fishing harvest. In the absence of fuller statistics for sub-areas of the North Sea the Directorate's figures can still be used to assess which types of catch are conducted in a given area, and estimate the significance of the area as a fishing ground. The quality of the Danish and Scottish fishing statistics is believed to be comparable with the Norwegian statistics, and the information is used accordingly.

In our presentation of the Norwegian fishery statistics they are broken down into the Ekofisk area and neighbouring vicinities to the north and east of Ekofisk. The breakdown by fishery locations is indicated in Figure 17. Danish fishery statistics embrace the locations corresponding to those given in Figure 17 as the Ekofisk Area. Scottish fishery statistics cover a slightly different group of locations which are also deemed representative for the Ekofisk Area.

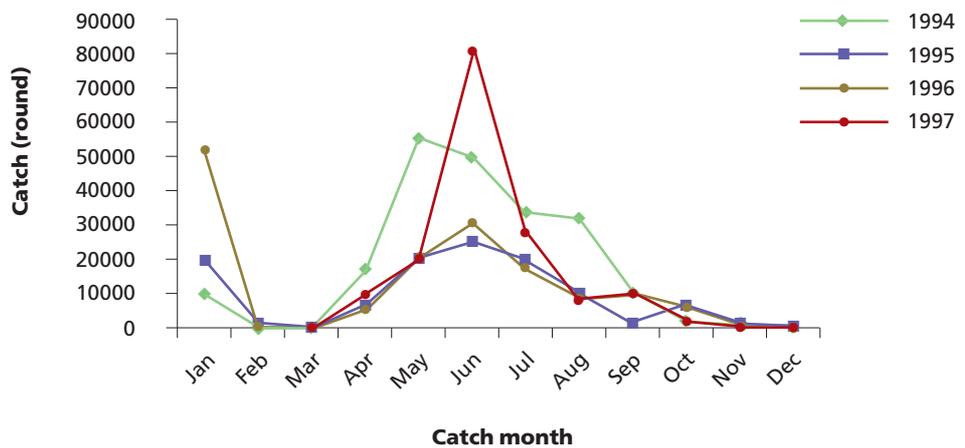
**Figure 17**

Chart of main areas and locations used in Norwegian Directorate of Fisheries Statistics. A red line (-) denotes the area designated Ekofisk Area, a blue line (-) denotes the neighbouring areas north and east of Ekofisk.



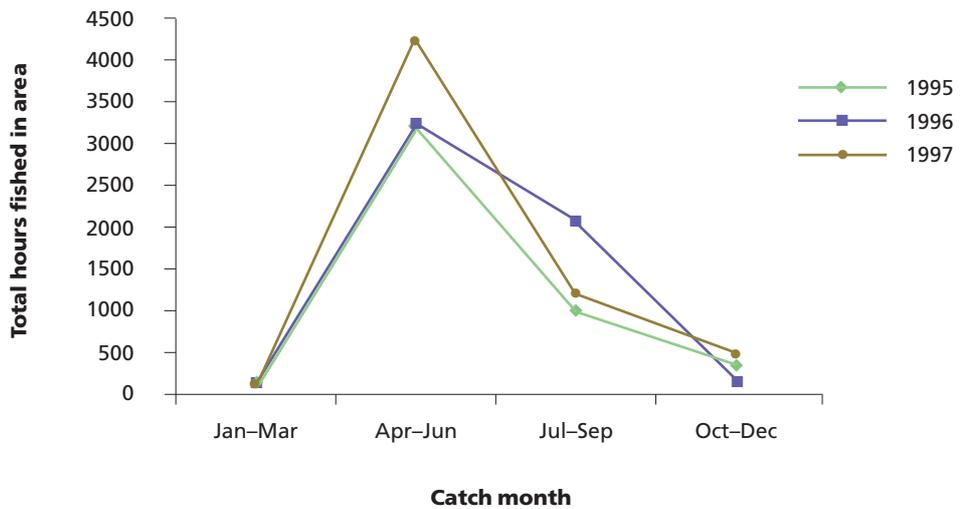
**Figure 18**

Monthly breakdown of Norwegian harvests in tonnes (round weight) in main area 41 including Ekofisk Area during period 1994-1997 (data from Norwegian Directorate of Fisheries, 1998)



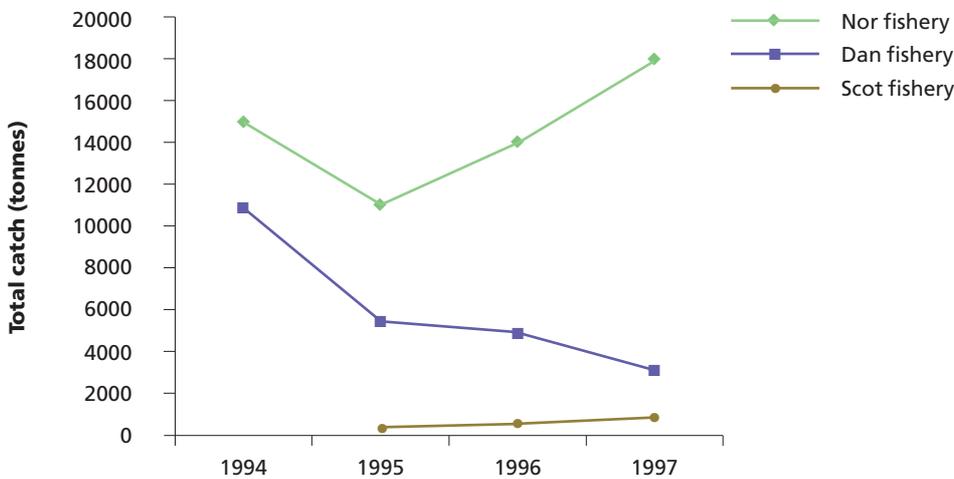
**Figure 19**

Quarterly breakdown of Scottish fishing operations in Ekofisk Area (locations 53, 62, 63, 64 and 73) indicated as total hours fished in area (data from Marine Laboratory, Aberdeen, 1998)



An idea of Norwegian fishing operations throughout the year in the central part of the North Sea is given by presenting monthly harvests for main area 41, see Figure 18. It suggests that January and May-June are the key periods for Norwegian fishing in this part of the North Sea. The statistics for numbers of hours fished in the Ekofisk Area by Scottish vessels indicate that the most intensive Scottish fishing is done in the second and third quarters, see Figure 19. Norwegian and Scottish statistics are believed to be representative of the total fishing activity in the Ekofisk Area, and collectively they also indicate that the fishing in the area is performed most actively in the summer six months.

Harvest statistics taken from Norwegian, Danish and Scottish fishing authorities are presented in Figure 20 and Table 10, Table 11 and Table 12. Statistics of the total fished volume indicate that Norwegian fishing predominates over international catches in the Ekofisk Area.



**Figure 20**  
 Total tonnes taken in Ekofisk area reported by Norwegian, Danish and Scottish skippers in period 1994–1997 (Scottish figures for period 1995–1997)

In the industrial trawling category the Ekofisk Area itself is most popular with Danish and Norwegian skippers. Otherwise considerable international industrial trawling takes place in this part of the North Sea, involving other nations also. Mainly the largest catches are taken east of the Ekofisk Area, within the trawling zone designated «Inner Shoal» (Directorate of Fisheries 1998, PPCoN 1993).

Limited international trawling for consumption also occurs within the Ekofisk Area. Danish and Scottish vessels account for the largest harvests here. Norwegian trawling for consumption is of little significance in the Ekofisk Area.

Norwegian fishery statistics also indicate that for several years considerable seine fishing has taken place at Ekofisk. This type of operation is very unusual for Danish and Scottish skippers.

Compared with other areas in the North Sea, catches in and around Ekofisk are still small. This is in line with the opinion that fishing in and around Ekofisk is actually quite small (Valdemarsen 1994).

A separate report (DNV 1999-c) presents trawling for consumption, industry trawling, and purse seining in the Ekofisk Area in greater detail.

**Table 10**

Norwegian catches (tonnes round weight) during period 1994–1997 in Ekofisk area, and in adjacent areas north and east of Ekofisk, and in entire central part of North Sea (data from Directorate of Fisheries 1998)

Year	Ekofisk Locations 52, 53, 62 og 63				North and east of Ekofisk Locations 54, 64, 72, 73 og 74				Central North Sea Main area 41		
	1994	1995	1996	1997	1994	1995	1996	1997	1994	1995	1996
Trawl for consumpt.	–	–	106	118	–	–	282	–			
Industry trawl	280	578	1,047	17,794	53,655	41,889	46,675	156,743			
Seine	14,599	10,754	12,994	399	4,847	3,502	5,734	1,309			
<b>Total</b>	14,879	11,332	14,147	18,311	58,512	45,401	52,691	158,052	217,432	121,591	161,433

For comparison, the total Norwegian catch in the North Sea in 1997 was about 630,000 tons (Agenda 1999).

**Table 11**

Scottish fishing harvests in tonnes reported in Scotland from Ekofisk area in locations 53, 62, 63, 64, 73 in period 1995–1997. Catches broken down by species and gear (deep purse seine, various trawls). (Data from Scientific Database, Marine Laboratory, Aberdeen, 1998)

Types	1995		1996		1997	
	Seine	Trawl	Seine	Trawl	Seine	Trawl
Plaice	24	19	25	41	37	67
Cod	214	60	204	210	281	250
Haddock	203	60	159	99	136	118
Sole	21	15	35	35	47	63
<b>Total broken down by gear</b>	534	168	485	422	531	531
<b>Scottish fishing total</b>	702		907		1,062	

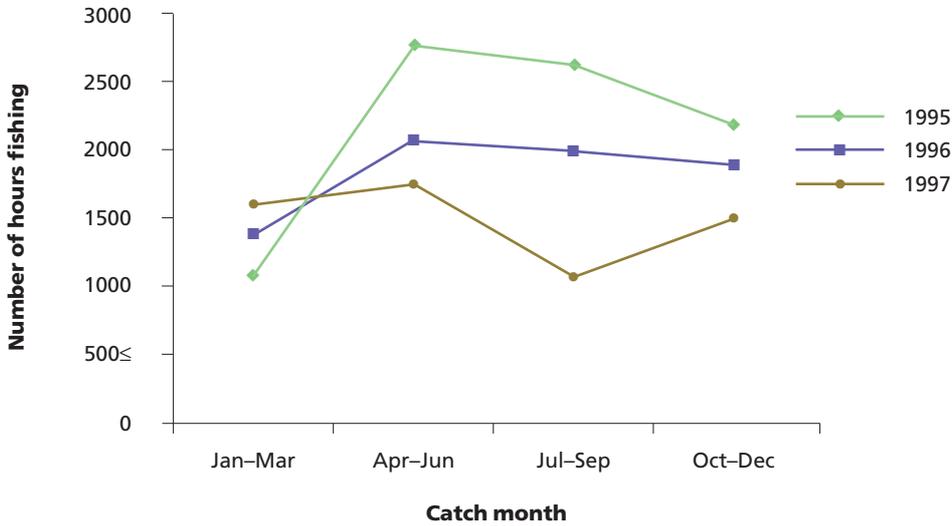
**Table 12**

Danish catches in tonnes from Ekofisk area locations 52, 53, 62, 63 in period 1994–1997, broken down by species and gear used. (Data from Directorate of Fisheries in Denmark, 1998)

Trawl for consumption	1994	1995	1996	1997
Plaice	366	166	399	347
Sole	142	82	139	112
Cod	834	422	950	355
<b>Total</b>	1,342	670	1,488	814
Industry trawl				
Sprat	185	115	180	80
Norway pout	1,293	1,233	495	–
Sandeel	7,594	2,875	2,593	2,311
<b>Total</b>	9,072	4,223	3,268	2,391
Seine/trawl				
Herring	31	97	13	–
Norse mackerel scad	520	80	49	–
<b>Total</b>	551	177	62	–
<b>Danish fishing total</b>	11,196	5,511	4,922	3,265

5.4.2 Areas around boosters 37/4A and 36/22A south-west of Ekofisk.

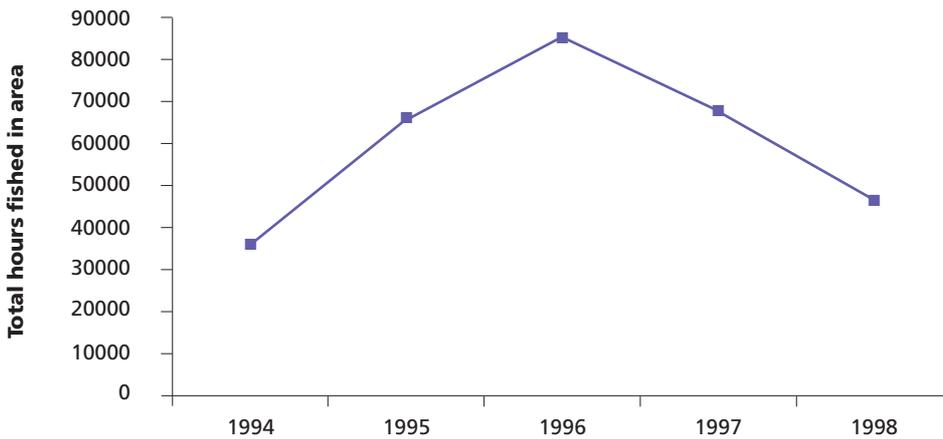
Statistics for the period 1995–1997 indicate that in the area around the boosters 37/4A and 36/22A on British side of the sector boarder, British fishery is present during the whole year (Figure 21).



**Figure 21**  
Distribution in quartiles of British fishery activity (vessels landing in Scotland) in the area around boosters 37/4A and 36/22A, showed as total number of hours fishing (data from Scientific Database, Marine Laboratory, Aberdeen 1999)

Catch statistics for 1997 in the actual area provided from Scottish and Danish fishery authorities are presented in Figure 22, Table 13 and Table 14.

There are also a modest activity in this area of British fishermen landing their catches in England. Such statistics are not provided, but according to MAFF (Ministry of Agriculture, Fishery and Forestry, London) these catches landed in England constitute only a minor amount compared to Scottish landings (Pers.comm. Alan Cornell, MAFF). Therefore only Scottish catch statistics are presented here as an indication of the extent of British fishery in the actual area.



**Figure 22**  
Danish fishery landings (given in tonnes) during the period 1994–1998 (preliminary statistics for 1998) in the area around boosters 37/4A and 36/22A (ICES-rectangles 39E9, 39F0, 39F1, 40E9, 40F0 and 40F1)

Danish fishery landings in the area around 37/4A and 36/22A (Figure 22) have varied during the last years. The statistics are complete for the period 1994–1997, and statistics for 1997 are in the following presented to describe Danish fishery in greater detail.

Danish catches in the area around 37/4A and 36/22A in 1997 were about 70,000 tonnes. The dominating Danish fishery in this area is the industrial

trawling fishery for Sandeels, where the largest catches are reported from the southern and eastern part of the area (especially ICES-rectangle 39F1).

Consumption trawling exploiting flatfish (mainly Plaice and Lemon sole) is also present, as well as gillnet fishery exploiting Turbot. Danish catches of Gadidae (Cod, Saithe and Haddock) in this area are low.

British fishermen delivered about 1,000 tonnes of fish caught by bottom gear to Scotland in 1997 (Table 14). About 70% of this were landed by bottom trawl. The total British catches landed in Scotland from this area are comparable to the British fishery activity in the Ekofisk-area, and are to be characterized as modest.

**Table 13**

*Total Danish landings (given in tonnes) from the area around the boosters 37/4A and 36/22A in 1997 (ICES-rectangles 39E9, 39F0, 39F1, 40E9, 40F0 and 40F1), distributed on fish species and type of fishery/gear*

Species	Consumption trawl (tonnes)	Industrial trawl (tonnes)	Gillnets (tonnes)	Total (tonnes)
Cod	12	-	7	19
Saithe	4	-	-	4
Plaice	43	-	8	51
Lemon sole	33	-	-	33
Turbot	1	-	14	15
Whiting	30	-	-	30
Horse mackerel	85	-	-	85
Angler fish	2	-	1	3
Herring	-	165	-	165
Sprat	-	1,435	-	1,435
Norway pout	-	870	-	870
Sandeel	-	67,294	-	67,294
Other	5	27*	4	36
<b>Total (tonnes)</b>	<b>215</b>	<b>69,791</b>	<b>34</b>	<b>70,040</b>

\* Unspecified trawlcatches; may include catches of both industrial trawl- and consumption trawl species.

**Table 14**

*Total Scottish landings (given in tonnes) in 1997 from the area around the boosters 37/4A and 36/22A (ICES-rectangles 39E9, 39F0, 39F1, 40E9, 40F0 og 40F1), distributed on fish species and type of fishery/gear*

Species	Demersal net (tonnes)	Demersal trawl (tonnes)	Pelagic trawl (tonnes)	Total (tonnes)
Plaice	9	16	-	25
Whiting	40	131	-	171
Cod	70	126	-	196
Haddock	144	245	-	389
Lemon sole	9	51	-	60
Dogfish	18	39	-	57
Angler fish	-	15	-	15
Catfish	-	3	-	3
Witches	-	4	-	4
Sandeel	-	79	-	79
Other bottom living fish	7	13	-	20
Crustaceans	3	43	-	46
Herring	-	-	269	269
<b>Total (tonnes)</b>	<b>300</b>	<b>765</b>	<b>269</b>	<b>1 334</b>

# 6 IMPACT ASSESSMENT FOR TOPSIDES DISPOSAL ALTERNATIVES

## 6.1 Description of Topsides Disposal Alternatives

Topsides Disposal Alternatives	
<p><b>Alternative IA</b></p> <p><i>Jacket Topsides:</i> Lift and transport to shore for recycling</p> <p><i>Tank Topsides:</i> Remove offshore and transport to shore for recycling</p>	<p><b>Alternative IB</b></p> <p><i>Jacket Topsides:</i> Lift and transport to shore for recycling</p> <p><i>Tank Topsides:</i> Remove at shore &amp; recycle after towing to shore on substructure</p>

One Disposal solution is short-listed for the topsides: Relocate to shore for demolition and recycling of materials. However, two different Alternatives for bringing the Tank topsides to shore are identified: (1) offshore removal (Alternative IIA), or (2) inshore removal (Alternative IIB – this Alternative would require the Tank substructure to be refloated together with the topsides and towed to shore).

For removal of the topsides on the steel jackets, preparations will be made on the platforms, involving partition into smaller pieces (modules) and readying for lifting operations. A heavy-lift vessel will then be employed to lift off major units (modules) and place them on transport barges or its own deck (see Figure 23). The topsides will then be taken to a demolition yard for further partitioning, with the units being either lifted or pushed ashore. Once onshore, the demolition operations will progress according to a firm plan and clear work procedures. Materials will be segregated and waste sorted. Units and equipment suitable for re-use will be tagged and put aside. Materials suitable for recycling will be segregated, broken into convenient sizes for transportation, and sent to recycling contractors.

The topsides on the Ekofisk Tank are very unusual, very large, and very extensive, with 82 modules. Due to the Protective Barrier Wall, there are limitations on use of heavy lift vessels during removal of the Tank modules. Removal of the modules offshore (Disposal Alternative IA) is estimated to require six months of preparation, followed by three months of removal activity. The modules could also be removed inshore (Disposal Alternative IB) if the Tank substructure is towed to shore. This Alternative would require insignificant additional energy to transport the topsides to shore and involves less use of heavy crane vessels to dismantle and lift off the modules once the Tank is inshore. However these aspects would have to be seen in conjunction with the additional burdens ensuing from refloating and towing the Tank substructure ashore – see Chapter 7.

Removal of the various topsides will be spread over many years (cf. Section 1.3). Preparations for removal can take some 2–3 months, whilst the actual heavy-lift operation will generally take about three to five days for each topside.

It is expected that topsides removal technology will evolve over time, bringing economic advantage (more cost-efficient solutions) as well as environmental benefit (in form of reduced energy consumption and lower atmospheric emissions) and improved safety levels. Use of new technology for lifting complete topsides in a single operation would also increase the opportunity for re-use.

**Figure 23**  
Lifting of topsides modules using heavy-lift vessel



## 6.2 Environmental Impacts of the Topsides Disposal Alternatives

The environmental consequences estimated to follow from the Topsides Disposal Alternatives are described below.

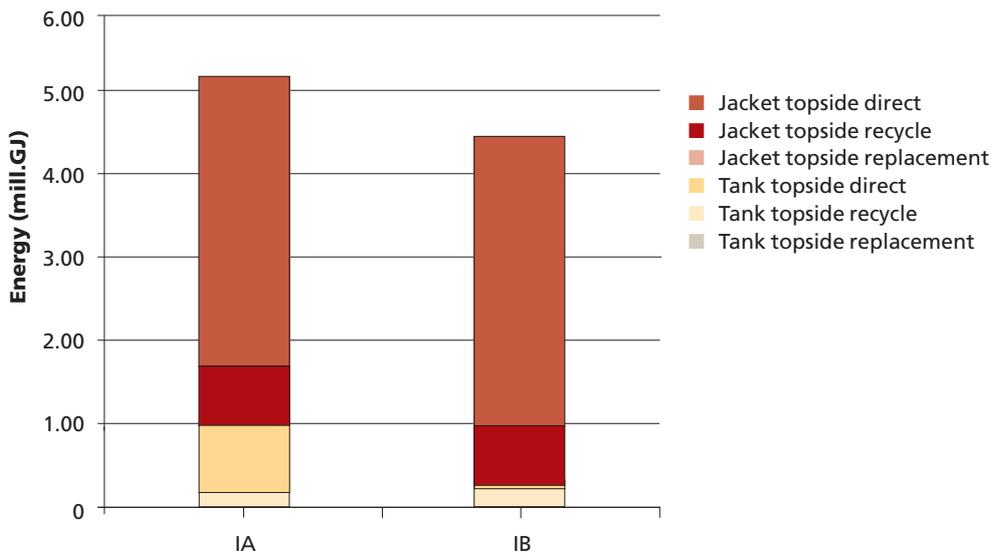
### 6.2.1 Energy consumption and Total Energy Impact

The energy assessments for disposal of the topsides are based on recycling the materials removed. No account is taken of re-use of parts of the topsides, since any re-use will only make up a small fraction of the total material volume.

Table 15 and Figure 24 show the Total Energy Impact in the case of removal of the topsides (because materials will be recycled, the energy consumption is the same as the Total Energy Impact):

**Table 15**  
Energy consumption and Total Energy Impact for removal of topsides (GJ)

Operation	Removal of topsides from steel jacket structures	Offshore removal of Tank topsides	Inshore removal of Tank topsides
Marine operations	3,300,000	780,000	40,000
Breaking	100,000	20,000	20,000
Metal recycling	700,000	200,000	200,000
<b>Sum (Total Energy Impact)</b>	<b>4,100,000</b>	<b>1,000,000</b>	<b>260,000</b>



**Figure 24**  
 Energy consumption and Total Energy Impact<sup>9</sup> for Toppides Disposal Alternatives

The two Disposal Alternatives for the topsides forecast an energy consumption in the region 4.4 to 5.1 million GJ. Removal of the Tank topsides inshore results in an energy saving of 14 % considering the topsides in isolation. The energy savings must, however, be considered in conjunction with the additional energy impacts caused by removing the Tank substructure to shore (see Chapter 7).

An energy consumption of 5 million GJ corresponds to the energy used by 125.000 family cars in one year, or 75 % of the electricity consumption of a town the size of Stavanger (about 100.000 citizens) in one year.

The fuel consumption of the marine operations is equivalent to the total oil production on the Ekofisk field for 2 days (approximately 330,000 barrels of oil per day).

### 6.2.2 Emissions to atmosphere

The two topsides Disposal Alternatives will result in atmospheric emissions, including exhaust emissions from ship operations as the main source. In addition, emissions will be caused by the recycling operations (re-smelting).

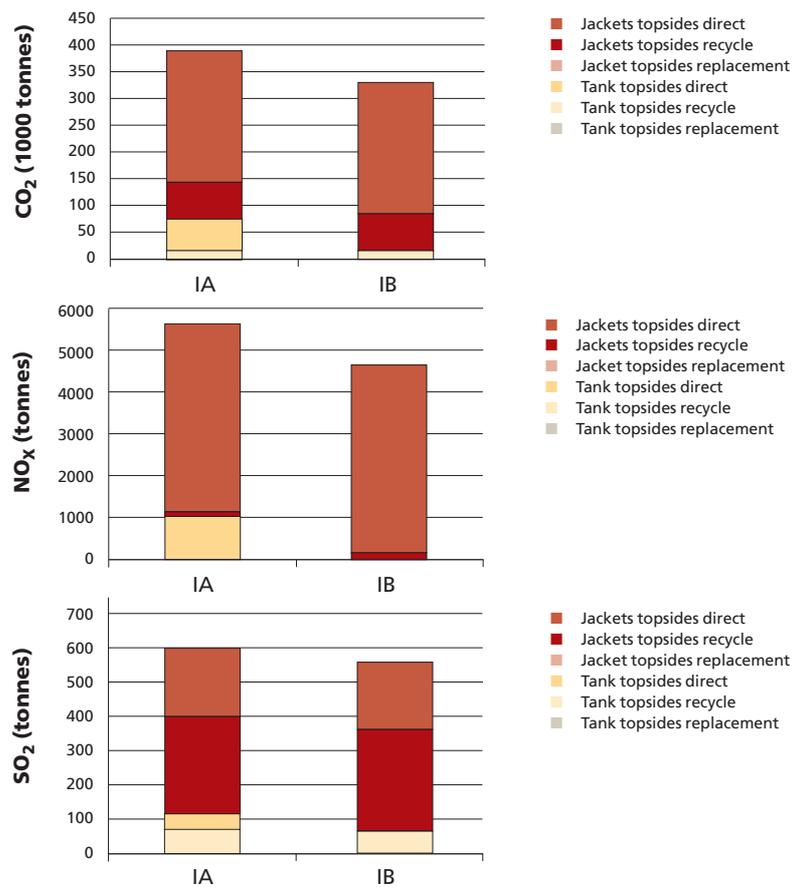
The estimated emissions from the topsides Disposal Alternatives are quantified in Table 16 below and illustrated in Figure 25.

<sup>9</sup> The Total Energy Impact is the sum of three different factors: (1) direct energy consumption for removal (e.g. fuels for vessels); (2) energy consumption required for processing and recycling of materials; and (3) indirect «replacement energy» i.e. the energy needed to produce new materials equal to the amount not being reused/recycled. See also section 2.3.1.

Operation	Removal of topsides on steel jackets	Offshore removal of Tank topsides	Inshore removal of Tank topsides
<b>CO<sub>2</sub>-emissions</b>			
Marine op./onshore demolition	240,000	60,000	3,000
Recycling of metals	70,000	17,000	17,000
<b>Total</b>	<b>310,000</b>	<b>80,000</b>	<b>20,000</b>
<b>NO<sub>x</sub>-emissions</b>			
Marine op./onshore demolition	4,500	1,000	50
Recycling of metals	120	30	30
<b>Total</b>	<b>4,600</b>	<b>1,000</b>	<b>100</b>
<b>SO<sub>2</sub>-emissions</b>			
Marine op./onshore demolition	200	50	3
Recycling of metals	280	70	70
<b>Total</b>	<b>480</b>	<b>120</b>	<b>70</b>

**Table 16**  
Emissions to atmosphere due to removal of topsides (tonnes)

**Figure 25**  
Atmospheric emissions from the Topsides Disposal Alternatives<sup>10</sup>



<sup>10</sup> See Chapter 2.3.1 for description of method

The estimated CO<sub>2</sub> emissions from removal of both the steel jacket topsides and the Tank topsides are 390,000 tonnes for Alternative IA and 330,000 tonnes for Alternative IB. The major difference in releases arises from removal of the Tank topsides inshore for Alternative IB, and the associated low NO<sub>x</sub> release. The cause of this relatively major reduction is that marine operations associated with offshore removal cause relatively high NO<sub>x</sub> releases.

### 6.2.3 Discharges to sea, water or ground

No discharges are anticipated either into the sea due to the removal or transport to shore of the topsides.

Nor are any discharges to sea, water or ground expected in connection with demolition of the topsides, as demolition will take place at suitable yards which are normally equipped with concrete aprons with collection drains for water containing any oil or chemicals.

Onshore demolition, however, will necessarily cause generation of waste that must be dealt with, and once disposed this waste has the potential to contaminate water through seepage at the site. The current criteria for waste dumps will counteract this, however. Spills due to accidents are impossible to predict, but process trains and similar will be subject to a clean-and-purge regime offshore before removal commences and thus there are only minimal amounts of oil and chemicals that can be released. The amount released, and the chance that accidents might happen, can both be reduced by setting up procedures for each work operation conducted. Precautions will also be designed to contain the impact of any spill.

The total scale of spillage into the sea, water or ground is described as small/none, and the environmental impacts are therefore considered «insignificant».

### 6.2.4 Physical impacts and impacts on habitat

The lifting vessels employed to remove the topsides can be expected to deploy anchors for mooring and steering. Alternatively, they may use dynamic positioning (DP). Mooring operations are likely to disturb the bottom sediments (0–2 metres deep) on the seabed. The physical impacts will be minute and extremely local, and the sandy bottom will soon level off again. It is estimated that the benthic community in this very limited area will recover in the course of a few years. The expected ecosystem effects are therefore considered «insignificant».

### 6.2.5 Aesthetic impacts

No particular noise, smell or visual pollution is expected from operations to dismantle and remove the topsides offshore.

After arriving ashore, dismantling of the topsides in a demolition yard can be expected to have repercussions for the local community. Storage of large platform components may be aesthetically displeasing in the local setting, but the potential effect is deemed insignificant as such operations will likely take place in an industrial area.

The negative aesthetic impacts in connection with demolition of the topsides are principally associated with noise. Results from different noise

surveys taken at Norwegian firms engaged in similar activities show the importance of ensuring a physical distance to the nearest neighbours. The maximum values for noise from a mobile shears or tipping of scrap steel in normal operations are given in Table 17. The equivalent noise level during a normal weekday is estimated by the factories at 50–55 dBA.

**Table 17**  
Noise level in dBA at different distances from demolition yard source

Distance to noise source [m]	Measured noise [dBA]
10	83
50	69
100	63
200	57



Similar measurements made at 10 metres distance from an oxy-acetylene cutter gave values of 70–73 dBA, for an angle-grinder 77–80 dBA, and for a diesel-driven mobile crane loading scrap iron onto a truck with an electromagnet 80–90 dBA (SFT 1992). Table 18 gives the noise zone radius (metres for noise levels for different activities) for the industry category «scrap dealers», with typical values for noise from this type of activity (Austrheim, SFT, personal communication).

**Table 18**  
Noise zone radius in metres for different noise levels at scrap dealer

40 dB	45 dB	50 dB	55 dB	60 dB	65 dB
1250	700	400	225	125	70

The Pollution Control Authority's («SFT's») «Guidelines for Noise Abatement in Industry» (SFT TA 506) set the following standards for industrial noise:

	Quarters/Classrooms:	Holiday cabins/Hospital:
Day (0600–1800):	50 dBA	40 dBA
Evening (1800–2200):	45 dBA	35 dBA
Night (2200–0600):	40 dBA	35 dBA

The sound levels are the equivalent intensity and free field values. The maximum intensity must not exceed the threshold for equivalent intensity by more than 10 dBA.

Accordingly, DNV assumes on this basis that it is not unreasonable to estimate an equivalent noise level from a demolition yard in normal operation using hydraulic shears to be about 50–55 dBA with peaks of 55–85 dBA at a distance of 200–10 metres from the source. This indicates that noise from the demolition process for the topsides has a certain negative impact potential. The choice of locality (seen among other things in relation to other buildings and topographical features) and abatement measures can reduce this potential considerably. If the selected location does not have resources (built-up area,

natural resources) affected by noise, then the impact can be described as «moderate negative». If demolition takes place close to a built-up area, however, the activity would represent a «large negative» impact.

### 6.2.6 Waste/Resource utilization

Locations for demolition and processing waste from the topsides have not yet been decided. This assessment of waste is therefore related to types and volumes of waste, and not directly to any local impacts at the place ultimately chosen, its processing facility, or the waste dump in question.

Removal and demolition of the topsides means processing a total of 105.000 tonnes of materials. Possible disposal options for each material type are considered more detailed in a separate report (DNV 1999-c). The main points are reviewed in this Section.

#### Metals

The main bulk of the materials in the topsides consist of metals – principally steel, copper and some aluminium.

Metal recycling (scrap dealing) is a well-established activity and networks exist for sorting, processing and sale.

The amount of steel in the topsides totals 92,000 tonnes. It is expected to be recycled mainly by being melted down at steel works. In this case, paint might represent a problem during melting since toxic gases will form, as will heavy metal dust and contaminated slag. The organic components in the paintwork products will also increase the temperature of the smelt and might cause flames to form, damaging filters and exhaust ducting.

Copper is found in electrical cables and amounts to some 2.900 tonnes in the topsides. Techniques (cable granulation) to separate the copper from the plastic sheathing have been developed for cables. The copper is almost exclusively melted down again. The plastic can be processed like other plastic waste, and is discussed separately below.

The aluminium content is about 100 tonnes, which is found in building structures in the topsides. It can largely be recycled by aluminium manufacturers and scrap dealers in Norway and abroad. Smaller volumes of scrap could be disposed of at a waste dump. It is not considered to be problem waste.

Nickel and cadmium in battery powerpacks total 1 tonne. These batteries are almost exclusively recycled by melting down to give the component metals (F. Hagen, AS Batteriretur, personal communication). It is expected that nickel/cadmium batteries in the Ekofisk I topsides will be recycled, not disposed of as waste.

DNV has also prepared a separate report (DNV 1999-c) for further assessment of disposal possibilities for metals.

#### Concrete

The topsides contain concrete mainly as a cement screed on the floors of the living quarters to make them flat and level. The screed used is a two-component blend called Ardex, and has an estimated thickness of 30 mm and makes up about 770 tonnes in total.

DNV has also prepared a separate report (DNV 1999-c) for further assessment of disposal possibilities for concrete.





**Timber**

A total approaching 30 tonnes of timberwork exists in the topsides, used as a construction material. It is expected that almost all timber will be recycled as an energy source.



**Other building and construction materials**

These are mainly the materials used in partition walls, ceilings, doors and windows in the living quarters, and similar materials in test laboratories, control rooms, compressor rooms, etc. The walls are structural panels consisting of painted steel sheet separated by mineral wool insulation mats and an internal aluminium foil. The estimated total weight of such building materials on all topsides is about 3,700 tonnes. This also includes waste mentioned as «Remainder» elsewhere in the Report.

Disposal of the building materials depends on how the topsides are removed and transported to shore. Re-use would demand special treatment of the materials during dismantling and transport of the modules. If walls and ceilings are not damaged physically or by moisture, they could be used again in new buildings. The same applies to doors and windows.

Material recycling does not require such extensive special treatment of building materials during removal and transport. However, it is very demanding where components are composites of several materials, since the materials have to be separated and sorted out. The metal panels could be separated and recycled in a smelter, but much of the building material would probably have to go straight to the disposal site.

Energy recycling is not an option for metals or glass/mineral wool (Rockwool) insulation mats.

A rough estimate of the fate of various types of building materials suggests that 10 per cent would go to material recycling, 10 per cent to energy recycling, and 80 per cent to the waste disposal facility.



**Insulation materials**

The outer walls of the living quarters and the walls of some modules contain insulation matting. These are generally various forms of spun rock known as Rockwool (mineral wool). Some of the mats are known to contain asbestos. The total weight of insulation on the Ekofisk I installations is about 800 tonnes.

Rockwool products of the kind found on Ekofisk I installations can be recycled for the materials if they are clean. Rockwool, the firm, is just starting an arrangement of this kind. At present customers purchase 250 litre bags from Rockwool, and pay Rockwool a freight rate for products for recycling.

Other types of insulation are rarely reused. As Rockwool consists of spun rock, binder, and oil, it is very unsuitable for energy recycling.

Of the insulation materials on the field, an estimated 40 per cent could be recycled for materials, and 60 per cent would have to be consigned to a waste disposal facility (landfill).



**Fire inhibitors**

Pyrocrete and Mandolite are two types of cement-based fire protection used on major structures in the topsides. They are used on important steel members in and below the living quarters. Further, they are inorganic products which do not contain sulphates, chlorides, or asbestos. This passive

fire protection is applied in a fairly thick coat to the outside of key structural members, etc. No estimate of the total volume of fire-inhibitor has been attempted for the Ekofisk installations.

The passive fire protection has to be removed before the material inside (steel) can be recycled. In connection with removal of the Odin installation, the passive layer was first removed, although the exact details are not known to DNV. Aker Stord informs that removal was not a particularly difficult task (F. Rogne, Aker Stord, personal communication).

There is also some experience of replacement of Pyrocrete-type fire protection on Valhall. It was chiselled off, and showed a tendency to loosen in large flakes due to ingress of water (Bjørn Hoff, Det Norske Veritas, personal communication).

It is expected that all fire protection of Pyrocrete and Mandolite type will be consigned to a waste disposal facility (landfill).

### Electrical and electronic waste

All loose electronic products (e.g. personal computers, televisions etc.) in the topsides will be removed before any cold phase. Electronic waste, such as electrical articles, instruments, cables and telecom equipment are a complex category of items spread around all parts of the topsides.

Almost 1.300 tonnes of electrical waste in total is quoted for the topsides of all Ekofisk I installations.

On 1 July 1999, a new «Regulation for Discarded Electrical and Electronic Products» (no. 0197) entered into force. This regulation does not embrace EE products that are fixtures in installations that can be registered in the Petroleum Register under the Petroleum Activities Act of 29 November 1996, no. 72 (SFT, 1998-a).

The different natures of the types of equipment concerned mean various challenges in regard to disposal. Gradually a number of scrap dealers have entered the market to take care of electronic waste.

Much of the electrical waste consists of wires and cables. Offshore cables are, very broadly, believed to consist of 60–70 per cent plastic sheathing and 30–40 per cent metals (T. Anda, Brødrene Anda, personal communication). Cables can be dealt with by cutting them up and putting them through a separation process where the different densities of the metals and plastics are exploited (for example on a shaker, blower grid, or similar). The metals obtained are generally aluminium, copper, and lead. They are then melted down. Plastic granules are at present partially used for material recycling, partly for energy recycling.

Some electrical components also contain heavy metals. This means that they must be segregated from the electrical waste before any automatic crushing and sorting. This complicates the recycling process.

Fluorescent tubes are a special case and are sent for «glassification» (F. Matillas, RENAS, personal communication).

It is assumed that directly reusable items are removed before the topsides are taken off. Of what remains, metals will usually be recyclable, without resulting in significant amounts of waste. The plastic can be either recycled as material or as energy. Plastics supply about 20 MJ/l in heat of combustion (Alcatel Kabel Norge 1998). Due to the resource-intensive sorting and treatment process that electronic waste is put through, some components are still expected to be consigned to a waste disposal facility (landfill).



A rough estimate says that 70 per cent of electronic waste not directly reused will be used for material recycling, 20 per cent for energy recycling, and 10 per cent will be discarded.



### Plastic products (including floorings)

Plastic is basically a mix of many different components. Insulation on wires provides a large portion of the total weight. Otherwise plastic is found in flooring, windows, sealing strips, etc. Altogether, plastics and floorings on Ekofisk I installations are believed to weigh about 925 tonnes.

Four different types of flooring have been identified in the living quarters: carpets, rubber flooring, polyurethane, and epoxy. The polish is vinyl and rubber-based Perigol Finish. Vinyl floorings containing asbestos have been identified in some modules. They are discussed separately under Asbestos.

Possibilities for second-hand of these plastics is severely limited. Yet there is a small market for recycling plastic granules as a cushion for race courses (horse racing) (T. Anda, Brødrene Anda, personal communication). There is little demand for second-hand flooring.

Pure fractions of plastics can be ground into granules, which can then be either melted down or burned for energy (Plastretur AS 1999). As of today there is little recycling of flooring in Norway. Some of the reluctance to recycle some types of flooring is due to the former use of cadmium in some floorings as a stabiliser. Moreover, it was not until 1982 that a ban was enacted in Europe against use of asbestos as a filler in PVC coverings (S. Eriksen, Tarkett AS, personal communication). A number of trials with recycling floorings are in progress in Norway. The process is generally to grind up the flooring into fairly pure fractions, and then put them in the smelter (material recycling). Adhesive on the underside can represent an added challenge, since it has to be removed.

Granules can also be incinerated for heat, in which case it is important to note that plastics often contain PVC. When PVC burns it has to do so at high temperatures to minimise the emission of dioxins. Furthermore, combustion of plastics can cause release of chlorine compounds.

Altogether it is estimated that some 35 per cent of plastics and floorings can be recycled for materials, 50 per cent for energy, and 15 per cent must be discarded.

### Paint



Different sorts of paints and coatings have been used during the lifetimes of the installations. It is believed that most of the primer is inorganic zinc silicate, while topcoats are of vinyl or epoxy. All surfaces, including pipelines, tanks, walls, and structural steel, have been painted. No exact material data sheets have been found for older types of paint, but it is possible they contain heavy metals.

In total it is estimated that the amount of paint on the topsides is about 980 tonnes.

In most cases paint will follow the substrate on which it is applied. Paint on steel sheet and other metallic surfaces will seldom be removed from the metal before melting down. Paint can represent a problem when metals are melted due to the formation of toxic fumes, dioxins, heavy metal dust, and contaminated slag. Experience indicates that this type of coating also contains much lead, zinc, chromium and copper, as well as organic tin compounds,

which will tend both to form impurities in the steel, and form waste products in the slag. The organic components of the paints additionally raise the temperature in the smelt and may cause flames to flare up, damaging filters in smokestacks and exhaust ducting.

Paintwork and other coatings can be removed by sand-blasting before the metal is sent for melting. However, this is very costly and produces huge volumes of waste in the form of contaminated sand. Generation of large volumes of difficult waste of this type means that removal of the paint from metals by this means is generally considered a very unfavourable solution.

Paint from the Ekofisk I topsides cannot possibly be used for any useful purpose. It represents a waste fraction when other materials are recycled.

### Asbestos

A special study presents the presently available knowledge and information on the occurrence of asbestos in the topsides in question (PPCoN 1999-a).

On the Ekofisk I installations asbestos has been located in the following areas:

- Fire walls, floors and ceilings
- Walls, floors and ceiling panels
- Internal insulation in walls, ceilings and floors
- Insulation of exhaust stacks and exhaust ducts
- Piping systems and valve gaskets/sealing strips
- Sealing strips in fire doors
- Coating around underwater pipelines
- Brake pads and clutch plates

Experience from older installations suggests that materials containing asbestos make up about 0.1–0.3 per cent of the weight of the topsides of a platform (DNV 1999-b). This seems to match well with the measurements made on Ekofisk 2/4 P and is the assumption made when estimating the volumes of asbestos on each of the Ekofisk I installations. This estimate results in a figure of approximately 260 tonnes of asbestos.

Due to the ban on using materials containing asbestos for building in Norway (see «Regulations for Asbestos», Ministry of Local Government 1991), second-hand asbestos products cannot be used for any form of recycling.

Asbestos on the Ekofisk I installations is largely combined with other building materials, and any removal of the asbestos from the building elements so as to recycle the latter would demand significant expenditure of resources, be difficult to achieve, and involve great risk to health. Therefore it is out of the question.

Building materials, insulation materials and similar containing asbestos must be handled separately according to strict guidelines as given in the Regulations for Asbestos cited above. These also describe Guidelines for Handling and Dismantling Asbestos Materials in Buildings (Ministry of Local Government 1991).

Asbestos materials are classified as special waste (Ministry of the Environment 1994) and must be delivered to an accredited reception facility. Once delivered, materials containing asbestos are disposed of in landfills. To



avoid dispersion of the asbestos fibres, such materials should be kept damp before sheathing in plastic and burying underground.

It is likely that all asbestos materials (260 tonnes) will have to be disposed of in waste disposal sites.

### 6.2.7 Littering

The topsides will be removed in their entirety and the seabed will be cleared of debris after final disposal of the installations (see Royal Decree of 26 October 1979: Provisional Regulations on Litter and Pollution by Petroleum Operations on Norwegian Continental Shelf). Therefore no litter is expected on the seabed in the areas in question as a result of removal of the topsides.

Alternative IB involves removing the Tank topsides to shore together with the Tank substructure. There is a certain risk that the structure would sink while under tow. The topsides contain a range of buoyant materials. In the event of an accidental sinking, these materials would constitute a littering potential.

Waste generated by the demolition of the topsides should be collected and processed according to relevant requirements and procedures. Disposal of waste will comply with the applicable requirements for waste disposal sites. No littering due to demolition and disposal of the topside is therefore expected.

## 6.3 Societal Impacts

### 6.3.1 Impacts on fisheries

Removal of the topsides will take place within the existing safety zones around the Ekofisk I installations. These safety zones will be maintained for as long as the jackets are in-place. Removal of the topsides will not, therefore, cause any impact on the fisheries. The Ministry of Petroleum and Energy has authority to allow a trial fishing within these safety zones in order, i.a., to study reef effects.

### 6.3.2 Impacts on free passage

Removal of topsides will require the close proximity of catering service vessels, lifting vessels, tugs, and barges. Including preparatory work, the number of vessel hire days is estimated at almost 3,500. However, this marine activity will be spread over many years.

In connection with removal of the topsides, therefore, there will be rather greater vessel activity locally, and thus a heightened risk for collision with passing traffic. Nevertheless, this increase is estimated to be very small.

If the jackets are left in-place for some years after the topsides are removed, they must be marked as per the navigation regulations. No significant degradation of markings is expected due to removal of the topsides, and no long-term effects of this solution are expected on free passage at sea. In relation to today's situation, one difference would be the absence of the stand-by vessels from the field.

### 6.3.3 Impacts on personnel safety

All topsides will be removed and taken to shore for demolition and recycling. This sequence of operations provides the highest single contribution to the overall risk assessment. The reason is not that the operations are particularly hazardous, but that the process is a long one lasting many years. Each individual topside will have to be broken down into its original modules, before each part is lifted onto a barge or the quayside. After towing and landing, the modules will in turn be cut up and the scrap recycled.

The topsides on the Ekofisk Tank are especially large and complex. If the Tank topsides are removed offshore, the work of removing just these topsides accounts for 30 per cent of the total risk of removal and demolition of topsides. If the Tank is floated to shore and the topsides removed there, the topsides removal operation will only account for about 10 per cent of the risks associated with topsides removal.

Table 19 shows the personnel risk (PLL – «potential loss of life») of removal and demolition of the topside structures.

**Table 19**  
*Risk to personnel (PLL) of removal of topsides*

Operation	Offshore removal of topsides from steel jackets	Offshore removal of Tank topsides	Inshore removal of Tank topsides
Remove and transport to shore	0.186	0.082	0.021
Demolition	0.013	0.003	0.003
Total	0.199	0.085	0.024

Disposal Alternatives	IA	IB
	Jacket topsides to shore for demolition and recycling of materials	Jacket topsides to shore for demolition and recycling of materials
	Tank topsides removed offshore and transported to shore for recycling	Tank towed to shore for topsides removal at shore
<b>Overall risk (PLL)</b>	0.284	0.223*

\* Risk of refloating and removing Tank substructure not included. See Chapter 7.

### 6.3.4 Costs and national supplies (goods and services)

Only one solution for the topsides on Ekofisk has been studied: the removal of all fifteen topsides for recycling onshore. The total costs of offshore removal of these topsides are estimated at 4.7 billion kroner (1998 Norwegian kroner). Of this total, removal of the Tank topsides accounts for 1.1 billion kroner. If the Tank is refloated instead, the topsides can be removed after towing the Tank inshore, and in that case removal costs for the topsides would be reduced by about 570 million kroner to approximately 4.1 billion kroner (the overall additional cost to remove the tank substructure to shore, however, dwarfs this cost saving – see discussion in Chapter 7).

For any contract award of this magnitude and scale it is probable that suppliers in each discipline will group together in co-operative alliances to have a stronger standing in the tender competition. A contract to remove the topsides is likely to be given to an alliance which can provide engineering, transport, and demolition. In the present market there are 2–3 possible such alliances.

An evaluation of the possible alliances is assumed in our estimate of the Norwegian content of supplies and employment effects resulting from removal of the Ekofisk I installations.

The table below summarizes the costs, broken down by cost components, for removal of the topsides on the steel jacket installations and the Ekofisk Tank.

**Table 20**  
*Costs and Norwegian content broken down by component (rounded) in 1998 million Norwegian kroner*

<b>Components</b>	<b>Total investments</b>	<b>Norwegian content %</b>
Project administration and engineering	350	80
Preparations	2,700	80
Removal	820	5
Transport	550	40
Demolition	280	100(0)
<b>Total</b>	<b>4,700</b>	<b>65 (55)</b>

The Norwegian content (value credited) of the goods and services supplies overall may reach approximately 65 per cent if the topsides are taken to shore in Norway and demolition and recycling is carried out in Norway. Altogether, the Norwegian content of the supplies may reach approximately 55 per cent if demolition and recycling is done abroad.

The estimated Norwegian content for each of the components provides a basis for estimating the Norwegian employment effect following from removal of the fifteen Ekofisk I topsides.

**Project administration and engineering**

This includes both the contractor’s administration of the project and PPCoN’s input as field operator for the project throughout the project duration.

The engineering design is done in part through an engineering firm and in part by the field operator. This work embraces analyses of the existing structures, planning temporary support structures during removal, estimates of structural strengths, and planning for the marine operations. There are a number of potential Norwegian suppliers in this market, and the Norwegian content is estimated at 80 per cent.

**Preparations**

Before heavy lift operations can be carried out the topsides must be cleaned and prepared. They need to be broken down into modules that are liftable and transportable to shore. Pedestal cranes, pump packages, bridges, deck frames and the like need to be dismantled. The largest items will weigh approximately 1400 tonnes. Preparations also involve welding on the lifting brackets and sea fastenings, to enable modules to be hoisted onto barges for transport to shore. The structural work involved will most likely be done by Norwegian contractors.

In addition to the structural preparations, there are the costs of hiring a flotel and catering services, plus supply boats and transportation for work-crews. The costs to hire a flotel are a large component of the preparation costs. At present there are few suitable rigs on the market, as many have been converted to drilling rigs since there was overcapacity in the market recently. The Norwegian content will depend on whether the rig hired is owned by a Norwegian or foreign ship owner. Operation of the rig includes buying

spares which will generally come from Norwegian suppliers. The rig crew will generally be a mix of Norwegian and overseas personnel.

The Norwegian content is estimated at 80 per cent.

**Removal**

Modules on the topsides will be removed from the deck frames using a heavy-lift vessel and placed on barges for transport to shore. There are no Norwegian lifting vessels large enough to do the required lifting operations at Ekofisk. The Norwegian content is estimated at 5 per cent, and consists of certain support services.

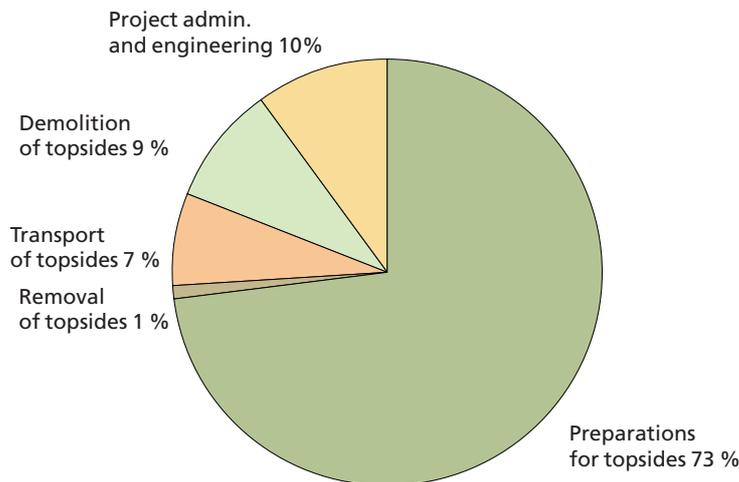
**Transport**

The deck modules will be taken to shore on barges for demolition and recycling. The costs involved cover mobilisation of large barges and towing with tugs. Barges of this size can be expected to be found mainly abroad, although for the towing operation we can expect Norwegian tugboats to be used. The Norwegian content is estimated at 40 per cent.

**Demolition**

Dependent on who is given the contract, the deck modules will be taken on barges to Norway or a foreign demolition yard. If the modules are taken to Norway for demolition and recycling, the content will be almost 100 per cent Norwegian. If they are taken abroad, the Norwegian content will be zero in respect of demolition and recycling. Employment effects have been calculated for both these scenarios.

The figure below shows the Norwegian content broken down by cost components. The total Norwegian content may reach about 3 billion kroner provided demolition and recycling takes place in Norway.



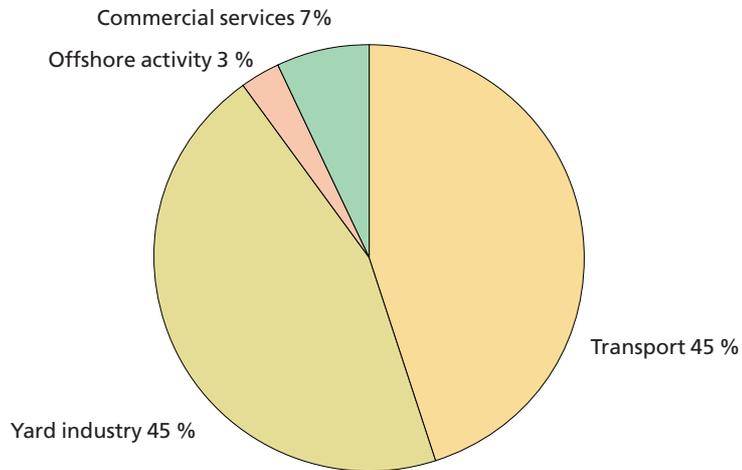
**Figure 26**  
Ekofisk I topsides – Norwegian supplies broken down by costs components

In connection with preparing the topsides for the actual removal operation, Norwegian industry could land contracts with a total value approaching 2.1 billion kroner. These preparation contracts will largely be mechanical work that can be done by offshore construction.

Demolition and recycling collectively can result in contracts to Norwegian industry worth about 300 million kroner.

Figure 27 below shows the Norwegian content broken down by industries that could provide direct supplies to Ekofisk I.

**Figure 27**  
Ekofisk I topsides – Norwegian content (first level) broken down by industry



The majority of the Norwegian supplies connected with removal of the topsides is expected to come from the yard (heavy engineering) industry and transport industry. Norwegian engineering yards will carry out the work associated with preparing the topsides prior to lifting off, as well as the demolition and recycling work on shore. Hire of a flotel and catering and helicopter transport and supply boats are the main components of the contracts that will go to the transport industry. Commercial services include engineering design and engineering consultants.

Based on the relevant alliances that already exist, it is conceivable that demolition and recycling could be carried out abroad. If this occurs, then the Norwegian content will total about 2.7 billion kroner.

Table 21, below, summarizes the types and volumes of materials in the topsides that can be recycled. Sale of these materials will bring revenue to the project depending on market price at the date in question.

**Table 21**  
Ekofisk I topsides – materials for recycling (tonnes)

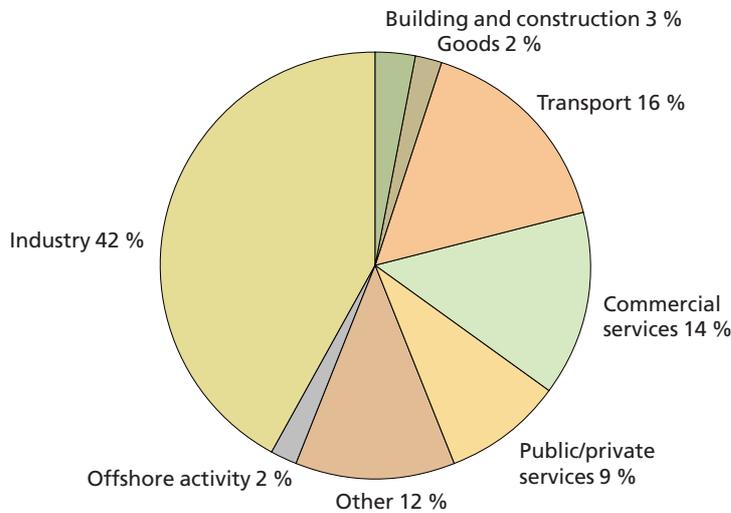
Material	Steel	Copper in wiring
Weight	92,000	2,900

Assuming a price of 300–500 kroner per tonne of recycled steel from the Ekofisk I topsides, this will give an income in the range of 28–46 million kroner. Recycling the copper could result in an income of 35–40 million kroner.

### 6.3.5 Employment effects

Based on the breakdown of anticipated Norwegian supplies, the national employment effect has been estimated. The Norwegian goods and services provided will give direct and indirect production effects at the national level. A total of 3,100 man-years in petroleum-related industry is assumed, provided the topsides are brought to shore for demolition and recycling in Norway. Consumer effects of about 50 per cent of this total will come in addition. The total employment effects are estimated to reach about 4,700 man-years.

Figure 28 below shows the industries that may benefit from the production effects.



**Figure 28**  
*Ekofisk I topsides – national production effects broken down by industry*

A large part of the production effects, about 1,300 man-years, is expected to come from industry. The employment effects will be spread over the years during which removal, demolition and recycling take place. The likely time window is 2003–2015, with average employment effects in the order of 300–400 man-years for each of these years, provided the topsides are brought to shore in Norway.

## 6.4 Summary: Impacts of the Topsides Disposal Alternatives

The assessment of the topsides Alternatives presented above provides details about the expected impacts of each Alternative on each separate issue. The following Sections provide a brief summary of the most important impacts as well as a comparison of the results, summing up the impacts within each issue in the context of a broader total evaluation.

### 6.4.1 Summary of Environmental Impacts

The following table summarizes the environmental impacts of the Topsides Disposal Alternatives:

	<b>Topsides Disposal Alternatives: Summary of Environmental Impacts</b>	
<b>Issues</b>	<b>Alternative IA</b> Topsides to shore for demolition and recycling of materials (Tank topsides removed offshore)	<b>Alternative IB*</b> Topsides to shore for demolition and recycling of materials (Tank with topsides towed to shore)
<b>Energy cons. (million GJ)</b>	5.1	4.4
<b>Total Energy Requirement (million GJ)</b>	5.1	4.4
<b>CO<sub>2</sub>-emissions (1000 tonnes)</b>	390	330
<b>Discharges to sea, ground and water</b>	None/insignificant	None/insignificant
<b>Phys./habitat effects</b>	None/insignificant	None/insignificant
<b>Aesthetic Impacts</b>	Moderate negative	Moderate negative
<b>Waste/resource utilization</b>	Large positive	Large positive
<b>Littering</b>	None/insignificant	None/insignificant

\* Note: these impacts do not include impacts due to refloating and towing the Tank substructure to shore.

### Energy and atmospheric emissions

The only significant environmental difference between the two methods of removing the Tank topsides is related to energy use and atmospheric emissions. Energy consumption and Total Energy Impact (see definition in Section 2.3.1) are normally different, in that the Total Energy Impact takes into account the energy that would have to be used to produce the material volume discarded and not recycled/reused. The energy consumption is thus the direct amount of energy used in connection with the operations to carry out the disposal alternative, while the Total Energy Impact also considers a theoretical amount of energy which is only valid in a global perspective. Since the topsides materials are recycled, this theoretical energy is negligible, and the energy consumption for each topsides Alternative is essentially the same as its Total Energy Impact.

Looking solely at topsides, the inshore solution (Alternative IB) has a lower Total Energy Impact. However, the inshore solution is dependent upon refloat and removal of the Ekofisk Tank, which represents an additional high energy consumption (see Section 7.2.1).

There are only minimal relative differences between the emission factors for CO<sub>2</sub>, NO<sub>x</sub> and SO<sub>2</sub>. The CO<sub>2</sub> emission figure is thus included in this summary as an indicative parameter. Norway’s emissions of CO<sub>2</sub> in 1997 were about 41.4 million tonnes (Statistics Norway, SSB 1998). Emissions for removing and recycling the topsides will count for about 1% of this, but spread over about 15 years.

### Discharges to seawater and ground, physical impacts and effects on habitat

Neither of the topsides Alternatives will give any significant impacts from discharges to sea, ground or water, nor any significant physical impacts.

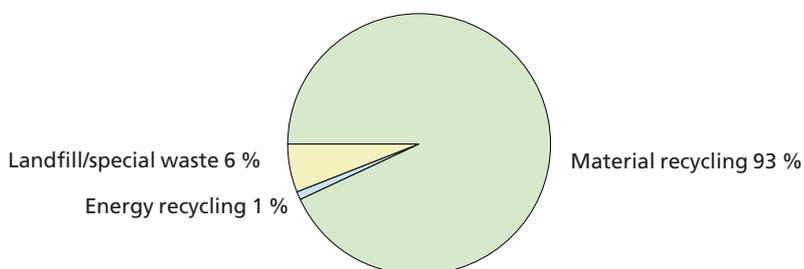
**Aesthetic impacts**

Noise will come from the scrapping process, and its impacts will depend on the suitability of the demolition yard (topography, location, distance to residential buildings and recreation areas, etc), duration, noise source, and abatement measures employed. Demolition of the topsides will in any case generate considerable noise and have a «moderate negative» impact.

**Waste/resource utilization and littering**

Waste is liable to be a problem due to volume and weight. The location of the demolition process has not been decided, and thus a direct assessment of impacts due to disposal of waste has not been performed. If large waste volumes are generated in an area with limited disposal capacity during a short period of time, then the impact on the local community may be severe.

Since most of the materials in the topsides will be recycled, both Alternatives were assessed as having «large positive» impacts in terms of waste/resource utilization (percentage given in Figure 29).



**Figure 29**  
Percentage share of recycling and disposal of topside materials if brought to shore for demolition

**6.4.2 Summary of Societal Impacts**

The work to be done is similar for both Alternatives. However, removing the Tank modules offshore will be more labour-intensive and time-consuming, and would thus pose higher risk to personnel. As offshore operations require more marine operations, and offshore work is generally more expensive than onshore work, the cost of Alternative IA is somewhat higher than that of IB. Taking into consideration the cost of refloat and removal of the Tank that would be necessary to carry out Alternative IB, the cost saved on topside dismantling inshore cannot be justified (see discussion in Section 7.4.3).

The impacts on society for removal, demolition and recycling the Topsides are summarised below.

Topsides Disposal Alternatives: Summary of Societal Impacts*		
Issues	Alternative IA Topsides to shore for demolition and recycling of materials (Tank topsides removed offshore)	Alternative IB Topsides to shore for demolition and recycling of materials (Tank with topsides towed to shore)
Impacts on fisheries	None/insignificant	None/insignificant
Impacts on free passage	None/insignificant	None/insignificant
Personnel safety (PLL)	0.29	0.22*
Costs (bill. kroner)	4.7	4.1
Norwegian content bill. kroner (%)	2.7–3.0 (55–65)	2.1–2.6 (55–65)
Employment (man years)	4,700	4,100

\*Note: Number does not include impacts due to refloating and towing the Tank substructure to shore.

### 6.4.3 Comparative Assessment of the Topsides Disposal Alternatives

There is only one solution for the topsides: remove to shore. The two different methods for removing the Tank topsides depend on the Disposal Alternative for the Tank substructure. A discussion of the Tank topsides is therefore included in Section 7.4.

# 7 IMPACT ASSESSMENT FOR SUBSTRUCTURE ALTERNATIVES

## 7.1 Description of Substructure Disposal Alternatives

The five Alternatives for the substructures (steel jackets and Ekofisk Tank) are summarized below:

Disposal Alternative	IIA	IIB	IIC	IID	IIE
	<i>Jackets:</i> Reef in place	<i>Jackets :</i> Reef at Tank	<i>Jackets:</i> Remove for onshore recycling	<i>Jackets:</i> Remove for onshore recycling	<i>Jackets:</i> Remove for onshore recycling
	<i>Tank:</i> Reef in-place	<i>Tank:</i> Reef in-place	<i>Tank:</i> Leave in-place	<i>Tank:</i> Deposit in deep water	<i>Tank:</i> Recycle onshore

A brief description of the disposal operations and final disposition is given below.

Section 7.2 describes the environmental impacts of each Alternative, and Section 7.3 the social impacts. Section 7.4 provides a summary and comparison.

### 7.1.1 Description of Substructure Disposal Alternative IIA – reefs in place

**(Topple steel jackets to make fish reefs in-place; leave Tank and Barrier as reef in-place)**

For the steel jackets, this Alternative involves toppling the steel jackets in-place to make artificial fish reefs. There are two different ways of achieving this: either by cutting the jacket pilings and employing a tug to pull the structure over, or by cutting the jacket legs to cause it to topple outward due to its own weight. The first is recommended since it gives better control and thus greater safety.

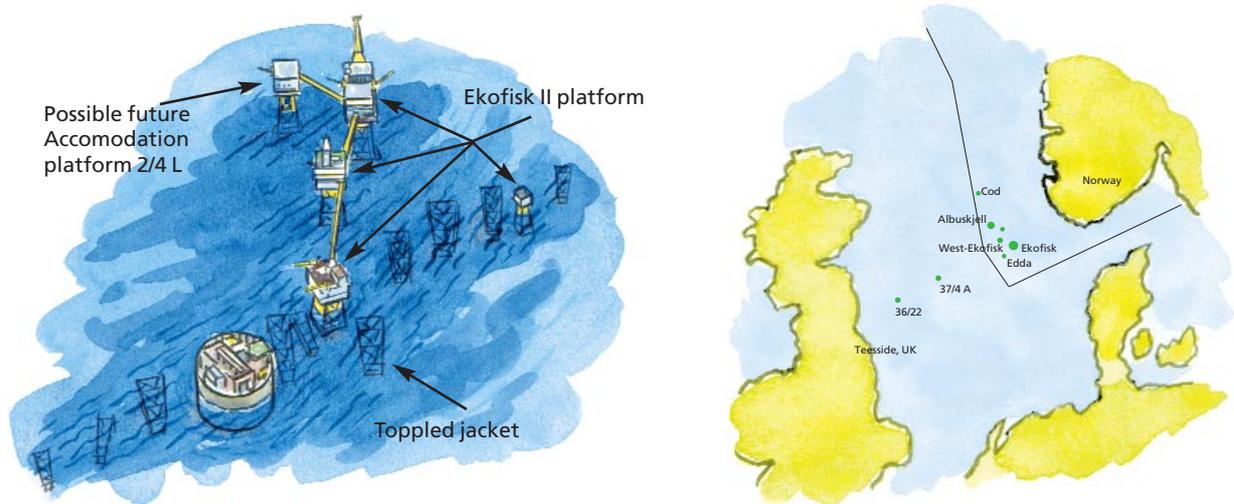
The jackets can be toppled after preparations are made from a diving vessel or ROV, or both. The toppling operation itself can be done by pulling with tugboats. The preparations and toppling of all steel jackets in-place is estimated to take 10 vessel days, plus mobilisation time.

With respect to the Tank, this Alternative involves leaving the combined Tank/Barrier Wall structure in-place, with installation and maintenance of appropriate navigation aids to ensure safety of other users of the sea. A monitoring and maintenance program will be put into effect to ensure the integrity of the navigation aids and access thereto. The concrete structure will deteriorate very slowly, and floating navigation markers will be employed to ensure continued safety of navigation if that ever becomes necessary.



The Ekofisk Cessation Project has investigated the possibility of demolishing the Tank by explosives after termination of Ekofisk II, to leave a free water column above structure as advised by the 1989 IMO guidelines in case of partial removal below the sea surface. This option was not carried forward, since the method is unproven. Further, the environmental benefits are questionable (this would actually result in environmental damage), and the costs and risks high.

The reefs-in-situ solution is illustrated in Figure 30. This also indicates the geographical spread of the reef locations.



**Figure 30**  
Alternative IIA. Possible configuration of Reefs in-place at Ekofisk Center (left). Locations of outlying installations and booster platforms relative to Ekofisk Center (right)

**7.1.2 Description of Substructure Disposal Alternative IIB – cluster reef at Tank  
(Relocate steel jackets to make a cluster reef around Ekofisk Tank and PRW)**



According to this Alternative, the steel jackets at the Ekofisk Center will be left in-place, while the outlying jackets will be moved and positioned in shallow water close to the Tank.

For the purpose of this assessment, it is assumed that the jackets will be moved using heavy-lift vessels. The leg foundation piles will be severed, requiring each jacket to be lifted in 2–4 pieces and carried to the designated area. Other methods, involving less energy consumption and not requiring the entire structure to come out of the water, are being considered, as well as methods whereby the jacket is moved in one piece.

The time needed to topple the jackets around the Ekofisk Tank, including time for preparations and mobilization, is about 18 vessel days. Removal of the jackets from outlying fields and careful placement of them would require approximately 350 vessel days.

Leaving the Ekofisk Tank in-place is as discussed in Alternative IIA above.

Figure 31 provides an illustration of Alternative IIB (cluster reef at the Ekofisk Tank):



**Figure 31**

*Alternative IIB. Possible configuration of artificial reef around Ekofisk Tank*

### 7.1.3 Description of Substructure Disposal Alternative IIC (Steel jackets removed to shore for recycling; Ekofisk Tank and Barrier left in-place)

The solution for the Tank and its Protective Barrier Wall is the same as described above for Alternatives IIA and IIB.

According to this Alternative, the steel jackets will be removed from the field and brought ashore for recycling. With today's technology, the removal of the steel jackets will be performed using heavy-lift vessels, in a manner similar to that used on the Odin jacket in 1997. The jacket will be cut into liftable sections underwater, lifted and laid on the crane vessel deck or a transport barge and taken to shore. Once at the quay it will be pulled or lifted off the barge and gradually cut up into small pieces for consignment to the scrap furnace.

The exact configuration of the cement inside the foundation piles is not known, and therefore there is some uncertainty as to the best way to cut the piles. The options are an inside operation using a waterjet (which will not be possible if the pile grout plug extends some distance above the sea-bed), or an outside approach using a diamond saw. The piles could also be cut using explosives. The situation is complicated in some instances by the presence of drill cuttings around the base of the jackets.

Most of the installations would need to be cut into several sections for removal, as happened with Odin, while only a few can be lifted in a single operation.

Preparations would require from three days to three weeks for each jacket, while the removal operation proper is expected to take 5–6 days for each. Total removal of the steel jackets using present-day technology would mean employing Diving Support Vessels (DSV) for about 310 vessel days, and lifts and transports using crane vessels, barges and tugs for about 240 vessel days. These operations would probably be spread over a long time period.

This Alternative is illustrated in Figure 32.



**Figure 32**

*Alternative IIC. Jackets to shore, Tank left in-place*

#### 7.1.4 Description of Substructure Disposal Alternative IID (Steel jackets removed to shore for recycling; Tank/Barrier deposited in deep water)

The difference between Alternative IID and Alternative IIC is the solution for the Ekofisk Tank with its Protective Barrier Wall, which according to this Alternative is proposed to be re-floated and towed for deep sea disposal.

The attempt to re-float the Tank would be the first attempt ever to remove such a structure. There is a high degree of uncertainty related to the structural condition after almost 30 years exposure to the marine environment, with respect to refloating and towing. A number of different ways of removing the Ekofisk Tank and its Protective Barrier wall have been considered. The least risky method that was found, though with many uncertainties and high technical risk, is to connect the Barrier with the Tank and utilise their combined buoyancy for collective removal (see 11.2.3 for further details). The ballast (gravel) would be removed as well as some of the water from the ballast tanks in the Wall and Tank, allowing the structure to become buoyant. Tugs would be used to tow the unit and correct its direction.

Preparatory work for a potential removal of the Tank would last for several days. Offshore preparations for removal would involve substantial offshore construction work to make refloat of the structures possible. The combined Tank and Barrier Wall structure could then be towed to shore where the topsides would be removed, or towed directly to the deep water site, if the topsides were removed offshore. These operations would require extensive work with high associated costs.

At the deep water site, explosive charges would be detonated and the structure would take in water and sink. The external water pressure at a depth of about 200 metres would probably cause the hollow structures to implode and disintegrate (in a manner similar to the accidental sinking of the «Sleipner A» concrete structure in Gandsfjorden, Norway).

Suitable areas for consigning the structure to the deep would be areas north of the Faeroe Islands where water depths are greater than 2000 metres (meeting OSPAR depth requirements), or in 700 metres of water in Nedstrandsfjorden in Rogaland, Norway. It would take about 15 days to tow the installation to the Faeroes, and 12 days to Nedstrandsfjorden.

This Alternative is illustrated in Figure 33.

**Figure 33**

*Alternative IID. Jackets removed to shore, Tank removed and deposited in deep water.*



### 7.1.5 Description of Substructure Disposal Alternative IIE (All jackets and Tank-Barrier removal to shore for demolition and recycling)

The removal of the steel jackets is as described for Alternative IIC. Removal of the Tank and its Protective Barrier Wall is as described for Alternative IID. Towing the Tank to shore for demolition and recycling would take about 12 days.

The structure will have a draught of about 60 metres, which limits the number of existing facilities that could be used for demolition activities. Potential sites have been found in Norway and Scotland. The concrete would be dismantled using a combination of explosives for larger sections and cutting and crushing by hydraulic nibblers for smaller sections. Fine crushing would make use of standard crushers, with sorting of the aggregate on a barge moored to the structure. Here the steel reinforcement steel and prestress cables would be recovered and sent for melting down. Once crushed, the stone aggregate and cement could possibly be used as an admixture in fresh concrete or as filler. Demolition on shore and in dry dock would take about 18 months.

Alternative IIE is illustrated in Figure 34.



**Figure 34**  
*Alternative IIE. All jackets and Tank to shore for demolition and recycling*

## 7.2 Environmental Impacts of the Substructure Disposal Alternatives

### 7.2.1 Energy consumption and Total Energy Impact

Table 22 shows that, of the three steel jacket Disposal Alternatives, leaving in-place and toppling in-place are the least energy consuming for the vessels involved. If the consequences of leaving in-place recyclable jacket steel, rather than recycling it, is also considered, then the energy account favours the demolition and recycling Alternative for the steel jackets.

**Table 22**

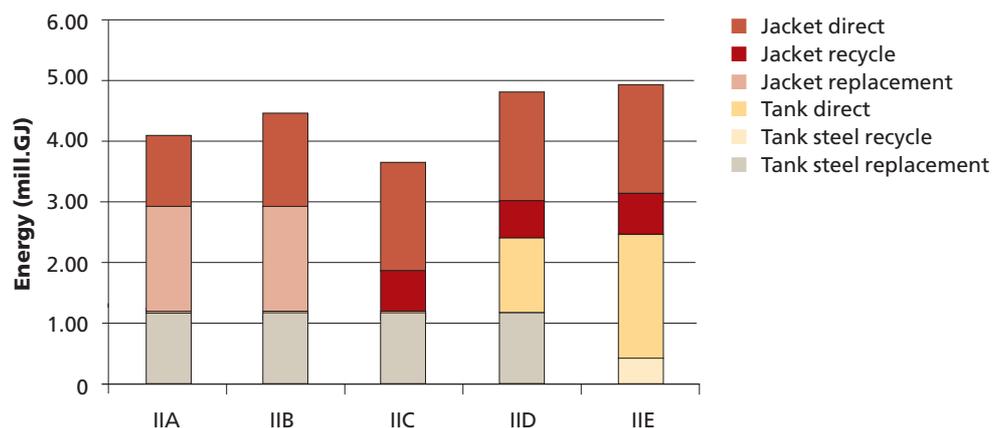
*Energy consumption and Total Energy Impact for steel jackets and Ekofisk Tank (GJ)*

Activity	Alt. IIA*	Alt IIB*	Alt IIC	Alt IID	Alt IIE
<b>Steel jacket;</b> marine op./demolition	1,200,000	1,600,000	1,800,000	1,800,000	1,800,000
<b>Steel jacket;</b> Replacem. of material not recycled/recycling	1,700,000	1,700,000	670,000	670,000	670,000
<b>Tank;</b> preparations	18,000	18,000	18,000	650,000	650,000
<b>Tank;</b> marine op./demolition	5,000	5,000	5,000	550,000	1,400,000
<b>Tank;</b> virgin production/recycl.	1,200,000	1,200,000	1,200,000	1,200,000	420,000
<b>Total Energy Impact</b>	<b>4,100,000</b>	<b>4,500,000</b>	<b>3,700,000</b>	<b>4,900,000</b>	<b>5,000,000</b>

\* For the reef Alternatives, full «replacement energy» for the steel left in the jackets is included in this calculation. There are several reasons for this, including: (1) the amount of steel used for the reefs, and (2) the steel used for the reefs cannot be recycled when the lifetime of the reef ends (contrary to other forms of re-use), and thus must be replaced in a global perspective. The benefits of re-use of the jackets as reefs, in terms of resource utilization, is addressed under the «waste/resource utilization» topic.

The different contributions to the Total Energy Impact from the solutions for the steel jackets and the Ekofisk Tank, broken down also by direct energy consumption, recycling energy and Replacement Energy, are illustrated in Figure 35 below:

**Figure 35**  
*Energy consumption and Total Energy Impact for Alternatives IIA-IIE (million GJ)*



The energy consumption to remove and recycle the steel jackets corresponds to about 40 per cent of Stavanger’s (city with about 100,000 citizens) annual electricity consumption.

### 7.2.2 Emissions to atmosphere

The general background for estimating emissions to atmosphere is described in the methodology (Section 2.3.1).

As Table 23 shows, the emissions to atmosphere from the various Substructure Disposal Alternatives largely follow the same pattern as their energy consumption. The difference between the highest and lowest emissions is approximately four-fold for CO<sub>2</sub>, three-fold for NO<sub>x</sub>, and eight-fold for SO<sub>2</sub>.

Alternative IIE would give the highest CO<sub>2</sub> emissions of all the Alternatives, equal to approximately 1 per cent of Norway’s total CO<sub>2</sub> emission during a single year (1997).

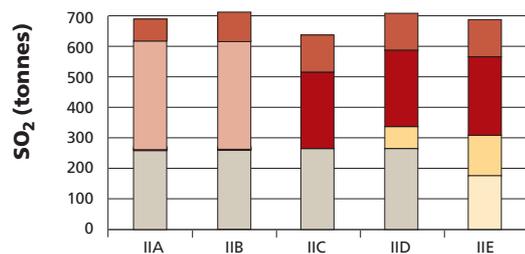
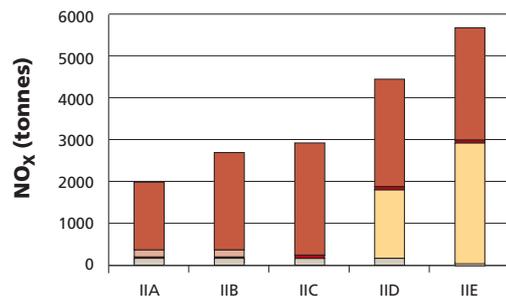
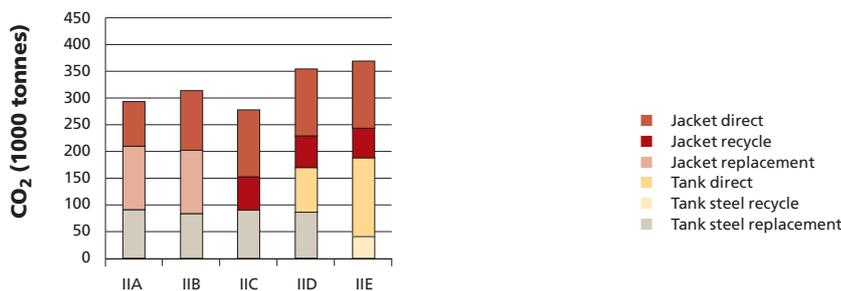
Figure 36 below shows, in graphical form, the total atmospheric emissions from the substructure Disposal Alternatives. This also includes estimated

emissions associated with production of virgin steel to replace any steel not recycled. Compared to «direct emissions» from the Alternatives, these theoretical emissions are somewhat different, and the results between the different gases also change in relation to one another. For NO<sub>x</sub> this is due, i.a., to the relatively high emissions associated with marine operations (e.g. heavy lift vessels), while for SO<sub>2</sub> this is due to high emissions from processing steel.

**Table 23**

*Emissions to atmosphere for removal of steel jackets and Ekofisk Tank (tonnes)*

Activity	Alt. IIA	Alt IIB	Alt IIC	Alt IID	Alt IIE
<b>CO<sub>2</sub></b>					
<b>Steel jacket</b> ; marine op./demolition	90,000	120,000	130,000	130,000	130,000
<b>Steel jacket</b> ; recycling			60,000	60,000	60,000
<b>Tank</b> ; preparations	1,300	1,300	1,300	47,000	47,000
<b>Tank</b> ; marine op./demolition	370	370	370	40,000	100,000
<b>Tank</b> ; recycling of steel				5,000	50,000
<b>Total</b>	90,000	120,000	190,000	280,000	390,000
<b>NO<sub>x</sub></b>					
<b>Steel jacket</b> ; marine op./demolition	1,600	2,200	2,500	2,500	2,500
<b>Steel jacket</b> ; recycling			100	100	100
<b>Tank</b> ; preparations	25	25	870	870	870
<b>Tank</b> ; marine op./demolition	5	5	5	740	2,000
<b>Tank</b> ; recycling of steel				17	100
<b>Total</b>	1,600	2,200	3,500	4,200	5,600
<b>SO<sub>2</sub></b>					
<b>Steel jacket</b> ; marine op./demolition	80	100	120	120	120
<b>Steel jacket</b> ; recycling			250	250	250
<b>Tank</b> ; preparations	1	1	1	40	40
<b>Tank</b> ; marine op./demolition	<1	<1	<1	35	90
<b>Tank</b> ; recycling of steel				4	180
<b>Total</b>	80	100	370	450	680



**Figure 36**  
*Atmospheric emissions from the Substructure Disposal Alternatives, also including indirect emissions associated with replacement of metals not recycled*

### 7.2.3 Discharges to sea, water or ground

#### Alternative IIA – (Reefs in-place)



The key issues in relation to the topic were found to be these:

- Impacts on the seabed and cuttings residues in connection with cutting work on legs/pilings and toppling of steel jackets, causing sediment to swirl up and any potential contaminants present to be released
- Leaching of metals from installations left in the sea
- Discharges of «structural water» (water inside steel jackets and module support frames) when the jackets are removed.

These are discussed below.

#### Steel Jackets

There are several ways to cut the legs/pilings, and the potential environmental impacts vary in each case. If the foundation piles are cut below the seabed from outside, the surrounding sediments will have to be dredged away first, for instance by suction-dredging. This could cause considerable re-suspension of sediments and any contaminants in the cuttings piles. If the legs/pilings are severed from the inside, for instance by using a water jet, no significant re-suspension of sediments would ensue. In practice, however, this option might be difficult since access is uncertain. An examination of the piles to study the feasibility cannot be done before the topsides are lifted off of the jackets. Use of explosives to cut the piling would also most likely disturb the sediments in the immediate vicinity.

The actual process of toppling the jackets would also cause re-suspension of sediment.

Re-suspension of sediment might easily cause the dispersion of hydrocarbons, metals and fine particles in the drill cuttings piles and sediments. The cuttings may be contaminated with hydrocarbons and a range of metals and metallic components (see Section 9.2), while the sediments at the Ekofisk Center are described as slightly polluted by hydrocarbons and significantly polluted by various metals (see Section 5.1). The level of contamination in the cuttings piles varies and is a factor of pile history. The acute effects will primarily be connected with dispersion of the hydrocarbons and the increased amounts of particulate matter in the water. These particles could potentially clog and damage gills of fish, filter organs and digestive systems (Brannon & Rao, 1979, Conklin *et al.*, 1980). Possible acute effects will occur in the area in and around the cuttings pile and persist for a limited period of time. Non-mobile and slightly mobile organisms, like fish larvae and some bottom-dwellers close to the swirl site, will be most susceptible to these effects. Certain hydrocarbons and metals are persistent and may remain in the marine environment for an extended period. Studies are inconclusive, however, they may exacerbate the overall contamination picture via bioaccumulation and concentration of toxins in the food chain. The complexity of the soft-bottom community in and around Ekofisk suggests high vulnerability to major disruption. Warwick & Clark (1991) suggest that the measured hydrocarbon concentrations (Mannvik *et al.* 1997) indicate that moderate disruption of the soft-bottom community has already occurred. This makes the community more susceptible to further disruption.

Oil-contaminated sediment, like the cuttings piles, may contain other components in various degrees, such as dibenzo-thiophene, naphthalene, and phenols. These are compounds that can spoil the taste of edible fish, a phenomenon called «tainting». Principally, fish living in close association with the bottom materials – like cod and the various flat fish – have the greatest potential to accumulate high hydrocarbon levels (Knezovich *et al.* 1987, Emst *et al.* 1989, Payne *et al.* 1989, Reiersen *et al.* 1989, Dow *et al.* 1990). A re-suspension of sediments in connection with cutting the legs/pilings, particularly in close proximity to the cuttings piles, might render these hydrocarbons more accessible both for bottom-dwelling fish and fish which spend their lives higher in the water column. Nevertheless, it seems unlikely that the swirling could cause any tainting of the fish.

The steel in the structures will be subject to various corrosion processes until it reaches an equilibrium state for the environment in which it is placed. After the anodes are consumed, the steel jackets, totalling 16,000 tonnes, will corrode eventually leading to collapse of the structure. The anticipated lifetime of a reef after toppling is estimated at over 150 years (Kjeilen *et al.*, 1995). Corrosion will be uniform for standard structural steel, while leaching and availability may be different for the sacrificial anodes. These, of type «Galvanium1» and «BA 777» (totalling 525 tonnes), have a lifetime of about 20 years. The attrition rate is estimated at 2.5–3 per cent per annum, and in 1998 it was estimated that 58–78 per cent of the anode mass had already been consumed.

Depending on the solubility coefficients of the metals, these will tend, after release, to form flocs which in turn precipitate as sediment. Rusty flakes of iron will also drop off the structure and settle in the vicinity around the jacket. Metal ions in the water mass will be available for assimilation into organisms, thus representing a potential negative impact. Precipitated substances, specifically complexes and organically bonded substances, may also accumulate in organisms, though in general they are less available than the free metals/ions to marine organisms. The percentage content of potentially harmful substances like copper, chromium and nickel in structural steel is low, about 0.25, 0.10 and 0.20 per cent, respectively. Iron is not considered a harmful substance to marine ecosystems: an absence of iron can in fact actually limit growth of marine organisms. The anodes are aluminium based (over 90 per cent), but also contain some zinc and copper, silicon, iron, indium, aluminium and mercury used as alloying elements. These alloying elements were added to achieve steady sacrifice and a stable electrical potential. An estimate of remaining metals in anodes on steel jackets and the Tank and PBW is given in Table 24.

**Table 24**

*Estimate of remaining amount of metals in anodes on steel jackets and the Ekofisk Tank*

<b>Installation</b>	<b>Copper (kg)</b>	<b>Zink (tonn)</b>	<b>Mercury (kg)</b>	<b>Lead (kg)</b>	<b>Cadmium (kg)</b>
Jackets	50	25	150	-	-
Ekofisk Tank/PBW	4	40	0	2	10
<b>Total</b>	<b>54</b>	<b>65</b>	<b>150</b>	<b>2</b>	<b>10</b>

Harmful effects of various metals depend on available concentration and state. Due to the low leach rates, metals from both the steel structures and the anodes have a fundamentally low availability potential. Therefore no negative impacts of significance are expected to result from leaching of metals from the

structural steel and sacrificial anodes into the surrounding ecosystem. Simple calculations made in connection with disposal studies of leaching concentrations from the Odin steel jacket passing into seawater concluded that the estimated values – at a reasonable distance from the anodes – are several tens of orders of magnitude lower than the lowest documented concentrations producing acute effects on organisms (Asplan Viak, 1995). The concentrations of zinc that can leach from the sacrificial anodes into passing seawater are moreover estimated to be 10,000 times lower than the lowest documented concentration for acute toxicity, and 1000 times lower than the lowest documented concentration for chronic toxicity. Direct harmful effects of leaching of metals into the marine ecosystem can therefore be ruled out. However, it is important to bear in mind that certain metals have the potential to bioaccumulate and/or accumulate in the food chain. Even so, the contribution from the Ekofisk installations is extremely modest in relation to other sources.

In sum, the scope of disturbance represented by discharges into the sea, water or ground from using the jackets as artificial reefs is described as «slight to moderate». The total environmental impacts resulting from these discharges are assessed as small negative.

#### **The Ekofisk Tank**

The Ekofisk Tank would be cleaned before entering service as an artificial reef (see Chapter 4).

It is expected that the rate of seabed subsidence beneath the Ekofisk Tank will gradually slow down and eventually stop when petroleum production from the Ekofisk Area declines and eventually stops. Based on the most recent subsidence measurements and forecasts, the Ekofisk Tank is expected to remain intact, projecting above the sea surface, beyond termination of Ekofisk production (after 2028).

The Tank consists mainly of concrete, with reinforcement steel and prestress cables. As this steel gradually corrodes, hollow spaces will appear in the concrete. This will make it more susceptible to collapse if subject to impact. However, this process will take an extremely long time, and leaching of concrete components into the water will therefore be very slow. Iron oxide and oxy-hydroxide, the products of the corrosion reaction (rusting) of iron, are almost insoluble in water (NERC 1996), and will gradually precipitate in the sediments around the Tank. Iron is a necessary micro-nutrient and enters the metabolism of organisms. Therefore it is not considered harmful. The scale of the effects of leaching from the concrete and the reinforcement rods of the Ekofisk Tank into sea and ground is therefore considered «none/insignificant».

#### **Overall impact from discharges**

The overall environmental impact of discharges to the sea/ground/water from Alternative IIA – reefs in place – is assessed as «small negative».



#### **Alternative IIB (cluster reef near Ekofisk Tank)**

The difference between this Alternative and Alternative IIA (reefs in-place) is that distant jackets are premised to be moved from their existing positions to an area closer to the Tank. Placement of the jackets on the seabed in this Alternative is considered somewhat more gentle than toppling. All told, the

total impacts regarding discharges in this case are considered to be of the same order of magnitude of Alternative IIA, i.e., «small negative» for the steel jackets, «insignificant» for the Ekofisk Tank in-place, and «small negative» in aggregate.

## **Alternative IIC (Jackets to shore, leave Ekofisk Tank in-place )**

### **Steel Jackets**

Full removal of the steel jackets means cutting the legs/pilings and transporting the steel jackets to shore for cleaning and possible re-use, dismantling, recycling, and disposal. As discussed in relation to Alternative IIA above, excavations prior to cutting and moving the jackets, or use of explosives to make the cuts, will cause re-suspension of the sediments and any cuttings piles close to and below the jackets.



Some of the jackets/deck frames contain «structural water» which contains biocide and corrosion inhibitor. The intention is to remove this water when the jackets are removed, in part to reduce the lifting weight, and in part to minimise dynamic effects during lifting and transport. Since the intention is also to cut the deck legs, it is evident that the water must be removed first. On some of the jackets there are drain plugs/valves that can be opened by divers. On others there are no provisions for removing this water, and in such cases cuts must be made in connecting pipes between the legs and struts. The alternative is to drill holes to permit the water to drain into the sea. The chemical in question is included in PPCoN's current discharge permit from the Pollution Control Authority.

The scale of the effects due to draining the structural water is considered small, and the consequences assessed as «none/insignificant».

There are no plans to make discharges into the sea, water or ground in connection with regulation demolition of the steel jackets on land. Nevertheless, it is important to note that demolition will generate waste that needs to be dealt with, mainly consisting of marine growth.

The responsible handling of the waste will also comply with PPCoN's strategy, and the principles stated in Storting Report no. 58 (1996–97) regarding «zero releases». The goal in this context is the maximum reduction of discharges into the sea, provided this takes place within practical and economically acceptable limits, and without causing significant releases elsewhere, for example to the atmosphere.

The total scale of the disruption due to discharges into the sea, water or ground is described as small. The environmental impacts are assessed as «insignificant».

### **Ekofisk Tank**

The discharges resulting from leaving the Ekofisk Tank in-place are the same as for the solution where this forms a reef (see Alternative IIA/IIB), i.e., the impact is assessed as «none/insignificant».

### **Overall impact – Discharges (Alternative IIC)**

The overall impact due to discharges of Alternative IIC are assessed as «none/insignificant».

## Alternative IID (Jackets to shore, Tank deposited in deep sea)



### Jackets

The impacts regarding discharges from removing the jackets to land and recycling onshore are identical to those described for Alternative IIC, i.e. «none/insignificant».

### Ekofisk Tank

The removal of the Ekofisk Tank would demand certain preparations to be made offshore, believed to require about 18 months. Food waste and sanitary waste would be generated during these preparations, and these would be discharged into the sea on a gradual basis, as happens on the Ekofisk field today. Food waste could be fluidised before discharge, and this would probably attract some fish and gulls. Sanitary waste and food waste represent nutrients added to the marine environment. Considering the scale of the releases and the fact that it happens in the open sea where the dispersion and dilution effects are massive, the scale of the impacts on the marine ecosystem from the discharged during this preparatory phase would be small.

The Tank, if it is to be moved, must be made to float before it can be towed anywhere. Some of the seawater and gravel ballast must therefore be discharged. From the ballast tanks above the oil storage tanks, all gravel and rock and seawater will be released, while 75 per cent of the seawater and all gravel will be released from the chambers in the Protective Barrier Wall, and 75 per cent of the seawater from the inner and outer annular spaces. Also, it is likely that some cleaning water from the purging process in the various tanks and chambers will be released into the sea. The seawater and gravel/rock in some parts of the Tank may contain smallish amounts of hydrocarbons. Releases in this connection can only take place in compliance with a permit from the Pollution Control Authority, and cleansing of seawater and any sediments would be done as necessary. The expected scale of the environmental impacts of these releases connected with removal of the Tank is assessed as small.

It is expected that a local reduction in water quality will result from the added particles in the water due to spreading of the gravel and rock from the ballast spaces above the oil tanks and the chambers in the Protective Barrier Wall. This could cause acute local effects since it would cause gills and tentacles of marine organisms to clog up. Non-mobile and slightly mobile marine organisms in the water column and on the bottom near the release site would be most susceptible to these effects. Nevertheless, the effects can be described as minimal and of short duration.

For Alternatives involving removal of the Tank (Alternatives IID and IIE), dumping the gravel from the ballast voids will cause an area that is already slightly contaminated to be buried in clean sand, 2 metres thick. This will result in a «small positive» effect in relation to the discharge issue since it stops secondary pollution from the exiting seabed.

The environmental risk of towing the combined Tank and barrier construction without the topsides has been assessed specifically (DNV 1998-g). Since it has been decided to purge the tanks before removal, the risk of discharges during an accidental sinking is accordingly very small (the environmental risks associated with an accidental sinking are related to the physical impacts, see section 7.2.4 below).

Sinking can take place by attaching and firing dynamite charges at strategic points on the concrete structure, allowing it to take in water. This can be done either inshore, for example in Nedstrandsfjorden where the water is about 700 metres deep, or offshore, for example northeast of the Faeroes where the water is over 2000 metres deep. The pressure build-up as the Tank sinks will cause the structural flotation chambers to implode at a depth of about 200 metres. The resulting concrete fragments will sink to the bottom with the reinforcement. This, in addition to the physical impact, will have a secondary effect by causing fine sediments to swirl up, and degrade the local water quality for a period of hours or days.

Components that gradually escape from the concrete rubble and steel rods will not attain toxic concentrations in the water mass. As described above, iron is not deemed harmful to the marine ecosystem.

About 75,000 m<sup>3</sup> water from the cavity in the Protective Barrier Wall, plus 260,000 m<sup>3</sup> from the inner and outer annular spaces and 30,000 m<sup>3</sup> from the storage cells in the Ekofisk Tank would be released during scuttling. This water will previously have been cleaned. The scale of the environmental effects due to release of this water to the sea during scuttling is therefore assessed as small.

#### **Overall impact – Discharges (Alternative IID)**

The total scale of the environmental impacts caused by releases to sea and ground due to scuttling in the deep sea is expected to be small. But it must be said that the goal of all Disposal Alternatives is to minimise the environmental and health impacts, and avoid possible conflict with other activities. A British scientific committee has stated that deep sea disposal should occur in as isolated a place as possible considering contact with coastal water, the upper water layers, and commercial fishing, and should not take place in a sensitive, unusual, or rare biological community (NERC 1996). Considering that Nedstrandsfjorden is a fjord on Norway's west coast and actually part of the coast, this location is deemed rather less suitable than the deep north-east of the Faeroes. The total environmental impacts of the releases to sea and ground described are nonetheless considered «none/insignificant» in both localities.

#### **Alternative IIE – Jackets and Tank to shore for demolition and recycling**

##### **Jackets**

The impacts regarding discharges due to removal and recycling the steel jackets are as described for Alternative IIC (see discussion above), i.e., «none/insignificant».

##### **Ekofisk Tank**

Preparations made offshore and removal of the Tank would result in discharges to sea, water or ground as described above for Alternative IID. There are also additional possible discharges to sea, water or ground in connection with demolition and recycling. Discharges of water, as described for Alternative IID, will be gradually released during demolition. This water will already have been cleaned and can only contain small concentrations of hydrocarbons and heavy metals. It is also likely that the water will contain



particles from the demolition process. Therefore it may be necessary to take samples of the water to determine its content of oil and particulate matter from time to time. Discharges would be subject to permit from the Pollution Control Authority, and cleaning of the seawater would take place as necessary. Discharges at the demolition yard could only cause local acute effects on certain marine organisms, primarily those which have no or only slight mobility. The scale of the environmental impacts caused by this water when released into the sea during demolition is assessed as small.

Marine growth should be collected and handled in accordance with the contractor's procedures and licensing terms, and thus would not cause discharges into the sea, water or ground.

Demolition is not expected to cause discharges since it will take place within enclosed spaces.

#### **Overall impact – Discharges (Alternative IIE)**

The total environmental impacts due to discharges to sea, water or ground are considered «insignificant» for Alternative IIE.

#### **7.2.4 Physical impacts and impacts on habitat – Substructure Disposal Alternatives**

The relevant issues in connection with these assessments include:

- Disruption of seabed and bottom fauna due to operations
- Impacts due to underwater explosions
- Covering seabed with gravel
- Reef effects

#### **Alternative IIA – Reefs in-place**

##### **Steel Jackets**

As described in the previous Section (Section 7.2.3), anchors for lifting vessels may sometimes be deployed during operations to lift and remove the jackets. This might disturb the top 0–2 metres of the seabed surface. The physical effects of such disturbance will be very small, very local in character, and reversible.

Dredging the sediment in connection with cutting the legs/pilings may alter the bottom substrate where soil is removed or dumped. Bottom-dwellers will be buried where the sediments are dumped. The changes to the bottom substrate will occur in a limited area and the bottom will gradually even out. The scale of the physical effects is therefore deemed small.

The legs/pilings can also be severed using explosives. This would cause sediments in the vicinity to swirl up, then settle again in near-by areas. Sedimentation may bury bottom-dwellers in the immediate vicinity. The physical effects are expected to be short-lived and «insignificant».

Use of explosives to cut the legs/pilings will clearly affect living organisms, the scope depending on the amount of explosive, depth, and population of organisms (Larsen 1994). Effects on fish have previously been modelled on several occasions, among others, Larsen 1994, in connection with removal of the Odin installation. Fish with swim bladders, including



cod, saithe and haddock, and larvae and small fish, are most susceptible. Only minor effects can be expected for larger fish, restricted to the area close by the installation. Larger fish are very mobile and can be scared off before blasting. Use of explosives for cutting will therefore be most suitable in the period August–October, since this takes account of fry and small fish being among the life forms most susceptible to explosion and these cannot be scared off. The scope of the physical impacts is deemed «moderate negative».

The steel jacket is a structural feature that may attract fish. A range of uncertainties exist regarding how the existence of such structures influences the population of fish. It is unknown whether reefs simply attract the fish in the area, or whether they create a new breeding habitat that increases the overall production (Aabel *et al.* 1997). The latest research in this field (Soldal *et al.* 1998) leans towards the conclusion that simple attraction is the predominant effect in the North Sea. Explanatory models supporting greater production are that the reefs cause more individuals to survive, more of them reach reproductive age, and thus the total production of eggs increases. If the fish simply congregate without any increase in biomass, then the attraction process will render these more likely to be harvested.

The total scale of the physical effects arising from use of the steel jackets as reefs in the North Sea is considered «moderate negative» (damage to the seabed habitat), regardless of where the reef is located (in-place or beside the Tank). The overall environmental consequences of the physical effects are deemed in both cases to be «moderate negative».

#### **Ekofisk Tank**

If the Ekofisk Tank is used as part of an artificial reef it will be left intact. In the long term parts of the Protective Barrier Wall may collapse and cause concrete pieces to drop off the structure, hitting the seabed. A concrete structure of this type is very enduring, and the date when it will start to collapse is difficult to predict. The upper parts of the Protective Barrier Wall may collapse in a few decades, and more solid parts will exist for several centuries. The effects of falling concrete on the seabed are intense but extremely local, depending on the size of the pieces. The effects will be temporary re-suspension of sediments, and burial of some local bottom-dwellers. The scale will be small and very local.

The total scale of the physical effects resulting from using the Ekofisk Tank as an artificial reef is deemed small. The total environmental impacts resulting from these physical effects are therefore also assessed as «small negative».

#### **Overall impact – Physical impacts/habitat effects (Alternative IIA)**

The overall physical/habitat impacts of using the steel jackets and Ekofisk Tank as artificial reefs in place is assessed as «small negative».

#### **Alternative IIB – Reef near Ekofisk Tank**

No significant differences are expected from this Alternative relative to the foregoing one, Alternative IIA. One can argue that the «reef effect» will be rather larger from a collective reef rather than several dispersed reefs, but available data in the North Sea, and hence our knowledge in this field, is not sufficient to draw a firm conclusion.





### Alternative IIC – Jackets to shore, leave Tank in-place

The consequences due to mooring and cutting the legs/pilings are expected to more or less replicate Alternative IIA. However, as no jackets are to be toppled or placed on the seabed, this Alternative will cause less impact.

No physical impacts are anticipated due to transport to shore or demolition of the steel jackets.

The total scale of the physical effects of removal of the jackets, their transport to shore, and demolition are considered small. The total environmental consequences resulting from these physical effects of removal of the jackets are therefore assessed as «none/insignificant». Use of explosives for cutting jacket piles would result in «small» to «moderate negative» impacts.

The physical/habitat impacts of leaving of the Ekofisk Tank in-place are the same as for Alternative IIA and IIB, i.e., «small negative».



### Alternative IID – Jackets to shore, Tank deposited in deep sea

The effects from removal of the steel jackets will be as described in Alternative IIC, i.e., «none/insignificant».

To provide the Ekofisk Tank with adequate buoyancy for removal, some of the ballast would have to be removed. Gravel and rock in the ballast voids above the oil storage tanks and in the chambers of the Protective Barrier Wall, about 355,000 m<sup>3</sup> in all, would therefore have to be removed and deposited on the seabed. Gravel and rock, as RaKon (1999) has proposed, could be released east and west of the Tank, but this depends on the infrastructure in the vicinity. The gravel would be dispersed over the seabed and, if laid in a layer 2 metres thick, would cover 177,500 square metres (see Figure 37). The bottom in the vicinity is naturally sand, in the main. Dumping of gravel and rock could thus alter the nature of the bottom surface. Structural unevenness would attract some organisms, fish, for instance, and might cause immobile organisms to establish themselves. In addition, the dumping of gravel and rock would bury organisms that live in or on the bottom, and change the fauna in the covered areas. Stone fills over many pipelines in the area are already a feature, and the scale of the physical effects of the gravel and rock is deemed «moderate negative».

The physical effects resulting from an accidental sinking during towing of the Tank would affect a few hundred square meters of the seabed, and are assessed as small. However, the effects would be somewhat dependant on location.

For the scuttling operation, explosive charges would be set, for instance in pipeways going through the Protective Barrier Wall, allowing the structure to take in water. The firing of these charges would clearly affect any marine organisms, and the extent of the impact would depend on the amount of explosive used, the depth, and the presence of organisms nearby. There are six pipeways, and the total explosive needed is estimated at 1080 kg (RaKon 1999). Lethal effects have to be expected on any nearby fish.

Pressures arising as the Tank sinks are expected to cause implosion of the flotation chambers at a depth of about 200 metres. The suction in the water due to the implosion has the potential to kill organisms in the water column near the implosion site. This effect is very local and the scale of the physical effects is therefore assessed as small.



**Figure 37**  
Possible location for disposal of Tank ballast on seabed near Ekofisk Center (Rakon 1999)

The implosion would cause fragmentation of the concrete structure, which would sink to the bottom with its reinforcement bars and cables. The fragments of the Tank would spread over several hundred square metres and might cover sediments and marine organisms in the vicinity. It is at present uncertain how long a re-colonisation period is required for bottom fauna in deepwater sediments (NERC 1996). Trials run by Grassle (1977) suggest that every physical impact on the bottom will cause lasting changes in the deep water community structure and composition for a minimum of two years. The scale of the negative physical disturbance is deemed moderate.

The total scale of the physical disruption from deepwater disposal is deemed «moderate negative». The total environmental consequences caused by the physical disruption are therefore expected to be «moderate negative».

**Alternative IIE – Jackets and Tank to shore for demolition and recycling**

Environmental effects due to physical disruption in connection with a removal of the Ekofisk Tank are similar to those described for Alternative IID above, i.e., «moderate negative» physical impacts.



No physical impacts are expected to result from demolition, recycling and disposal of the Ekofisk Tank.

### 7.2.5 Aesthetic effects of the Substructure Disposal Alternatives

The aesthetic issues identified and examined are as follows:

- Visual sensitivities for demolition (yard activities) and final disposal
- Noise
- Generation and dispersal of dust from demolition of concrete
- Odors due to decomposition of marine growth (fouling)

#### Alternative IIA – reefs in-place



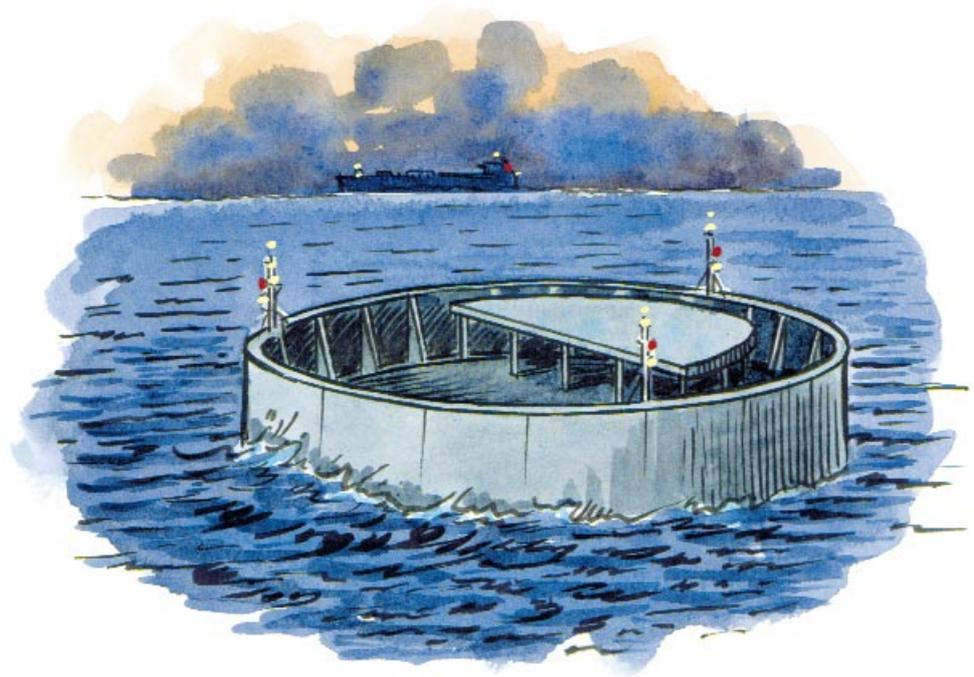
No particular aesthetic effects are anticipated from use of the steel jackets as artificial reefs.

Should the Ekofisk Tank be used as a reef, it will be visible to passing shipping (Figure 38). The situation will be much as it is today, but without any form of smoke or other emissions. To what extent this might be considered negative is likely to be a subjective assessment. If the installations – in the worst case – are deemed unsightly, then the potential impact still remains small, since few people will be directly affected.

The aesthetic impacts of the Tank left in-place is therefore considered negligible and thus assessed as «insignificant».

**Figure 38**

*Leaving the Tank in-place, intact with navigation lights, for instance in conjunction with artificial reef (from DNV 1999)*



#### Alternative IIB – cluster reef around Tank

The aesthetic effects of Alternative IIB are considered identical to those of Alternative IIA, i.e. «insignificant».

## Alternative IIC – Jackets to shore, leave Tank in-place

### Steel Jackets

No particular aesthetic effects due to noise, odors or ugliness are expected due to removing the jackets offshore.

Marine growth on the steel jackets will quickly start to rot once the jackets come out of the sea, thus causing a stench. Growth should therefore be removed as promptly as possible, for instance by jet-hoses, either during transport or when the jacket arrives at the dock. Materials removed should be collected and disposed of at a suitable location (cf. 7.2.6). The scale of the negative aesthetic effects due to foul smell is considered moderate. If marine growth is removed, the problem of rotting marine growth will be avoided. There is some experience of mechanical removal of dried growth, but such a method could presumably only be used a good distance from housing or recreational areas.

Handling and dismantling at the quayside on reception may impose a load on the local environment. Storage of these large jackets can have an undesirable visual effect, but the scale of this disadvantage will be limited since storage will be in an industrial area. On the other hand, a significant impact is liable to result from the noise of demolishing the steel jackets. Noise monitoring at Norwegian firms that engage in similar activities shows normal and maximum values sometimes approaching or exceeding the guidelines issued by the Norwegian Pollution Control Authority (see Section 6.2.5 on Topsides). This indicates that noise from demolition operations on the steel jackets have a potentially large negative impact. The choice of location – seen in light of i.a., possible housing and topography – and noise-abatement measures can significantly reduce this potential. If the area selected lacks qualities that might be affected by the noise, e.g. housing or recreational areas, the effects can be described as «moderate negative». Noise-abatement measures could serve to significantly reduce the impact potential.

In a built-up area the consequences can be «large negative».

### Cold phase for steel jackets

The visual impact of a cold phase of the installations is that they will remain visible to passing shipping – much as they are today, but without any form of smoke or other emission. To what extent this might be considered negative is likely to be a subjective assessment. For instance it has been discussed in the Foundation for Social and Industrial Research (SNF) (part of DNV 1998-f) without any clear conclusions being reached. If the installations – in the worst case – are deemed unsightly, then the potential impact still remains small, since few people will be directly affected. SNF has cited the passengers on the Stavanger-Newcastle ferry, but this passes at night, and the installations left in-place will only be visible due to their navigation lights on the horizon.

The aesthetic impacts of a cold phase are therefore considered «insignificant».

### Ekofisk Tank

The aesthetic effects of leaving the Tank in-place are the same as Alternative IIA and IIB, i.e., «insignificant».



**Overall aesthetic effects – Alternative IIC**

The overall aesthetic effects of Alternative IIC are assessed as «small negative», primarily due to the noise associated with recycling the jackets onshore.

**Alternative IID – Jackets to shore, Tank deposited in deep water**



The consequences of removing and demolishing the steel jackets will be as described in Alternative IIC (i.e., either «moderate negative» or «large negative» depending on the location of the dismantling yard and the scope of noise-abatement measures).

No particular aesthetic effects are anticipated due to noise, odors or visual impact from lifting, transporting, or scuttling the Ekofisk Tank. During sinking a rumble and a waterspout are anticipated – though this is not considered to be negative from an aesthetic point of view. The tow operation, it might be argued, could have considerable interest, rather than being a negative visual effect, and would in any case only last a very short time.

The overall aesthetic effects for Alternative IID are assessed as «small negative».

**Alternative IIE – Jackets and Tank to shore for demolition and recycling**



**Steel Jackets**

The consequences of removing and demolishing the steel jackets will be as described for Alternatives IIC and IID, i.e. «none/insignificant».

**Ekofisk Tank**

Marine growth (fouling) will come into contact with the air when the Tank is refloated, towed inshore, anchored or brought into dock, and will gradually rot and develop odours. The scale of the growth, temperature, and exposure time to air before treatment or cleaning, are all factors that can affect the potential impact. It is estimated that the structure is host to as much as 3000–4000 tonnes of fouling (DNV 1999-b). Fouling has the potential to cause bad odours for workers and the local environment. As an example, Hanøytangen was investigated as a demolition site. It has a number of holiday homes just by the industrial limits, and about 100 regular homes 0.5–1 km north and west of the site. The coastal district nearby is also much used for recreation and outdoor activities, including boating, bathing and fishing. Some of these open-air areas are protected in the municipal zoning plan. Therefore, marine growth should be removed as promptly as possible to avoid any unpleasant smells. This is feasible, for instance, with jet hoses. It is recommended that cleaning should be more or less constant during the demolition period at the quayside or dock. Waste from the cleaning must be collected up and disposed of at a suitable site. The scope of the odour problem if not cleaned off is deemed «moderate negative».

The greatest potential negative aesthetic effects related to removal and recycling the Tank are nevertheless expected to come from noise and also dust. Demolition would be done beside a quay, then in a dock during the final stages, while crushing would be done in a unit mounted on a barge. According to RaKon (1999), major sources of noise are hydraulic jack-hammers with a noise intensity of 123 dBA (periodic noise), the concrete

crusher with 105 dBA (steady noise), cranes, diesel engines, etc with a level of 80 dBA (steady noise). The level would be reduced as the distance to the source increases. The demolition process would take about 18 months. The yard is on the southern part of Hanøytangen in Askøy municipal district in Hordaland (near Bergen). As mentioned above, this is an area with homes and very popular holiday region. For example the area borders on Kollevågen, which is a conservation area and provided by the local council for recreational use, with regional importance as an open-air area. Also Nordre and Midtre Rotøyene, and another island, Skorpo, about 1–2 km south of the industrial area, are reckoned as important regional recreation areas. Nordre Rotøyene and Skorpo are listed as recreation areas, whereas Midtre Rotøyene is under planning for listed status. Hauglandsøy, which lies 1 km west of Hanøytangen, is not listed, but in the municipal plan is designated as having local and regional value as a recreational area. Hanøykubben, some 1.5 km north-west of the industrial area, and Laksholmen, some 2 km east, are both regionally important seabird refuges with protected nature reserve status.

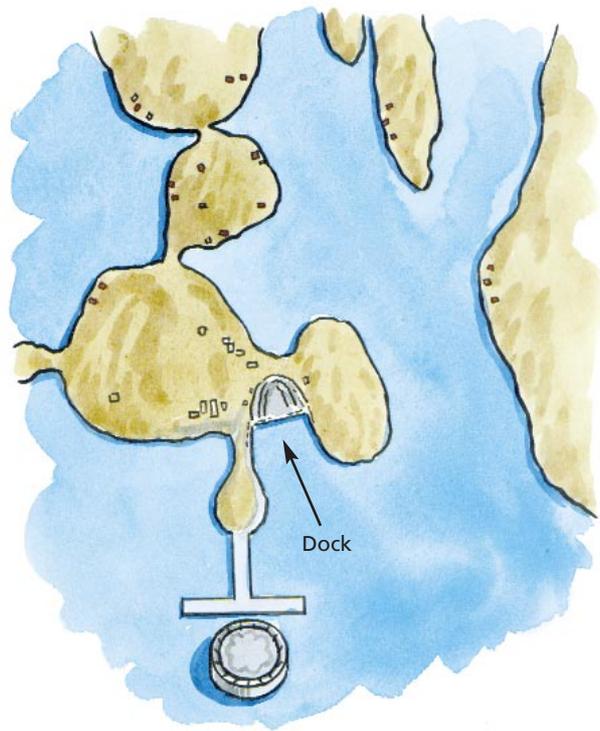
If the expected noise levels and usage areas are compared with the general guidelines given in the Norwegian Pollution Control Authority's «Guidelines for Noise Abatement in Industry etc» (SFT TA 506) (see Section 6.2.5), the implications are that in this case the potential impacts are «large». Noise-abatement measures could reduce the potential significantly.

It is also expected that dust will be generated in connection with demolition, blasting and crushing, but can be reduced by implementing appropriate measures. The total volume of dust generated without countermeasures is estimated at about 200 tonnes (RaKon 1998). Suspended dust is the type that represents the greatest threat to health. For the type of crusher plant envisioned in this case, concentrations have been measured during previous operations of 4130 mg/m<sup>3</sup> air some 30 metres from the plant (RaKon 1999). This is believed also to include precipitating dust (fall-out). One simple measure to mitigate the spread of suspended dust is a water spray. Earlier measurements of crusher plants suggest an efficiency of 70–80 per cent by this measure alone. It is also possible to use filters and extraction fans where useful to reduce the dust volume considerably. Current regulations in this field – Regulations for Threshold Values for Local Air Pollution and Noise – give the following threshold limits for dust:

- 150 mg/m<sup>3</sup> air for survey and analysis of countermeasures
- 300 mg/m<sup>3</sup> air for implementation of countermeasures.

The spread of dust will depend on the wind direction and air humidity. At high humidity the dust will be bound and fall to the ground. At the Hanøytangen location, it is mainly expected that the winds from south-east and south-west to carry the dust inland over populated areas (see Figure 39). According to the data from the Meteorological Institute, the wind comes from this quarter 43 per cent of the time (Rakon 1999). No detailed models have been made of how the dust might spread through the area. Still, it is clear that fine dust particles in a given strength of wind and low humidity can spread over large distances. If the Tank were broken up it would therefore be important to take samples and implement measures to reduce any dust nuisance.

**Figure 39**  
*Buildings in relation to potential demolition yard at Hanøytangen*



**Overall aesthetic effects – Alternative IIE**

The total scale of the aesthetic effects following from removal and demolition of the Ekofisk Tank is considered «large negative». Noise-abatement measures on the other hand can reduce the scale of effects significantly, and the noise problem is also believed to be amenable to control. The total consequences of the aesthetic effects for this Alternative are nevertheless considered to be «large negative».

**7.2.6 Waste/Resource utilization of the Substructure Disposal Alternatives**

Locations for demolition and processing the waste from the steel jackets, if taken to shore, have not been finalised. This assessment of the waste issue thus looks only at types and volumes, not directly at the local consequences at each potential locality, treatment plant, or waste dump.

Disposal of the steel jackets as an artificial reef either in-place or collectively around the Tank will not generate waste. Removal of the jackets (but not the Tank) will generate a total volume of waste of almost 79,000 tonnes. This is made up of steel, concrete, anodes, and marine growth.

In the case of the Ekofisk Tank, waste problems largely arises in the case of Alternative IIE (removal and demolition).

**Alternatives IIC, IID, and IIE**

**Steel**

Steel in the jackets amounts to about 63,000 tonnes. The jackets could, theoretically, be used again as jackets for new platforms. However, it has not been possible to identify specific re-use options for the various parts of the

installations, and re-use of the steel structures is not therefore considered further in this Impact Assessment.

Essentially all the steel from the jackets is expected to go to the scrap furnace. Recycling of steel is discussed further in Section 6.2.6, to which we refer for a further assessment of waste arising in connection with the solution for the steel.

### **Concrete**

There are 7,000 tonnes of concrete associated with the steel jackets, including that in the legs and foundation piles of the jackets. The concrete will remain inside the jackets when the jackets are removed to the demolition yard.

Concrete from the jackets could mainly be used for recycling as filler material, or otherwise will be disposed of in a landfill.

### **Anodes**

The jackets of the various installations are protected from corrosion (rust) by aluminium or zinc based sacrificial anodes. These also contain small quantities of silicon and other metals, including copper, iron, and mercury. The weight of these anodes totals about 1,440 tonnes.

The anodes are engineered for a predicted lifetime of at least 20 years. It is assumed that they corrode by 2.5–3 per cent per year, which will have resulted in the consumption of between 50 and 80 per cent of the Ekofisk I anodes already, depending on date of installation in each case (DNV 1999-b).

Reuse of the Ekofisk I anodes is not feasible. All materials from these anodes are melted down again (O. Lyngstad, Norsk Metallretur, personal communication).

The material of the anodes is well suited to recycling, and the metals can either form the raw material for new anodes or similar products, or go into entirely different products. Recycling anode material is a well-established industry. Almost all anode metal recovered on the Norwegian side is sent to Germany for melting down. The various components of the anodes are separated by their melting points. The products, mainly aluminium and zinc, are standard commodities that are traded on the international market (O. Lyngstad, Norsk Metallretur, personal communication).

When Odin was broken up, all anode materials were sent for melting down (plus a small fraction which was re-commissioned) (F. Rogne, Aker Stord, personal communication).

Disposal of anode materials can result in leaching of metals into the run-off water and then to the surrounding environment. Any disposal would therefore demand special and extensive measures to preclude leaching. Anode materials must be treated as special waste under the Special Waste Regulations (Ministry of the Environment, 1994). Disposal of anode materials in special waste facilities is subject to a disposal fee, and therefore this alternative is less economic than recycling.

We assume that anodes on the steel jackets will be recycled. Therefore no waste is anticipated from anode materials on the jackets.

### **Marine growth**

The total weight of fouling on the steel jackets is estimated at over 7,000 tonnes. The estimate is based on assumed colonisation space, an average fouling thickness of 50 mm, and a specific density of fouling which is put at 1 tonne per cubic metre.

Mussels and anemones are generally the bulk of the growth, plus acorn barnacles and algae (weed). Thus the growth consists both of soft, organic material and a harder, calciferous portion made up of shells and skeletons. The greatest volume of growth will be in the upper 10–30 metres as it is here that light penetrates, nutrient salts concentrate, and the water is warmer.

Marine fouling can be removed mechanically from steel panels using a jet hose or similar. Calciferous deposits (barnacles etc) could also be scraped off. Practices regarding removal of the resulting organic material varies. Usually it is hosed into the sea without any treatment. Composting or other forms of disposal are not commonplace. Smaller volumes of organic growth from offshore structures can be washed into the sea without problem, if the location, existing organic impact, tidal flows etc are taken into account. The material is quickly degraded with the sole result that natural components of the marine ecosystem are repatriated.

If the steel jackets are taken to shore this will occur over many years. In that sense the marine growth that needs to be processed at each demolition yard will be far less (some 200–1000 tonnes per installation) than the field total. Compostation onshore might provide an alternative to disposal in the sea. It is more controllable, and causes less nuisance to the local community.

### **Alternative IIE – Removal and demolition of Ekofisk Tank**

#### **Steel**

There are about 46,000 tonnes of steel (pre-stress cables and reinforcement bars) in the Tank structure and Protective Barrier Wall. This steel can be expected in all essentials to be melted down. The recycling options for steel in general are discussed above.

The steel reinforcement would accompany the concrete if disposed of without being broken into rubble first. More likely, however, the concrete would be separated from the reinforcement so that almost all the steel could be recycled.

If removed and demolished, a total of 99 per cent of the steel is expected recycled as scrap.

#### **Concrete**

Concrete in and around the Ekofisk Tank with its Protective Barrier Wall provides the major contribution to the total estimated volume of Ekofisk I concrete, constituting about 470,000 tonnes of the total of 520,000 tonnes of Ekofisk I concrete.

Much of the concrete can theoretically be recycled. Concrete used offshore is generally of high quality, with great strength and low permeability. Generally therefore it is suitable for material recycling (S.W. Danielsen, Franzefoss Bruk, personal communication). The concrete can be crushed and used as aggregate in fresh concrete, asphalt for roads, rubble for roads, filler, etc. It is expected that there is a potential market for broken concrete as a filler on the Continent. The effort to make the concrete recyclable (i.e. refloating the Tank, crushing the structures, processing the concrete and transporting it) must however not be underestimated.

The immense volumes of concrete in the Tank and PBW make demolition operations for these structures a real challenge. During cutting, lifting and crushing, concrete chunks can loosen and get spread about on land and in the

sea at the demolition yard. Concrete waste from crushing should be gathered up and processed according to the demolition contractor's procedures and licensing terms. It is assumed that all disposal would take place in accordance with current rules and regulations for waste (SFT 1994).

The concrete in the Ekofisk Tank and PBW occupies huge volumes, and is therefore expensive to dispose of. Also, the concrete would occupy huge areas, and disposal in a landfill is therefore considered a poor solution.

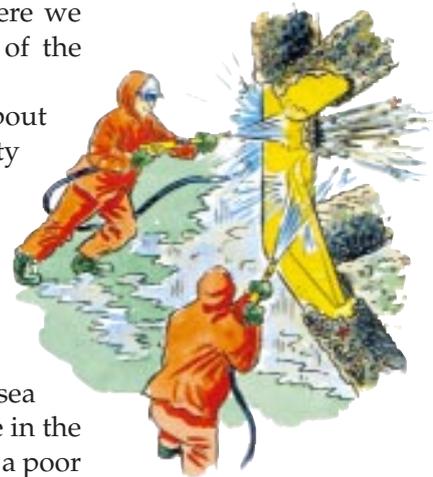
A separate report (DNV 1999-c) provides a thorough assessment of alternative disposal methods for concrete.

**Marine growth**

See the discussion on marine growth under steel jackets, above. Here we mention other factors of particular importance for the demolition of the Ekofisk Tank.

The marine fouling on the Tank structure is estimated to weigh about 3,700 tonnes. If the Tank and Barrier Wall are broken up, this quantity would be processed over a longish period of time (some 18 months). Marine organic material very quickly rots and decomposes. The marine growth on the Tank structure represents a significant volume of organic material. Therefore it must be treated and removed quickly to avoid foul odors at the demolition yard and adjacent areas.

The disposal of large volumes of marine growth by hosing into the sea at the demolition yard would lead to a concentration of organic waste in the water and seabed close by. Therefore this potential method is deemed a poor solution when demolishing the Ekofisk Tank. Marine growth, alternatively, can be processed as wet organic material and fed into a composter at a waste disposal site. The marine growth will be tested for metals before disposal.



*Removal of marine growth by high pressure hoses*

**7.2.7 Littering effects of the Substructure Disposal Alternatives**

Debris will be cleared from the seabed after the installations are removed from their various fields (see Royal Decree of 26 October 1979, Provisional Regulations on Littering and Pollution from Petroleum Operations on the Norwegian Continental Shelf).

Potential litter is therefore associated with Alternatives involving final disposal in the sea.

No floating material will be disposed of in the sea. The potential for littering is thus considerably reduced, and is linked to steel and concrete, and the purely aesthetic concerns of leaving material in the sea.

**Alternative IIA – reefs in-place**

**Steel Jackets**

This Alternative involves the leaving of large quantities of steel in the sea. Gradually, as the protective anodes are sacrificed, the steel will start to rust and the structure will weaken. Parts of it will gradually fall apart, and may be subject to powerful forces (like fishing trawls) which would tend to spread them out of the area. Constraints on trawling and similar activities can reduce the risk of this type of trash dispersal. It also is assessed as being very improbable that spreading in this manner could ever attain significant



proportions. It is also possible to remove remains of reef structures after their function as a reef ceases. The lifetime of an artificial reef is estimated at 150–200 years. Since the time factor here is not particularly critical, there is a good chance of taking mitigation measures if the situation ultimately proves negative to other users of the sea, for example.

The consequences of this type of impediment are more aesthetic than environmental. The fact that this is an effect that may arise in a very extended time period, and last for a similarly extended period, means however that the impacts are deemed «large negative». This is then due to the effect of leaving in-place something that was not there before petroleum activities commenced (cf. methodology Section 2.3).

**Ekofisk Tank**

The Ekofisk Tank when left in-place will contain no buoyant materials. The only chance of litter is fragments of the structure getting caught in fishing gear and being spread about. There is very little chance that this can attain significant proportions.

Debris will be cleared from the seabed around the Ekofisk Center after the various installations are removed. Therefore, no litter effect is expected and it has been determined that using the Ekofisk Tank as an artificial reef has a consequence of «none/insignificant».



**Overall Littering Effect – Alternative IIA**

The overall littering effect for Alternative IIA is «large negative».



**Alternative IIB – cluster reef around Tank**

Relative to Alternative IIA, the steel reef components here will be assembled closer together and the potential for spreading and litter formation is thus somewhat smaller. The consequences are therefore deemed «moderate negative».

The assessments for the Ekofisk Tank will be as described for Alternative IIA, i.e. no litter effect of any significance.

The overall littering effect for Alternative IIB is evaluated as «moderate negative».



**Alternative IIC – jackets to shore, Tank left in-place**

No litter effect is expected in the sea due to removal of the steel jackets to shore. This assumes that waste generated from demolishing and recycling the steel is collected and processed according to current requirements and procedures. Similarly, it is assumed that any disposal is in accordance with current requirements for waste deposits. Therefore no littering effects from removal, demolition or recycling are expected.

The assessment for the Ekofisk Tank will be as described for Alternative IIA and IIB, i.e. no litter effect of any significance.

The overall littering effect for Alternative IIC is evaluated as «small negative».

**Alternative IID – jackets to shore, Tank deposited in deep sea**

The situation for the steel jackets will be as for Alternative IIC.

Debris will be cleared off the seabed after the various installations are removed. Therefore no litter impact is expected as the result of removal of the Ekofisk Tank.

Implosion when the Tank is sunk in deep water will cause concrete rubble and steel reinforcement to spread over an underwater area of several hundred square metres. The choice of a deep water site will avoid places popular with fishing skippers. Therefore there is very small probability that further spreading of the material will occur. Nor will the installation contain floating materials when deposited on the sea bed. The scale of the littering effect from sinking the Ekofisk Tank in deep water – inshore or offshore – is therefore expected to be insignificant to slightly negative.

The overall effect for Alternative IID is evaluated as «small negative».



**Alternative IIE – jackets and Tank to shore for demolition and recycling**

The situation for the steel jackets will be as for Alternative IIC, i.e. no littering effects are expected.

As in Alternative IID, no littering impact is expected at the Tank’s original location after it is removed.

Waste from demolition of the Tank should be collected and processed in accordance with the demolition contractor’s procedures and licensing terms. Disposal is expected to comply with the current regulations and legislation in this field (SFT 1994). Even so, demolition may nonetheless cause concrete chunks in some cases to fall to the bottom at the site of the demolition operation, despite precautions being taken. The chunks will sink and have no tendency to spread. Marine growth should also be collected to avoid spreading. The litter effect of all this is considered insignificant.

The overall litter effect of removing and demolishing the Ekofisk Tank is considered small. The overall impact of the operation of Alternative IIE is deemed «none/insignificant».



**7.3 Societal Impact Assessment of the Substructure Disposal Alternatives**

**7.3.1 Impacts on fisheries**

**Alternative IIA – reefs in-place**

It is well known in other areas of the world that artificial reefs can both promote greater production of fish and improve catches. To estimate the effects of a reef in the Ekofisk Area, a special investigation, known as «Ekoreef» (RF and Dames & Moore, 1998), was carried out in which both the location and design of the habitat were considered. The fishing consequences were further evaluated by the Institute of Marine Research (Soldal et al. 1998).

There is a suggestion that use of the platform jackets as fishing reefs may produce positive effects for fisheries which can operate very close to them. In the North Sea today this is only true for net and line fishing. Here, the positive



impacts predicted are a concentration of populations and possibly an increased production around such structures, resulting in greater profits to fishermen. It has also been suggested that steel jackets, when toppled to form a reef, can act as a refuge for threatened species, and provide shelter for fry and juveniles.

The study by the Institute of Marine Research (Soldal *et al.* 1998) attempted to illuminate the aforementioned topics. During the study, periodic harvest and volume measurements were made of fish around the platforms Albuskjell 2/4 F and Gullfaks C in the North Sea<sup>11</sup>. The study concluded that jackets act as artificial reefs by attracting fish from neighbouring areas. No indications of increased biomass production were found (as measured by better individual growth) at such places in relation to non-reef sites. The study also showed very small occurrence of fry and younger generations of fish around the jacket structures. This indicates that such structures fail to act as nurseries for the fish, at least in these studies. The steel jacket was considered unsuitable for protection of juveniles, since it is too open to provide adequate shelter from large predators. Studies in other parts of the world where unmodified structures were converted into reefs have shown similar effects (West *et al.* 1994). The Institute of Marine Research's study found a significant presence of large cod around the platforms, which are known to be a highly effective predator of younger generations, and this would tend to indicate an enhanced predation effect also in the North Sea.

Moreover, the same study (Soldal *et al.* 1998) concludes that toppling as an artificial reef might assist the profitability of Norwegian cod fisheries in the North Sea<sup>11</sup>. However, this study was described by its authors as a pioneering work, where many issues regarding variation in fish concentrations over time, catch potentials at an installation, and effects on production, remained unanswered. Based on the lack of experience we have with artificial reefs in the North Sea, this Impact Assessment has found that there is inadequate knowledge to decide whether an artificial reef at the Ekofisk Tank might create profitable fisheries in this area. Because such fisheries would in any case be restricted to a small number of fishermen in a very small area, it suggests that a reef that any such disposal method would not create any significant improvement in the overall profitability of the North Sea fisheries.

Information from skippers who took part in the fishing trials at Albuskjell in 1998 suggests that one boat needs two reefs at the same time to fish efficiently (500 nets). They suggest that they could fish here for three days, then return a couple of weeks later. The catch required to operate at a profit would be about three tonnes a day, depending on species and price.

In the Ekofisk Area, petroleum activities have been going on for an extended period of time, and the area around the Ekofisk Center is currently described as «slightly contaminated» (see Section 5.2). Fish caught from this area are first class quality for human consumption and meet all standards from the health and nutrition authorities. Still, intensification of commercial fisheries in the vicinity of enduring petroleum operations might meet with scepticism from the consumer. This might cause fish from an artificial reef at the Ekofisk Center to get a negative connotation, resulting in declining sales and profits. This effect was observed after the Braer disaster in regard to

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<sup>11</sup> Norway is presently not taking its cod quota in the North Sea due to low efficiency.

marketing of Shetland salmon in the UK and Europe – where the quality of the fish was good but its reputation in the market was poor.

Toppled jackets would be foreign structures on the seabed and could snag trawls and similar deep-going or bottom-going fishing equipment. Trawling and seining vessels, therefore, could not operate near such reefs. The steel jackets and Ekofisk Tank, if combined into a reef, would represent a direct limitation of area for such fisheries of about 0.3 square kilometres. The safety margin that trawlers would have to work to when pulling the trawl (3–4 sq.km) would come in addition. In relation to traditional (trawl and seine) fishing in the vicinity, a reef made up of the jackets in-place and Tank would occupy the largest area of the reef alternatives (safety zone about 24 sq.km). The toppling of the Ekofisk I installations today in the existing safety zone around the Ekofisk Center would not, however, have any direct consequences on the area of fishing ground available for as long as Ekofisk II remains in operation (until at least 2028<sup>12</sup>).

The effects of such a reef would therefore be dependant on the time period in question. Before 2028 the reef would be associated with the jackets on the outlying fields. After 2028 the Ekofisk Center could also be part of such a reef project. Optimisation of the location of the structures in a reef must be made after such a decision to ensure the best possible harvest.

The area is the most highly developed in the North Sea and fisheries must in any case steer clear of foreign objects on the seabed there in the future. Therefore it is only in the long term – when the safety zone is finally lifted – that an artificial reef including the Ekofisk Tank could represent a lasting, albeit limited, impediment and loss of grounds for the trawlers and seine fishermen.

To the fisheries, therefore, the toppling of the outlying platforms will have the greatest impact, since they would represent an impediment plus a continuing limitation on grounds for trawling and seining by comparison with the removal option – but toppling would not represent a major change from the present situation. Toppling could therefore cause about the same loss of fishing grounds as is presently forfeited to the individual safety zones around the outlying platforms and boosters. All told this amounts to somewhat less than 7 sq.km.

In order to calculate the effect of the forfeiture of acreage using the OLF method, we have looked at statistics of catches in this fishing location. A «location» is an area of 30 by 30 nautical miles, or about 3,080 sq.km in total. The area occupied by the Ekofisk I installations, including safety zone (22 sq.km), is thus about 0.7 per cent. For the boosters, which are in another location, the area occupied will be about 0.07 per cent. The fishing statistics have serious limitations for such a local area, and do not include catches landed abroad or caught in foreign vessels. To smooth the statistics, therefore, the catches from many years and many locations are summed for the calculation. The value of the catch is estimated at less than 200,000 kroner per year. This estimate is still not very reliable, and our focus here is an evaluation of the physical obstacles on the seabed and forfeiture/release of fishing ground acreage over a long time perspective.

Seen in relation to the nuisance value of major impediments on the seabed for trawling and seining, the establishment of artificial «reefs-in-place» is deemed more negative than positive to the fisheries in both the short and long

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<sup>12</sup> Present date of PL018 Ekofisk licence expiry.

term. In particular, this is believed to be the case for the outlying platforms, which will represent a number of unconnected obstacles, and provide only «small positive» reef benefits.

However it must be stressed that significant uncertainty exists regarding the magnitude of the reef effect, both as it affects fish resources and North Sea fisheries.

The total impact on fisheries of «reefs-in-place» at Ekofisk is therefore deemed «moderate negative».

### **Alternative IIB – reef around Ekofisk Tank**



A placing of the various platform jackets around the Ekofisk Tank may also be both positive and negative to the fisheries.

The reef effect is expected to correspond with that in the «in-place» case above, but there is a potentially greater positive reef benefit from a tailor-made reef concept. A collective reef may offer greater harvest opportunities within the limited geographical area, and thus represent more efficient fishing operations. The positive benefit of reef fishing must nonetheless be seen in the context of its magnitude, which will be moderate. This assessment assumes that such a collective reef could form the basis for fishing by one vessel full-time or two-three vessels part-time (1000 tonnes cod per year). A reef at the Ekofisk Tank would only become available after the closure of Ekofisk II, which means after 2028.

A reef at the Tank consisting of the steel jackets means that impediments to fishing are removed at the outlying fields. The safety zones around the outlying installations and some of the fishing restricted zone around the Ekofisk Center could therefore be lifted. In the long term this represents the relinquishment of about 21–22 sq.km of grounds, and will simplify access by fishing boats to the grounds around the Ekofisk Center. Due to the release of acreage in surrounding areas, the option to collect the jackets in an artificial reef at the Tank is deemed considerably more attractive than toppling of the jackets in-place.

On the downside, the jackets will still occupy some acreage close to the Tank after 2028, although this is small compared to the acreage relinquished.

Altogether, the effects of a collective reef will be to remove most of the obstacles to seiners and trawlers, but to occupy a reduced area after 2028. No exact design has been made of the appearance of such a reef, but an assumption has been made that looks like Figure 30, and with about 50 metres between structures the direct acreage occupied is 0.2 sq.km, with a restricted zone for seining and trawling of 3–4 sq.km. For this type of vessel, which represents the industry that currently frequents the area, a collective reef is found to provide a «small negative» impact, while release of the remaining areas has a «moderate positive» impact.

The effects of tying up the area are calculated using the OLF method (see description above). The area committed by the installations and safety zones is about 0.12 per cent for trawling, and 0.10 per cent for purse seining, of a fishery «location». The value of the catch is estimated at less than 30,000 kroner per year. This figure is not accorded much weight here, and our focus is rather on the nuisance value of the physical impediments and area commitment/relinquishment in a long-term view.

For seine skippers, the reef may offer a livelihood for a very small number of boats. Still, this only translates into a «small positive» impact. The overall evaluation is therefore how to price something that is slightly negative for the existing industry, and somewhat positive for a «new» industry. Before we can draw conclusions about this, the best thing is to make further studies of the feasibility and scope of any such net operations around such a reef. Since the further area unavailable to trawl fishing is so small, it seems that such a reef will have a certain positive potential – and small negative consequences.

The overall consequences of this Alternative are therefore assessed as «small positive».

### Alternative IIC – jackets to shore, Tank left in-place

The removal of the steel jackets on the outlying platforms will mean the safety zone around these installations can be lifted, relinquishing acreage for fishing operations. The safety zone at each installation is almost 1 sq.km, so the total freed up area for the seven outlying installations is about 7 sq.km.

Removal of the jackets on the Ekofisk I installations lying within the Ekofisk II fishing restricted zone will not, initially, result in any relinquishment of area to the fisheries. The zone around the Ekofisk Center occupies about 17 sq.km. Not considering Ekofisk II, removal of the Ekofisk I installations would release areas to fishing.

Elimination of obstacles and relinquishment of area to the fisheries can make fishing operations more efficient in the vicinity. A solution where the steel jackets from the Ekofisk I installations are removed from the continental shelf is therefore deemed a good solution from the point of view of the fisheries.

Leaving the Ekofisk Tank in-place will not have any effect as long as Ekofisk II remains in operation. No effect than therefore occur until sometime after 2028 or later. The exclusion zone for fisheries is about 1 sq.km. However, it is generally assumed that in practice this is decided by trawl direction and safety zone, and thus the area is more of an ellipse than the theoretical circle (Valdemarsen, 1995), see Figure 40 and 41. The area of this ellipse is estimated at 1.5 sq.km, but since the area is flat without any predetermined trawl direction, it may nevertheless be smaller.



**Figure 40**  
*Perceived exclusion zone for trawling by comparison with legal exclusion zone (after Valdemarsen 1995)*

The effect of occupying the area is calculated according to the OLF method. The area occupied at the Ekofisk Tank with its safety zone is thus 0.06 per cent for trawling, and 0.05 per cent for seining, reckoned as a fraction of the fishery «location».

**Figure 41**  
*Perceived exclusion zone for purse seine fishing by comparison with legal exclusion zone (after Valdemarsen 1995)*



The value of the catch is estimated at 13,000 kroner per year. This value is not accorded much weight, and the focus is rather on an assessment of the physical nuisance value of the impediments and occupation of area/ relinquishment of area in a long term perspective.

Therefore this solution (jackets to shore, Tank left in-place) is considered to give a «small positive» impact for fishing interests, with a perceived occupied area of about 1 sq.km and the relinquishment of about 23 sq.km.

**Alternative IID – jackets to shore, Tank deposited in deep sea**



The consequences of removing the steel jackets are as described for Alternative IIC above.

Marine operations to remove the Ekofisk Tank would take place over a period of 1–2 years within the safety zone for the Ekofisk Center. Since fishing is not permitted within the safety zone, these operations will not further limit fishing in the region.

If the favoured solution is to deposit the Tank in deep water, it would be towed to the consignment site, either in 2000 metres of water north-east of the Faeroes or in 700 metres of water in Nedstrandsfjorden in Rogaland (Norway).

If consigned to the deep north-east of the Faeroes, the Tank would end its days far deeper than fishing vessels and fishing equipment operate at, and would thus represent no conflict of interest with fisheries. If consigned to the bottom of Nedstrandfjord the Tank would disintegrate in an area that is not suitable for fishing and which is designated and previously used as a permanent dumping ground. Several ships and the Alexander Kielland platform have been sunk here. Therefore no conflicts with fishery interests are anticipated.

Before sinking the Tank would be cleaned and purged so as not to represent a source of contamination at its final disposal location. Based on this fact, it seems unlikely that disposal of the Tank will result in littering that can harm fish or fishing.

The remove and deposit in deep water alternative is therefore deemed in sum to have a «moderate positive» impact on fisheries, due to the relinquishment of all fishing grounds in the Ekofisk area.

**Alternative IIE – jackets and Tank to shore for demolition and recycling**

The consequences to fishing of removal of the jackets are as described for Alternative IIC. The consequences to fishing of removing the Tank would be as discussed for Alternative IID. The actual towing operation and demolition work onshore are not expected to have any impact on fisheries.

Removal of all obstacles to fishing in the area is deemed to have a «moderate positive» impact on fisheries.



**7.3.2 Impacts on free passage of the Substructure Disposal Alternatives**

**Alternative IIA – reefs in-place**

Construction of artificial reefs in-place will mean that most of the jackets would no longer occupy the part of the water column used by ordinary ships. An exception is that some reefs that will extend into the top 55 metre layer of free water column recommended by the International Maritime Organisation. Submarines which operate throughout the water column are another exception. We have no knowledge of what parts of the North Sea are used by Norwegian and other nations’ submarines, but the area is assessed to have medium value. The reefs will in any case be marked on navigation charts, including their vertical height, and will be known to the navies of the world.



Use of steel jackets to form artificial reefs is considered altogether to have no effect on normal free passage. In relation to today’s situation, where the structures represent a risk, the change will be for the better. However, the reef will be a negative element in relation to Royal Norwegian Navy operations (though only for submarines, and not, like today, for surface vessels), and the total consequence is assessed as «moderate negative» for these alternatives. The total effect is evaluated as a «small positive» impact.

There are no major ship lanes in the immediate vicinity of the Ekofisk Tank. Seen in relation to all installations on the field, the value of the area taken up by the Tank is assessed as having moderate value.

In establishing a reef at Ekofisk Tank the entire water column will remain occupied and the present small risk of collision with shipping will therefore persist.

The Ekofisk Tank is 140 metres across at the widest. As a part of a reef it would be fitted with lights and horns to be readily visible and detectable by passing ships. The probability of collision has been estimated at  $1.1 \times 10^{-5}$  (DNV 1998-a and f), or once every 90,000 years.

The scale of this continued risk is calculated as small to moderate. The total consequences will be «small negative».

**Alternative IIB – cluster reef around Ekofisk Tank**

For ordinary passage at sea the consequences of this collective reef alternative will be like the reefs-in-situ option. In relation to submarine passage a collective reef must mean less threat, since it will occupy less volume. Another consideration is the jackets proximity to the Ekofisk Tank (see below). The total consequences are therefore assessed as «small positive».



**Alternative IIC – remove steel jackets to shore, leave Tank in-place**



Leaving the Ekofisk Tank in-place will have the consequences outlined in Alternative IIA.

Removal of the steel jackets will demand the presence of diving service vessels, lifting vessels, and tugs and their barges. A total in excess of 1,700 vessel hire days has been estimated for removal of all steel jackets.

The long-term effects of removing the steel jackets will be positive in relation to today’s situation, since this would represent an improved risk level. The magnitude of the change is deemed moderate to large since it frees up a number of areas and reduces the number of installations in other areas.

Therefore removing the steel jackets is evaluated as «large positive». The total consequence for the alternative including the Tank has been found to be «small positive».

**Cold phase**

Putting the jackets in a cold phase will uphold the risk of collision with passing ships during the period. During the cold phase, the installations will be properly marked, but there will be no stand-by vessels on the field. This is not expected to affect the chances of a collision significantly. It has been calculated that the total annual probability of collision with passing commercial and fishing vessels is about  $1.1 \times 10^{-3}$  and  $2.5 \times 10^{-3}$  (once every 900 and 400 years) respectively (DNV 1998-f). The consequences to the vessel and installation will depend on a number of circumstances, such as the vessel’s speed (energy), where and how the collision takes place, and which installation is involved. For example, a fishing craft (trawler) during fishing operations has a very low speed compared with other ships, which in turn may mean that the consequences of a collision would be less.

The final solution is deemed to be equivalent to removal, with positive payoffs for free passage of shipping.

**Alternative IID – remove steel jackets, deposit Ekofisk Tank in deep water**



Removal of the steel jackets is as described for Alternative IIC.

For the Ekofisk Tank the solution means some vessel activity in the area during preparations for removal, lasting for a year or more. Further operations could be to tow the structure to a specified site (8–9 tugboats). The speed of the tow will be about 0.5 knots, and it could take some 12–15 days to reach the disposal destination, depending on the location chosen. The tow could only proceed in a window of good weather and could be clearly visible. Therefore it is not expected to cause any significant encumbrance to free passage.

A solution where the Ekofisk Tank is removed will probably mean that all fixed installations on the field are removed. This means therefore that after removal operations are completed there will be no risk of collision with passing ships. Seen in comparison with the alternative to remove the jackets from the trafficked part of the water column, removal of the Ekofisk Tank will therefore have an effect with a positive sign. Seen in relation to the risk figures estimated for the installations, the scale can be described as moderate to large positive. The total consequences of this are thus «large positive».

Sinking the Ekofisk Tank in deep water is not expected to affect either commercial or military activities, since the area chosen for such disposal will be cleared in advance with the parties concerned.

**Alternative IIE – remove jackets and Ekofisk Tank for demolition and recycle**

Both the operational phase and the consequences on the field will be similar to those described for Alternative IID, i.e. «large positive» impacts on free passage of shipping.



**7.3.3 Impacts on personnel safety of the Substructure Disposal Alternatives**

**Alternative IIA – reefs in-place**

When establishing reefs in-place the steel jackets would be toppled where they stand. Before toppling, the legs would be cut off at the seabed. The smaller jackets can be toppled using tugs, while the large jackets can be toppled using special pull-barges. The primary contributors to personnel risk are the preparatory work on the jackets and the towing and cutting activity.



Table 25 shows the total risks of toppling.

Activity	PLL
Preparations	0.02
Toppling	0.07
<b>Total</b>	<b>0.08 (rounded)</b>

**Table 25**  
*Risk to personnel from toppling steel jackets (Alternative IIA)(rounded)*

After leaving the Ekofisk Tank in-place it will be fitted with navigation lights and fog horn to reduce the risk of collision with shipping. Leaving and marking of the Ekofisk Tank in-place has a potential for loss of life of (PLL) of less than 0.01.

**Alternative IIB – cluster reef around Ekofisk Tank**

Establishing an artificial reef around the Ekofisk Tank involves toppling the steel jackets close-by the Tank from where they stand. Other, outlying jackets are cut loose and carried to the Ekofisk Tank, where they are placed on the bottom. Cutting and transport of the steel jackets from outlying areas to the Tank accounts for the majority of the personnel risk (85 per cent).



Table 26 shows the risks of creating a collective reef around Ekofisk Tank.

Activity	PLL
Cutting and transporting outlying jackets to Tank	0.12
Toppling adjacent jackets	0.02
<b>Total</b>	<b>0.13</b>

**Table 26**  
*Risk to personnel of collective reef around Ekofisk Tank (Alternative IIB) (rounded)*

The PLL for leaving the Tank in-place is as described for Alternative IIA, i.e. PLL less than 0.01.

**Alternative IIC – jackets to shore, leave Tank in-place**



In most cases, removal of the jackets will be accomplished by cutting them into smaller pieces and then lifting them onto barges using a heavy-lift vessel for transport to shore. Once onshore the pieces will be cut up and scrapped. The far largest contribution to personnel risk here is from the offshore operations of cutting and lifting the jackets. Demolition and recycling of the metal scrap onshore only accounts for 4 per cent of the risk of removal and recycling the steel jackets.

Table 27 shows the risk to personnel of removing and dismantling the steel jackets.

**Table 27**  
Risk to personnel of  
Alternative IIC (rounded)

Activity	PLL
Remove jackets and carry to shore	0.16
Demolition	0.01
Leave Tank in-place	<0.01
<b>Total</b>	<b>0.16</b>

The PLL for leaving the Tank in-place is as described for Alternative IIA, i.e., PLL less than 0.01.

**Alternative IID – remove and scuttle Tank in deep sea**



The personell safety risks (PLL) for removing and recycling the jackets onshore are as shown for Alternative IIC above.

For removal of the Ekofisk Tank for scuttling, the same operations are required as for removal and demolition (see Alternative IIE below), except the towing distance is longer and no scrapping takes place on shore. The Tank would first be towed to shore for removal of the topsides, then towed to a deep sea disposal site.

Table 28 shows the risks of refloating, towing and sinking the Ekofisk Tank.

**Table 28**  
Risks to personnel of  
Alternative IID (rounded)

Activity	PLL
Remove and transport jackets to shore	0.16
Demolition of steel jackets	0.01
Preparations on Tank	0.09
Tow Tank to shore if topsides removed at shore	< 0.01
Tow Tank to disposal ground and scuttle	0.01
<b>Total</b>	<b>0.27</b>

**Alternative IIE – remove jackets and Tank for demolition and recycling**



The personell safety risks (PLL) for removing and recycling the jackets onshore are as shown for Alternative IIC above.

Removal of the Ekofisk Tank would require substantial structural modifications to the present structure to render it watertight and stable for towing. Work to make watertight and to stabilise the Ekofisk Tank represents 60 per cent of the total risk. In this solution, the Tank topsides are not removed until the Tank reaches the quay, but this is not included in the risk assessment.

Table 29 shows the risk to personnel of removal and demolition of the Ekofisk Tank.

Activity	PLL
Remove and transport jackets to shore	0,16
Demolition of steel jackets	0,01
Preparations on Tank until buoyant phase	0,09
Tow Tank to shore	< 0,01
Demolition of Ekofisk Tank	0,03
<b>Total</b>	<b>0,29</b>

**Table 29**  
Risk to personnel of removal and breaking of Ekofisk Tank

### 7.3.4 Costs and national supplies (goods and services) of the Substructure Disposal Alternatives

#### Steel Jackets

Three main removal options have been explored for the Ekofisk jackets: (1) topple as reefs in-place (Alternative IIA); (2) place as part of a cluster reef around the Tank (Alternative IIB); and (3); full removal and recycling (Alternatives IIC, IID). The total costs (for disposing the jackets) are estimated at 0.2 billion for the reefs-in-situ alternative, 2 billion for the reef-near-Tank alternative, and 3.2 billion for removal and recycling (figures in 1998 Norwegian kroner).

The contract for removal of the jackets would probably go to an alliance that could provide engineering, marine operations and mechanical work. There are 2–3 such alliances operating in today’s market.

Based on the respective partnership alliances on the supplier side, the supply and employment effects were analysed at the national level.

Table 30 below gives the costs of the three disposal options for the steel jackets, broken down by cost components.

In the case of all three of these solutions for the jackets, a relative Norwegian content of about 20 per cent of the total supplies is expected. The Norwegian content in the case that demolition and recycling occurs abroad is given in brackets.

**Table 30**  
Ekofisk I jackets – costs and Norwegian content for alternative solutions broken down by cost components, (million kroner 1998 terms)

Components	Reefs in-place	Reef around Tank	Removal	Norwegian content %
Project adm. and engineering	70	120	160	80
Preparations	30	320	475	20
Removal	570	1,300	1,860	10
Transport	0	280	570	40
Demolition	0	0	95	100 (0)
<b>Total Cost</b>	<b>700</b>	<b>2,000</b>	<b>3,200</b>	
<b>Norwegian content (%)</b>	<b>17 (13)</b>	<b>20 (18)</b>	<b>23 (20)</b>	

Note: Costs for steel jacket disposal only

This presupposes that all topsides are removed, and all wells are plugged in the case of drilling installations, before the jackets are removed or toppled. It also presupposes that all pipelines have been disconnected. The costs of these other operations are not included in the table above.

If the jackets are to be positioned as part of an artificial reef in conjunction with the Ekofisk Tank, then a monitoring program is foreseen that will examine the reef's effect on fish stocks. The cost of this five-year monitoring program, involving monitoring of all installations left in-place as reefs, is estimated at 30 million kroner. These costs are not included in the table above.

The Norwegian content of the goods and services supplied for each of the identified activities is estimated and provides the basis for the national employment effects following from each alternative.

### **Project administration and engineering**

Project administration includes the input from contractors and the field operator alike.

Engineering design will be performed in part by an engineering contractor and in part by the field operator. The work involves analysis of the existing structures, planning temporary support bracing for removal operations, estimation of strengths, and planning of marine operations.

The Norwegian content is an estimated 80 per cent.

### **Preparations**

Preparing the jackets means cutting off the legs/pilings, which can be performed with different methods.

Underwater operations will probably be contracted to a Norwegian company. There are several competent Norwegian underwater contractors. The work will be performed with an underwater remote-operated vehicle (ROV). The diving support vessels operate in an international market where a hire charge is paid to an international company. Some of the crew are likely to be Norwegian.

Possible digging around the pilings could be done by Norwegian or foreign diving support vessels.

The Norwegian content is estimated at 20 per cent.

### **Removal**

Once the pilings are cut, the jackets can be lifted onto barges and transported to shore for demolition and recycling, or to the Ekofisk Tank for placement to form an artificial reef. If the jackets are reused as a reef where they stand («reefs in-place»), then they will simply be toppled.

There are no Norwegian contractors capable of performing the marine lifting operations or toppling the jackets on Ekofisk. Supply ships and crew transport are other components of the removal costs, and these components can be furnished by Norwegian companies.

The Norwegian content is estimated at 10 per cent.

### **Transport**

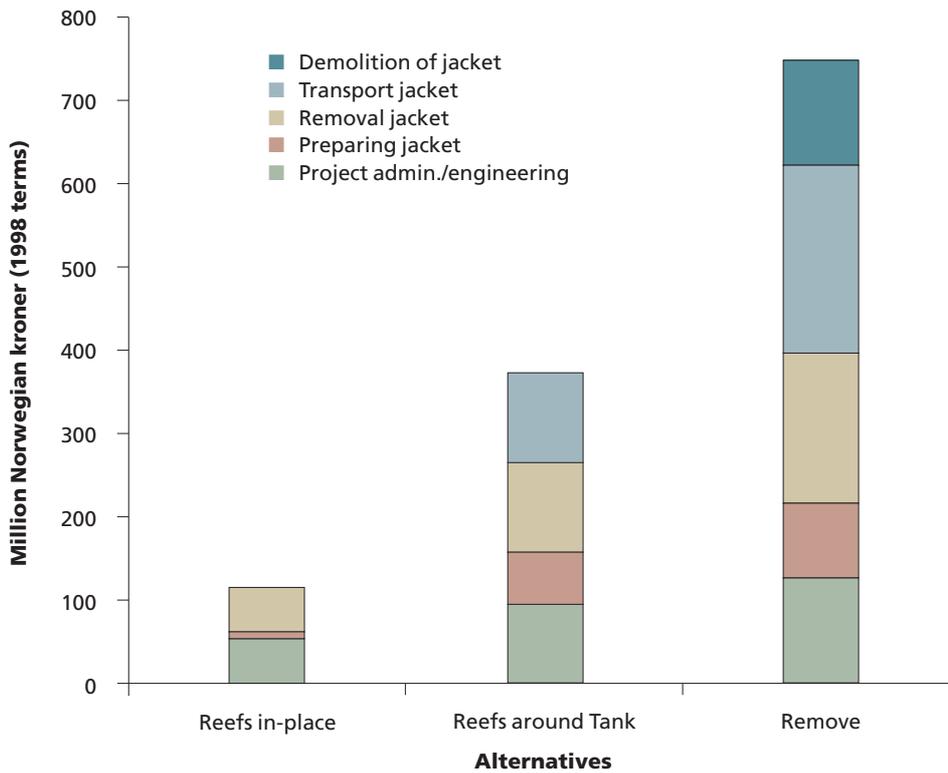
The jacket sections will be taken to shore on barges for demolition and recycling. The costs include mobilisation of large barges and towing using tugs. Barges must generally be obtained from abroad, although for the towing operation Norwegian tugs could be used.

The Norwegian content is estimated at 40 per cent.

**Demolition**

If the jackets are brought to Norway for demolition and recycling this will be done by a Norwegian demolition contractor. The Norwegian content will then approach 100 per cent. It is also conceivable that demolition and recycling could take place abroad. Employment effects have been estimated for both these options.

Figure 42 gives the breakdown of Norwegian supplies in connection with alternative Disposal Scenarios for the Ekofisk I jackets by cost component.



**Figure 42**  
Ekofisk I Jacket  
Substructures: Norwegian content, broken down by cost component for each Alternative, (mill. NOK, 1998 costs)

The Disposal Alternatives for the Ekofisk I jackets can provide a basis for Norwegian supplies totalling 120 million kroner for reuse of each jacket as «reefs in-place», 400 million kroner for reuse as a combined «reef around Tank», and 730 million kroner for full removal and recycling in Norway. The largest contributors would come from marine operations like towing, supply boats, and crew transportation.

Figure 43 shows the Norwegian content for each of the three options, broken down by industries which potentially can supply deliveries directly for the Ekofisk I Cessation Project.

The largest contracts are expected to be for the transport industry, and will embrace flying the crews and providing supply boats for the duration of the preparation and removal operations. There are also the towing operations for the jackets if they are placed near the Tank, or taken to shore for demolition and recycling.

Commercial services include engineering design and engineering consultancy.

The jackets might also be towed to an overseas yard for demolition and recycling. If this option is chosen, the Norwegian content will be reduced in total by about 640 million kroner for the «remove and recycle» alternative.

**Figure 43**  
 Ekofisk I Jacket  
 Substructures:  
 Norwegian content  
 (first level) broken  
 down by industry for  
 each Alternative (mill.  
 1998 costs)

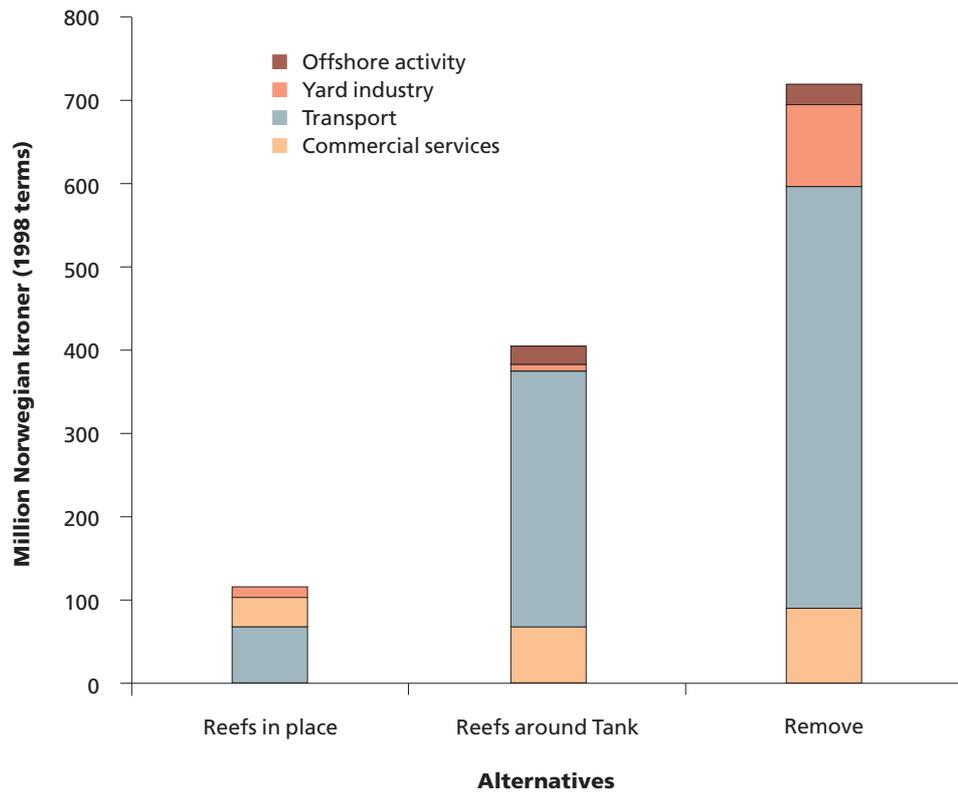


Table 31 below gives a summary of the types and volumes of materials in the jackets that are susceptible to recycling and resale. This will bring revenues to the project depending on market price of the scrap at the time in question.

**Table 31**  
 Ekofisk I Jackets  
 Substructures:  
 Materials for  
 recycling (tonnes)

Material	Steel	Anodes
Steel jackets, bridges, flare stacks etc.	63,000	920

Assuming a price of 300–500 kroner per tonne recycled steel from the Ekofisk I jackets, this would give an income in the range of 20–33 million kroner.

**Ekofisk Tank**

Three main alternatives have been assessed regarding the fate of the Ekofisk Tank: (1) leave in-place; (2) deposit in deep water; and (3) take to shore for demolition and recycling. The total costs in each case have been estimated at: 35 million kroner for leaving in-place, 2.6 billion kroner for deep water disposal, and 3.4 billion kroner for removal and recycling.

The Cessation Plan also includes an Alternative where the Tank is re-used as a reef in a collective structure using other jackets from Ekofisk. With respect to the Tank, this Report assumes the cost of that solution is the same as for the leave in-place Alternative.

Table 32 below presents the costs of the various alternatives examined. These costs do not include removal of the topsides. These, in so far as they relate to the Tank, are accounted for in Sections 6.3.4 and 7.4.3.

**Table 32**

*Ekofisk Tank substructure: Costs and Norwegian content for alternative disposal solutions, broken down by cost component (mill. NOK, 1998 costs)*

Components	Leave in-place	Deposit in deep water	Remove and recycle	Norwegian content %
Project administration and engineering	2	230	270	80
Preparations	34	1,090	1,080	60
Removal	0	1,060	1,080	80
Transport	0	180	35	60
Demolition	0	25	900	100 (0)
Total	35	2,600	3,400	
Norwegian content (%)	60	70	80 (50)	

The Norwegian content of the total goods and services supplied for the various disposal solutions for the Ekofisk Tank may reach 60–80 per cent depending on which alternative is selected. The maximum Norwegian content is expected from the «remove and recycle» alternative, since all dismantling, demolition and recycling is expected to be done in Norway. Demolition and recycling abroad would result in a Norwegian content for the removal option of about 50 per cent of the total goods and services input.

Leaving in-place would entail cold phase costs. The cost estimates are based on the assumption that the topsides are removed and the two decks (20 metres and 30 metres) remain as part of the substructure. The bridges are partly removed and the openings at the infill panels are sealed. Also the Tank proper is cleaned and purged. A temporary navigation lights system will be installed on the Protective Barrier Wall. When the Barrier Screen Wall starts to disintegrate (in 20 to 100 years), the system will be replaced by another, floating system around the Tank.

The costs of cleaning the Tank are part of the decommissioning costs and are not included in the table above.

**Project administration and engineering**

The administrative tasks here involve input from the field operator and from the disposal contractor.

Engineering includes planning and integrity calculations for the various operations and will be done by both the engineering contractor and field operator.

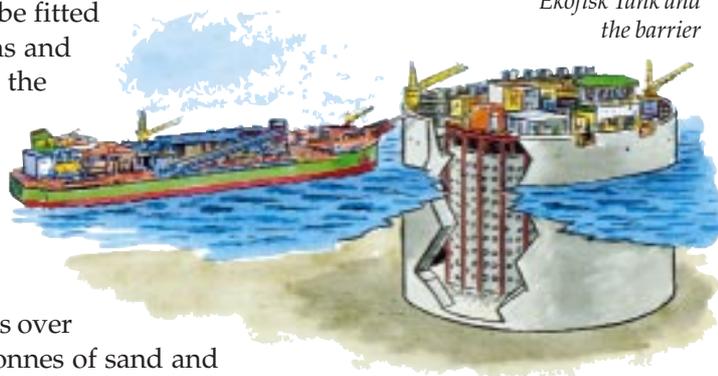
The Norwegian content is an estimated 80 per cent.

**Preparations**

If the Ekofisk Tank is left in-place, it must be fitted with a system of navigation lights, beacons and reflectors that will initially be placed on the Protective Barrier Wall. When the wall eventually disintegrates, a floating system will have to replace it around the Tank proper. Most likely this can be supplied by a Norwegian vendor, albeit with some international content.

The Barrier Wall and the ballast chambers over the Tank cells contain more than 600,000 tonnes of sand and

*The making of watertight connection between the Ekofisk Tank and the barrier*



gravel between them. Before the Tank can be refloated this sand has to be dredged out. The suggested removal method also calls for a watertight concrete connection to be made on the seabed between the Tank and the Barrier Wall. This requires delivery of concrete and steel reinforcement in addition to work platforms, pumps, cranes and so forth.

There are several Norwegian contractors with offshore experience who could do this work.

The underwater operations would probably be done using a remote operated vehicle (ROV). The Norwegian content would be very modest.

The Norwegian content in connection with preparations on the Ekofisk Tank for its removal is estimated at 60 per cent.

### **Removal**

Once the watertight connection has been made between the Tank and the Barrier Wall, the water can be pumped out and the Tank should refloat due to its own buoyancy. Marine operations in connection with removal will largely be within the capabilities of Norwegian shipowners.

There will also be the costs of hiring a flotel, supply boats and transporting the workforce. These services can be provided by Norwegian contractors if competitive. The Norwegian content will depend on whether the quarters rig is owned by Norwegian or international interests.

The Norwegian content is an estimated 80 per cent.

### **Transport**

Transportation of the Ekofisk Tank involves mobilisation of diving service vessels and underwater vessels and towage of the Tank to shore or a suitable location for scuttling in deep water. The job of towing the Tank would probably be offered on the spot market. It would require mobilisation of eight tugboats in addition to one on stand-by. There are many Norwegian boats capable of inclusion in this job.

If the Tank is to be deposited in deep water, holes need to be blasted to pierce the structure and allow it to sink. The Norwegian content is here estimated at 100 per cent and is included in the «transport» component for the Tank.

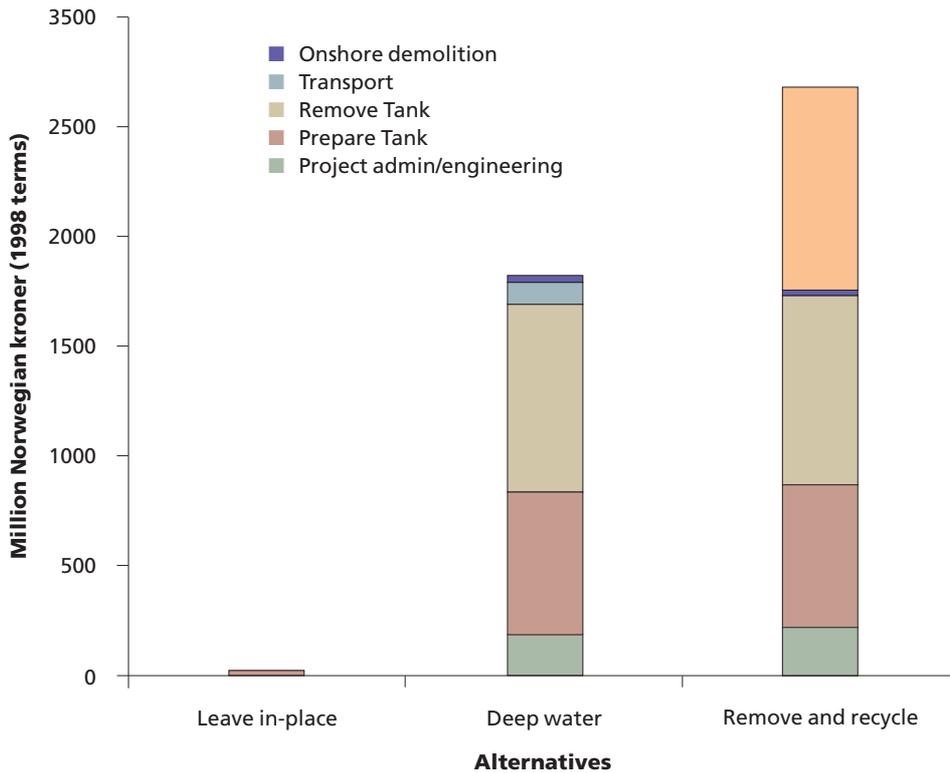
The Norwegian content of the transport operation is estimated at 60 per cent.

### **Demolition and recycling on shore**

To demolish and recycle the Tank, it would first have to be towed to shore. During towing it would have a draught of 60 metres and could, for instance, be taken to Hanøytangen (near Bergen) which has a deepwater quay with 80 metres clearance. It is also conceivable it could go to a foreign demolition contractor. Once inshore, the Tank would be broken into smaller units using dynamite, cutting, and crushing. Reinforcement steel, prestress wires and other items would be removed from the concrete. Fine crushing can be done with standard crusher and grading equipment anchored on a barge beside the Tank. The finely crushed concrete could possibly be used as an aggregate for fresh concrete or as a filler.

The Norwegian content of the onshore processing is estimated at either 100 per cent (if in Norway) or 0 per cent (if abroad).

Figure 44 shows the industries that may land contracts for goods and services input in connection with leaving in-place, sinking in deep water, and removal of the Ekofisk Tank, respectively.



**Figure 44**  
 Ekofisk Tank  
 Substructure:  
 Norwegian supplies,  
 broken down by cost  
 components, for  
 Disposal Alternatives,  
 (mill. Norwegian kroner,  
 1998 terms)

Norwegian supplies in connection with alternatives for the Ekofisk Tank could reach 20 million kroner for leaving in-place, 1.8 billion kroner for consignment to the deep, and 2.7 billion kroner for full removal and recycling in Norway.

If the Tank were towed to a foreign yard for demolition and recycling, the Norwegian content would be reduced by about 900 million kroner.

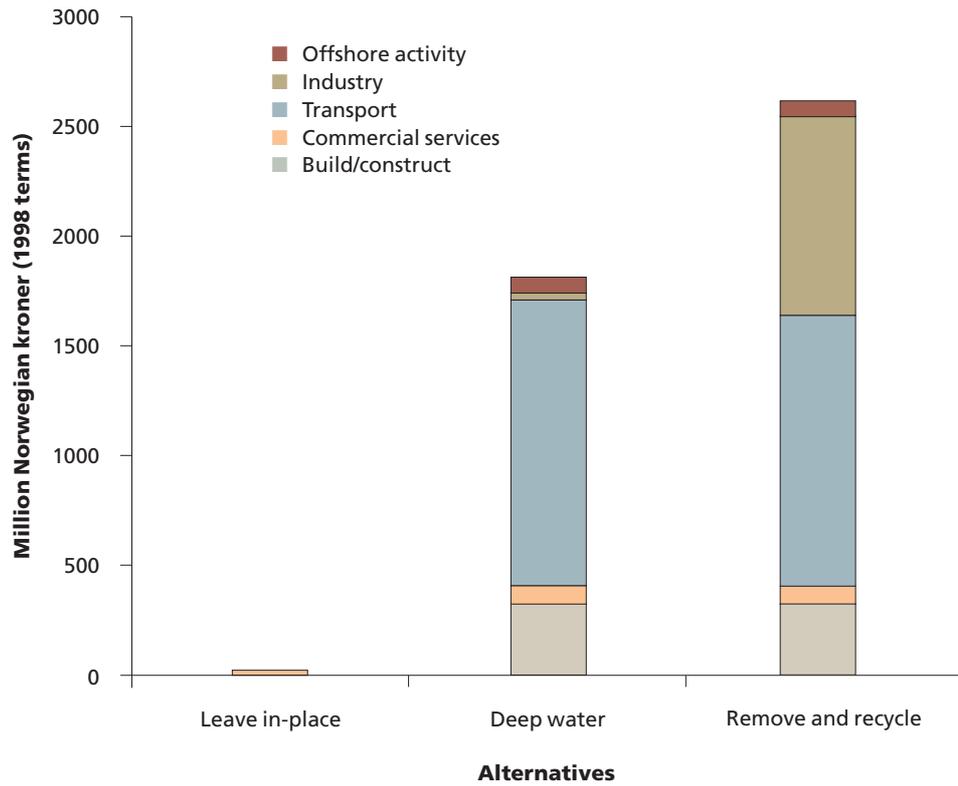
The major supplies from Norwegian industry are expected to relate to preparations, removal, and processing on shore. Preparations are mainly the removal of ballast using pumps, and concrete construction to make the Tank watertight for flotation. Much of the jobs would fall to the offshore-related building and construction industry. Jobs in connection with actual removal will largely fall within the capabilities of Norwegian ship operators.

Figure 45 below depicts the industries that might contribute goods and services in connection with leaving in-place, scuttling, and removal of the Ekofisk Tank, respectively.

The Norwegian minerals production industry can accept the concrete from the Tank for crushing and recycling. The engineering yards can accept scrap reinforcement steel and structural steel for demolition and recycling. Commercial services include engineering and engineering consultancy.

Table 33 below is a summary of the types and volumes of materials in the Ekofisk Tank which are susceptible to recycling, can be resold, and may provide revenue for the project. The magnitude of the revenues would depend on the market prices of scrap at the date in question.

**Figure 45**  
 Ekofisk Tank  
 Substructure:  
 Norwegian supplies  
 (first level) broken  
 down by industry  
 for Disposal  
 Alternatives, (mill.  
 NOK, real 1998  
 costs)



**Table 33**  
 Ekofisk Tank – materials  
 for recycling

Tonnes	Steel	Concrete
Tank and Protective Barrier Wall	46,000	440,000

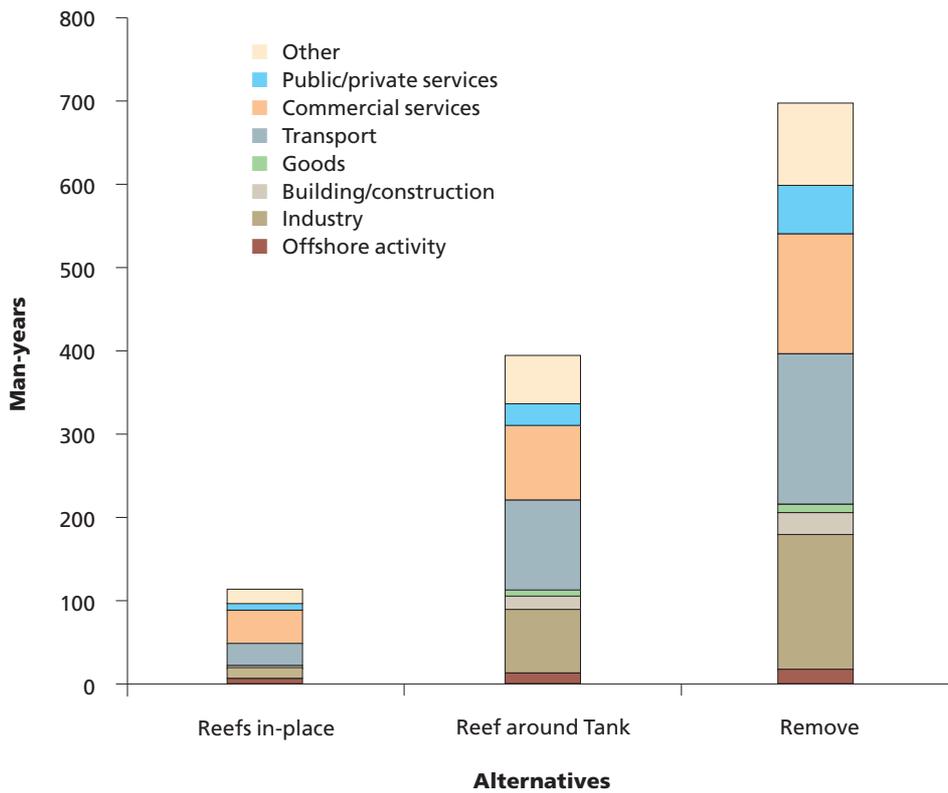
Assuming a price of 300–500 kroner per tonne recycled steel from the Ekofisk Tank, this would give an income in the range of 14–23 million kroner. A price per tonne of concrete of 30 kroner could give an income of about 13 million kroner, if sold of as filler material.

### 7.3.5 Employment effects

#### Steel Jackets

Based on an industry breakdown of the expected Norwegian supplies the national employment effects have been estimated. The Norwegian goods and services will be supplied directly and indirectly to give production effects at the national level. Production effects are expected totalling about 100 man-years from the reefs-in-situ solution(part of Alternative IIA), about 400 man-years from the cluster reef at the Tank solution (part of Alternative IIB), and 700 man-years from the removal and recycling solutions (part of Alternatives IIC, IID, IIE). The production effects will ensue in petroleum-related industry. This assumes that the jackets are taken to shore for demolition and recycling in Norway. The consumer effects will come in addition to the production effects and are estimated to give an additional employment effect of about 50 per cent.

Figure 46 below shows the industries that will benefit from the production effects.



**Figure 46**  
*Ekofisk I jackets – national production effects broken down by industry (man-years)*

The total employment effects are estimated at about 150 man-years for a reef in-place solution, about 600 man-years for the reef around Tank alternative, and 1000 man-years for the removal and recycle option.

The employment effects will be spread over the years of the removal and demolition/recycling process. In the current plans this should take place between 2003 and 2018. If the jackets are removed and taken to shore in Norway for demolition and recycling, the employment effect may amount to some 50–100 jobs (man-years) per year.

The production effects are expected to come mainly within transport and industry. They will mainly derive from offshore transport and towage, demolition and recycling. Engineering services will have production effects within commercial services.

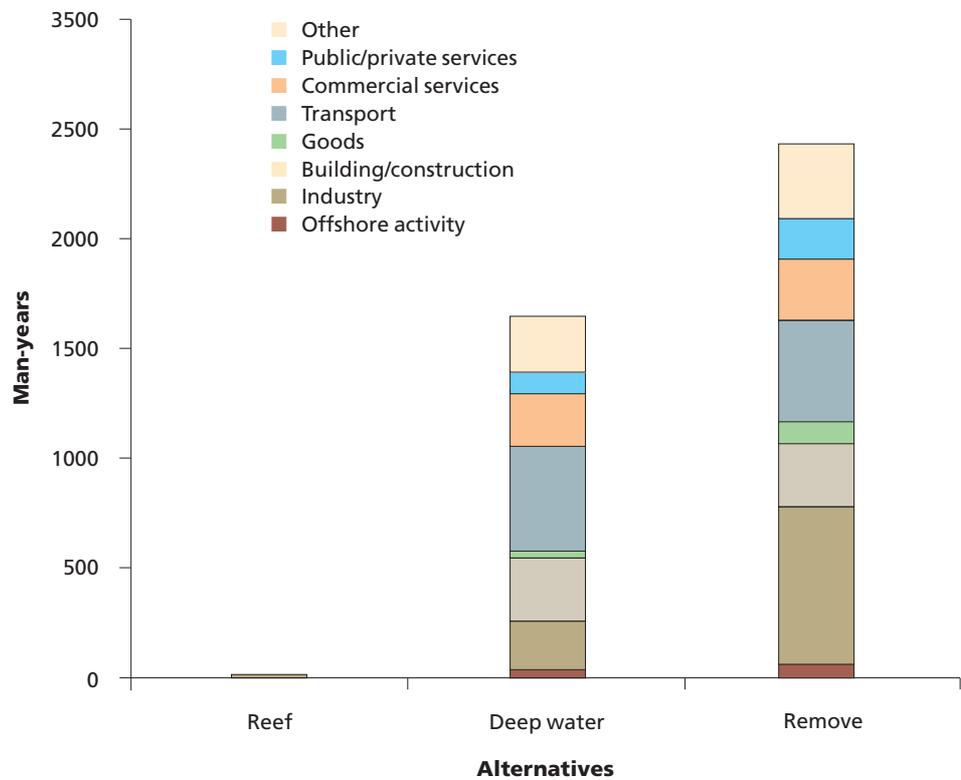
If demolition and recycling is done by a foreign contractor the total production effects in Norway would be reduced by about 100 man-years.

**Ekofisk Tank**

Based on a breakdown of industries for the anticipated Norwegian supplies, the national employment effects have been estimated. The Norwegian goods and services input will give direct and indirect production effects at the national level. Production effects are anticipated of about 25 man-years all told if the Tank is left in-place, around 1,700 man-years if it is consigned to the deep sea, and about 2,500 man-years if it is removed to shore and recycled. The production effects will accrue within petroleum-related industry. It is assumed that the Tank is taken to shore for demolition and recycling in Norway. Consumer effects will augment the production effects and are estimated to add about 50 per cent to the employment effects.

Figure 47 below shows the industries that may benefit from the production effects.

**Figure 47**  
*Ekofisk Tank – national production effects broken down by industry (man-years)*



The total employment effects, inclusive consumer effects, are estimated at about 40 man-years for the leave in-place alternative, some 2,500 man-years if the Tank is refloated and deposited in deep water, and around 3,700 man-years if the Tank is refloated and recycled.

The employment effects will be spread over the years that the removal and demolition and recycling process continues.

A major part of the production effects are expected to accrue in the transport and shipping sector, with 450–500 man-years if the Tank is refloated and either deposited in deep water or recycled. These would largely accrue in connection with hire of a flotel, catering, crew transport, and supply boats. There would also be contracts for towing of the Tank which would offer an opportunity to maintain the employment in Norwegian shipping industry. Demolition and recycling the steel and concrete would offer an employment opportunity in Norwegian land-based industry.

If the demolition and recycling contract goes to a foreign demolition contractor, the production effects in Norway will be reduced by about 600 man-years in mainland industry.

## 7.4 Summary – Impacts of the Substructure Disposal Alternatives

### 7.4.1 Environmental Impacts of the Substructure Disposal Alternatives – Summary

The environmental impacts of the Substructure Disposal Alternatives are summarized in the Table below:

	<b>Jackets/Tank Alternatives: Environmental Assessment Summary</b>				
<b>Issue</b>	<b>IIA</b> Reefs in-place	<b>IIB</b> Reef around Tank	<b>IIC</b> Jackets to shore for recycling. Tank left in-place	<b>IID</b> Jackets to shore for recycling, Tank deposited in deep water	<b>IIE</b> Jackets/Tank to shore for demolition and recycl.
<b>Energy consump. (million GJ)</b>	1.2	1.6	2.5	3.7	5.0
<b>Tot. Energy Impact (Mill.GJ)</b>	4.1	4.5	3.7	4.9	5.0
<b>CO<sub>2</sub>-emissions (1000 tonnes)</b>	90	120	190	280	390
<b>Discharges to sea</b>	Small negative	Small negative	None/insignificant	None/insignificant	None/insignificant
<b>Physical/habitat effects</b>	Small negative	Small negative	None/insignificant	Moderate negative	Moderate negative
<b>Aesthetic effects</b>	None/insignificant	None/insignificant	Small negative	Small negative	Large negative
<b>Waste/Resource util.</b>	Large positive	Large positive	Small positive	Small positive	Moderate positive
<b>Littering</b>	Large negative	Moderate Negative	Small negative	Small negative	None/insignificant

#### Energy

As can be seen from the table above, the reef Alternatives (Alternatives IIA, IIB) have the lowest direct energy consumption of all the Substructure Alternatives. Of these two, the cluster reef Alternative (IIB) has the higher energy consumption due to the additional energy required to gather the outlying steel jackets around the Tank.

Alternative IIC (remove steel jackets to shore for recycling, leave Tank in-place) has the next lowest energy consumption of all the Substructure Alternatives. The increase in energy consumption (of approximately 50% and 100 % more compared to the reef Alternatives IIA and IIB) is attributable to the energy required to remove the steel jackets to shore and recycle them.

The two Alternatives requiring removal of the Tank from its current location require the most energy consumption. Alternative IID (steel jackets to shore, deep-sea deposit Ekofisk Tank), requires 3.7 million GJ in direct energy consumption, while Alternative IIE (jackets and Tank to shore for recycling) requires the highest energy consumption of all alternatives: 5.0 million GJ.<sup>13</sup>

The 50% and 100% increases in energy consumption compared to Alternative IIC are due to the additional energy required to refloat and remove the Tank and also, in the case of Alternative IIE, to demolish and recycle the Tank materials onshore.

If one also includes the theoretical «replacement energy» to account for the energy required to produce new steel in lieu of any steel that is left and not recycled (i.e. the «Total Energy Impact», as defined in Section 2.3.1), the relative performance of the Alternatives changes. In this analysis, Alternative IIC (remove jackets to shore, leave Tank in-place) has the lowest Total Energy Impact, followed by the reef Alternatives (10% higher Total Energy Impact for Alternative IIA and 20% higher Total Energy Impact for Alternative IIB). The Alternatives requiring removal of the Tank have the highest Total Energy Impacts (Alternatives IID and IIE being about 35% higher than Alternative IIC).

The increase in energy requirements for Alternatives IID and IIE is due to the removal and disposal of the Tank. Alternative IID also includes «replacement energy». Section 7.4.3 below considers the energy effect of the Tank substructure removal in isolation, and in combination with the Tank topsides.

### **Atmospheric Emissions**

Emissions follow the same pattern as for direct energy consumption discussed above (not counting theoretical emissions from «replacement energy»). The reef Alternatives (IIA and IIB) have the lowest CO<sub>2</sub> emissions, followed by Alternative IIC (with about twice the CO<sub>2</sub> emissions of IIA), Alternative IID (about three times the CO<sub>2</sub> emissions of IIA) and Alternative IIE with the highest emissions (more than four times the CO<sub>2</sub> emissions of IIA). NO<sub>x</sub> and SO<sub>2</sub> emissions follow the same pattern as CO<sub>2</sub> emissions. The maximum CO<sub>2</sub> emissions, 390,000 tonnes, result from Alternative IIE. By comparison Norway's CO<sub>2</sub> emissions in 1997 were about 41.4 million tonnes (Statistics Norway, SSB 1998).

### **Discharges to sea/water/ground**

The activities that could result in discharges to the sea are related to release of «structural water» from some of the steel jackets, and release of (cleaned) produced water from the storage cells in the Ekofisk Tank. The consequences of these are assessed as «none/insignificant».

Other discharges could also occur, for example, deterioration of water quality as a result of re-suspension of particles when toppling jackets (short-term perspective) and leaching of metals from structures and anodes in a long-term perspective. These were assessed to have «small negative» impacts for the reef Alternatives (Alternatives IIA and IIB).

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<sup>13</sup> Expressed in a more everyday context, we can compare 5 million GJ of energy consumption with the consumption of a town the size of Stavanger (100,000 citizens) for about eight months. Another measure is to say that the fuel required to remove and demolish the topsides is equivalent to 2 days oil production from the Ekofisk field.

**Physical impacts and habitat effects**

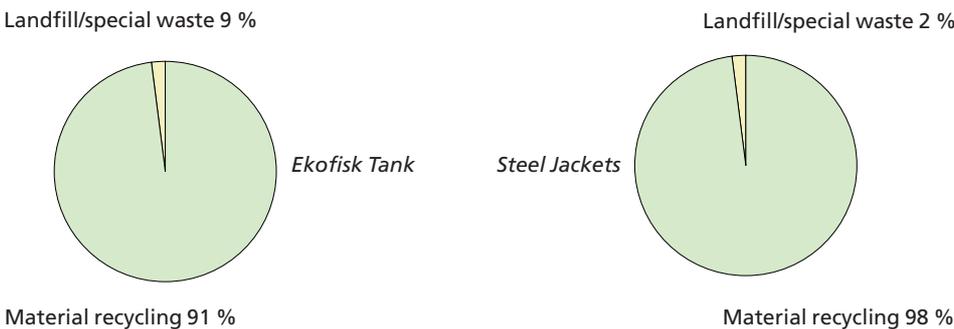
The reef Alternatives (IIA, IIB) are assessed to have «small negative» impacts in relation this issue, mainly due to the effects caused by toppling the steel jackets. Leaving the Tank in-place is assessed as having «insignificant» impacts. Alternative IIC gives no impacts in this category. The physical impacts due to Alternatives IID and IIE were assessed as «moderate negative» due mainly to the dumping of the Tank ballast during the operation to refloat the Tank (and also a small negative impact due to deep-sea disposal of the Tank (IID)).

**Aesthetic Effects**

The reef Alternatives were assessed as resulting in no negative aesthetic effects. Operations to recycle the steel jackets were assessed as having negative aesthetic impacts due to generation of onshore noise and odors. Alternative IIC was thus assessed as having a «small negative» impact with regard to this issue (the aesthetic impacts of leaving the Tank in-place were assessed as «insignificant»). Alternative IID – recycle the steel jackets and deep sea disposal of the Tank – received the same assessment («small negative») for the same reasons. Alternative IIE – recycle both the steel jackets and the Tank onshore – was assessed as having a «large negative» aesthetic impact. This was mainly due to the large quantities of dust that would be generated from the onshore recycling of the Tank’s concrete, which, depending on wind direction, humidity and location of the demolition yard, could result in a health hazard and a general nuisance in the local community. Odors from rotting Marine growth, as well as noise, associated with recycling the steel jackets and the Tank also contribute to this negative rating.

**Waste, resource utilization, and littering**

Generally, waste generation is a significant factor in Alternatives involving demolition and recycling materials onshore. The following pie chart shows the percentages of materials that are expected to be recycled or disposed as waste.



**Figure 48**  
*Percentage share of recycling and disposal for jackets and Tank if brought to shore for demolition.*

Recommissioning the steel jackets for further use at another location would be the most optimal utilization of the jackets. No such re-use possibilities have been identified, and the technical difficulties involved in moving jackets make this an unlikely disposal option for the jackets.

Re-use of the jackets as artificial reefs may be a good resource utilization, though not as optimal as re-use (for their original purpose) at another

location. Thus, the reef Alternatives (IIA and IIB) were assessed as having «large positive» impacts on the resource utilization criteria.

Alternative IIC was assessed as having an overall «small positive» impact with regards to the waste/resource utilization issues. Leaving the Tank in place was considered «insignificant» on these issues, due to the high energy and resources that would be required to recover materials mostly of inherent low value (concrete and aggregate). The positive impact thus derives from recycling the steel jackets. Recycling the steel jackets but depositing the Tank in deep sea (Alternative IID) received the same rating («small positive»).

As mentioned above, demolition of the Tank for recycling the scrap materials would demand substantial input in the form of resources and energy in order to facilitate the re-use or recycling of materials of inherent low value (concrete and aggregate). The steel reinforcements can be recycled, but required disproportionately large amounts of energy to accomplish. Thus recycling the Tank as well as the jackets (Alternative IIE) was assessed as only having a «moderate positive» impact on resource management criteria.

In the littering assessment, the reef Alternatives were assessed as having «large negative» (IIA) and «moderate negative» (IIB) impacts, based on the view that, in the very long-term, the jackets will disintegrate and end up as litter. The fact that this condition would potentially last a long time was a factor considered in assessing the degree of this impact. The impact was greater for the reef-in-place Alternative IIA due to the greater potential for spreading of the material. Leaving the Tank in place (Alternative IIC) or deep-sea deposit of the Tank (Alternative IID) were assessed as having «small negative» littering impacts in light of leaving something behind that was not originally present in the environment (cf. «littering» definition in Section 2.3.1).

#### 7.4.2 Summary of the Societal Impacts of the Substructure Alternatives

The societal impacts and key figures regarding the Substructure Disposal Alternatives are summarised below:

	<b>II Jackets/Tank: Summary of Societal Impacts</b>				
<b>Issues</b>	<b>IIA</b> Reefs in-place	<b>IIB</b> Reef around Tank	<b>IIC</b> Jackets to shore for recycling. Tank left in-place	<b>IID</b> Jackets to shore for recycling, Tank deposited in deep sea	<b>IIE</b> Jackets/Tank to shore for demolition and recycl.
<b>Impacts on Fisheries</b>	Small negative	Small positive	Small positive	Moderate positive	Moderate positive
<b>Impacts on free passage</b>	Small negative	Small positive	Small positive	Large positive	Large positive
<b>Personell Safety (PLL)</b>	0.08	0.13	0.16	0.27	0.29
<b>Costs (bill. kroner)</b>	0.7	2.0	3.2	5.8	6.5
<b>Norw. content (bill. kr. and %)</b>	0.1 (15–19)	0.4 (19–21)	0.6–0.7 (20–23)	2.5–2.6 (43–44)	2.4–3.4 (36–52)
<b>Impacts on free passage</b>	190	640	900–1000	3,400–3,500	3,700–4,700

**Fisheries**

The Ekofisk Area has been described by the Institute of Marine Research as not being very important for Norwegian or international fisheries (Valdemarsen, 1994; Soldal et al. 1998). Still, some fishing takes place in the area, mainly from boats with trawl or purse seine gear.

An assessment of the impacts on fisheries for the Ekofisk I substructure Disposal Alternatives is complex. In relation to majority of the existing fishing activities in the area (trawling and seining), the Alternatives involving the removal of potential obstacles will be positive. The magnitude of this benefit is difficult to estimate, however. On the other hand, establishing artificial reefs should mean some level of positive impact for another branch of the fishing industry – that using passive instruments, mainly nets. Just how large this positive effect would be is also very difficult to estimate. Therefore the Institute of Marine Research has performed studies to quantify these effects, but concluded that there are still many unanswered questions and unresolved issues. This Impact Assessment has chosen to follow the approach that most weight should be given to the pre-existing industry (trawl and seine), and thus the benefits that accrue due to removal of obstacles to trawls and seines, rather than the benefits that might accrue from reef effects.

Based on this the following impacts have been identified on fisheries for the various substructure Alternatives:

	<b>IIA</b>	<b>IIB</b>	<b>IIC</b>	<b>IID</b>	<b>IIE</b>
	Jackets and Tank used as fish reefs in-place	Jackets and Tank used as fish reef around Tank	Jackets to shore for recycling, Tank left in-place	Jackets to shore for recycling, Tank deposited in deep sea	Jackets/Base to shore for recycling
Area released (km <sup>2</sup> )	0	21–22	22.5	24	24
Number of areas with obstacles	8	1	1	0	0
Reef effect	1–3 boats	1–3 boats (post 2028)	None	None	None

A number of reefs spread in different locations would present obstacles to existing fisheries (trawl and seine) over a wide area. A positive reef effect of this constellation of small reefs is found to be small compared to the nuisance to trawling. One reef collectively around the Ekofisk Tank will mean far fewer obstacles to fishing and thus a smaller negative impact than the «reefs-in-situ» option. By comparison with the present situation the collective reef option means freeing up a considerable acreage. The reef effect (added fish stock production value) is uncertain, but assessed as positive.

Alternative IIC, involving removal of steel jackets and leaving the Ekofisk Tank where it stands, will mean that only a single obstacle remains, and the positive effects of removing the others result in a «small positive» rating.<sup>14</sup>

Full removal of jackets and Ekofisk Tank at Ekofisk I (as in Alternatives IID and IIE) will mean removal of all obstacles to fishing and thus a «moderate positive» impact.

<sup>14</sup> Not taking Ekofisk II into consideration

**Free passage**

The operational phases of the various Disposal Alternatives will all be of limited duration, and will not influence navigation to such a degree that measurable effects would ensue.

In relation to today’s situation, most of the substructure Disposal Alternatives can be considered positive from a passage point of view. It could be argued that the «reef in-place» Alternative (IIA) would have a «small positive» impact, since the jackets will generally have sufficient sailing clearance. Some of the jackets, however, could intrude into the 55 metre surface zone that the IMO Guidelines advise as the safety clearance for large surface vessels in storm conditions, and all sunken objects will represent a potential threat to submarines. Another difference compared with today’s situation is that the field standby boats will no longer be on station at the outlying fields, and even if adequately marked, these reefs would represent a potential risk to maritime activities. The reefs in-place option is therefore given a «small negative» rating.

Leaving the Ekofisk Tank in-place is rated as having a «small negative» impact, comparable to today’s situation. Altogether, Alternative IIC is assessed as having a «small positive» impact, since all the jackets will be removed and only a limited obstacle will remain. A similar rating is given to the «reef around Tank» option (Alternative IIB), since any obstacles to shipping are concentrated in one place. If the result is compared with the original undeveloped field and not with today’s situation, the consequence of a cluster reef is assessed as a «small negative» impact.

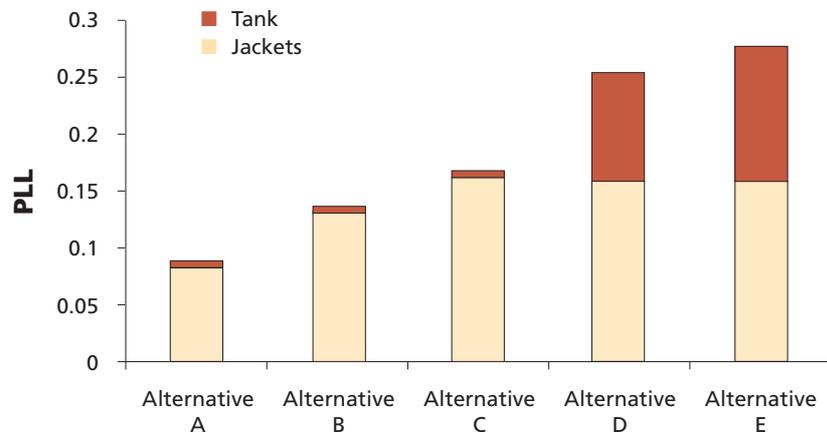
Removal of all the substructures (Alternatives IID, IIE) results in a «large positive» impact in relation to the free passage of shipping.

**Personnel safety**

The safety of the personnel engaged in the removal work is of vital concern. Therefore calculations have been made of representative parameters for personal safety to assess the level of risk. The results are presented as Potential Loss of Life (PLL) below.

If we only consider the risk contributions from the jackets and Ekofisk Tank, then Alternative IIE has the highest risk to life (see Figure 49).

**Figure 49**  
*Personal risk comprised of contributions from Jacket and Tank alternatives*



The increase in PLL for Alternatives IID and IIE is solely due to the removal of the Tank. Section 7.4.3 below, presents the PLL effect of the Tank substructure removal in isolation, and in combination with the Tank topsides.

### Norwegian content and employment effects

The maximum Norwegian content is 3.4 billion kroner for the most expensive solution if all demolition and recycling is awarded to Norwegian contractors. The Norwegian content of the most inexpensive Alternative, if demolition and recycling is performed abroad, can be as low as 0.1 billion kroner.

If all substructures and the Ekofisk Tank are removed the total production effects will reach 4,000–5,000 man-years provided demolition and recycling take place in Norway. The least costly Alternative if demolition and recycling are done abroad will result in about 190 man-years in production effects in Norway.

### 7.4.3 Comparative Assessment of the Substructure Disposal Alternatives

The societal and environmental impacts of the substructure Disposal Alternatives are summarized in the two matrices at the beginning of Sections 7.4.1 and 7.4.2. An examination of the two matrices, particularly of the environmental matrix, reveals that the performance of the various Alternatives varies depending on the assessment issue. A total evaluation of all issues in a total framework is thus necessary to be able to differentiate among the options.

The reef alternatives (Alternatives IIA, IIB) have the best performance on energy, emissions and safety. They are also positive on resource utilization and cost. However, in a long-term perspective they have a «small negative» potential littering. The reef Alternatives were also assessed as having the lowest rating with regard to fisheries («small negative» for IIA and «small positive» for IIB), as the approach of this Impact Assessment put more weight on the large positive impact to trawling and seining resulting from removal of obstacles, and less weight on the small positive reef effects for passive fishing techniques in the North sea. The reef Alternatives also had the lowest ratings on the free passage criteria («small negative» for IIA, and «small positive» for IIB, IIB getting a better rating since all obstacles are assembled in one small location).

Alternative IIC – remove and recycle steel jackets, leave Tank in-place – had the lowest Total Energy Impact and, after the reef Alternatives, the best performance on direct energy consumption, CO<sub>2</sub> and other atmospheric emissions, and safety. Alternative IIC was assessed to have «no/insignificant» discharges or physical/habitat effects, and a «small negative» aesthetic impact due to the onshore recycling of the steel jackets. Alternative IIC received a «small negative» rating on littering due to the in-place disposal of the Tank. Alternative IIC was assessed as having a «small positive» impact on fisheries, as it releases significant areas for fishing and leaves only a limited hindrance for trawling, and also received a «small positive» rating on safety of navigation for the same reasons.

The total removal options (Alternatives IID, IIE) have the worst performance on energy, atmospheric emissions, physical impacts/habitat effects, and cost. As the total demolition of the Tank requires vast amounts of energy and resources to bringing it afloat and tow it to shore, and the recyclable products are of rather low quality, the performance of Alternative IIE – recycle the Tank – with respect to waste/resource utilization criteria is considered sub-optimal. This solution also has a very poor performance

(«large negative») on aesthetics due to noise and dust. The cost-benefit of Alternative IIE is also very poor, with a cost of about 3.5 billion kroner and a return from recycling of about 25–35 million kroner. The total removal Alternatives also have the highest risk to personnel. The total removal Alternatives, however, have «no/insignificant» littering impacts, and, due to emphasis on removal of obstacles, have «moderate positive» impacts fisheries and «large positive» impacts on free passage.

The ultimate disposal solution for the Tank has a significant effect on the total evaluation of all substructure Alternatives. As stated above (in Sections 6, 7.4.1 and 7.4.2), bringing the Tank substructure ashore opens up the possibility of removing the Tank topsides ashore as well, with some potential cost, energy, emissions and safety benefits. Therefore, it is instructive to consider the combined impacts of the Tank topsides and substructure Alternatives on these key issues as summarised in the Tables below.

The first Table presents the impact of Tank removal and recycling (Alternative IIE), compared with leaving the Tank in-place (Alternative IIC). It is in this Table assumed that the Tank topsides are relocated to shore on the refloated substructure, and removed inshore.

	<b>Combination 1 Alternatives IA + IIC (Leave Tank in-place; Remove Topside offshore and recycle)</b>			<b>Combination 2 Alternatives IA + IIC (Refloat Tank and recycle; Remove Topside offshore and recycle)</b>			<b>Difference Between Comb 1 and 2 (%)</b>
	IA	IIC	IA + IC	IB	IIE	IB + IIE	
<b>Energy Consumption (million GJ)</b>	1.00	0.02	1.02	0.26	2.47	2.73	+168
<b>Total Energy Impact (million GJ)</b>	1.00	1.20	2.20	0.26	2.47	2.73	+24
<b>CO<sub>2</sub>-emission (1000 tonnes)</b>	80	2	82	20	197	217	+164
<b>Personell Safety (PLL, %)</b>	8.5	0	8.5	2.4	29.0	31.4	+269
<b>Cost Estimate (million kroner)</b>	1,139	35	1,174	570	3,400	3,970	+238

The effect of removing the Tank topsides offshore, prior to refloating is presented in the following table:

	<b>Combination 1 Alternatives IA + IIC (Leave Tank in-place; Remove Topside offshore and recycle)</b>			<b>Combination 3 Alternatives IA + IIE (Refloat Tank and recycle; Remove Topside offshore and recycle)</b>			<b>Difference Between Comb 1 and 3 (%)</b>
	IA	IIC	IA + IC	IA	IIE	IA + IIE	
<b>Energy Consumption (million GJ)</b>	1.00	0.02	1.02	1.00	2.47	3.47	+240
<b>Total Energy Impact (million GJ)</b>	1.00	1.20	2.20	1.00	2.47	3.47	+58
<b>CO<sub>2</sub>-emission (1000 tonnes)</b>	80	2	82	80	197	277	+237
<b>Personell Safety (PLL, %)</b>	8.5	0	8,5	8.5	29.0	37.5	+341
<b>Cost Estimate (million kroner)</b>	1,139	35	1,174	1,139	3,400	4,539	+287

Finally, the option of refloating and depositing the Tank substructure in deep water (Alternative IID) is compared with leaving the Tank substructure in-place (Alternative IIC). It is assumed that the topsides are removed offshore prior to refloat.

	<b>Combination 1 Alternatives IA + IIC (Leave Tank in-place; Remove Topside offshore and recycle)</b>			<b>Combination 3 Alternatives IA + IID (Refloat Tank and deposit; Remove Topside offshore and recycle)</b>			<b>Difference Between Comb 1 and 4 (%)</b>
	IA	IIC	IA + IC	IA	IID	IA + IID	
<b>Energy Consumption (million GJ)</b>	1.00	0.02	1.02	1.00	1.20	2.2	+115
<b>Total Energy Impact (million GJ)</b>	1.00	1.20	2.20	1.00	2.40	3.4	+55
<b>CO<sub>2</sub>-emission (1000 tonnes)</b>	80	2	82	80	45	125	+52
<b>Personell Safety (PLL, %)</b>	8,5	0	8,5	8.5	27.0	35.5	+317
<b>Cost Estimate (million kroner)</b>	1,139	35	1,174	1,139	2,600	3,739	+218

As the Tables above demonstrate, the potential improvements in energy, emissions, cost and safety represented by an onshore removal of the Tank topsides fall far short of making up for the significant negative performance an attempt to refloat and remove the Tank substructure would have on with respect to the issues assessed.

Overall, therefore, Alternative IIC is assessed as the best Disposal Alternative for the substructures, in relation both to environmental and societal impacts.

# 8 IMPACT ASSESSMENT FOR PIPELINES

## 8.1 Description of Alternatives

There are two Disposal Alternatives for the Ekofisk I pipelines:

Alternative IIIA: Remove to shore for demolition and recycling of materials

Alternative IIIB Leave, in buried state, in-place

For both Alternatives IIIA and IIIB, the pipelines will be cleaned internally prior to disposal.

### 8.1.1 Description of Alternative IIIA – Remove pipelines to shore

Removal of the pipelines can be done in several ways. There are two different removal methods (ETPM 1998), see Figure 50:

- Recover the pipelines in an operation that is the reverse of laying (for 65 per cent of the pipelines)
- Cut pipelines on seabed and recover sections piece by piece (for 30 per cent of the pipelines)

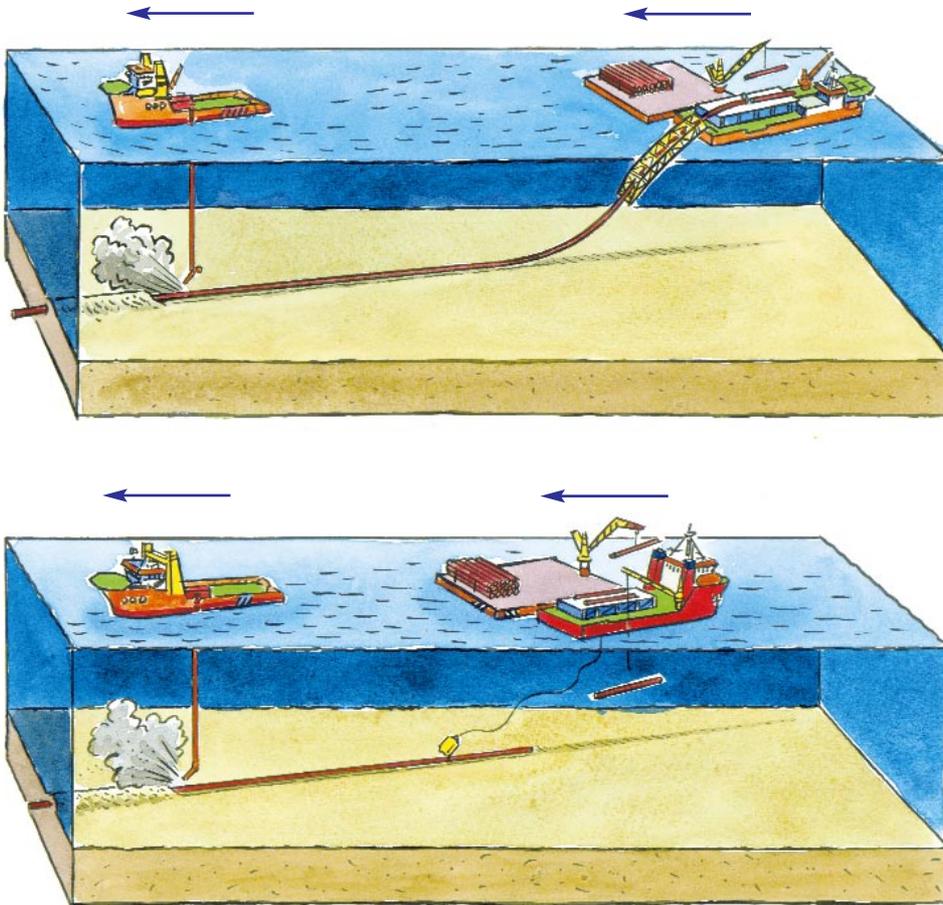


The proposal is to leave the remaining 5 per cent in place, as they are inside the Ekofisk II safety zone. They could later be removed using the «cut on seabed» method or be disposed in the same way as the Ekofisk II pipelines. Reverse laying means pulling the pipelines up starting at one end using a pipelaying barge. Onboard the lines would be cut at each joint, or every other joint, to produce convenient lengths (12–24 metres). The sections would then be taken to shore and landed for further work and cutting. Usually lines of diameter less than about 10 inches can be coiled up or run onto a drum, so that further cutting can be left to the shore crews.

Since the lines are buried to a depth of 0.8–2.5 m below the seabed, the top cover has to be excavated before the lines are recovered. There are a number of proprietary systems that can do this job. Generally they blow away the sediments which settle some 2–10 metres to the side of the line, or the sediments are suctioned onto a barge. The method of cutting single lines on the seabed utilises a remote operated vehicle (ROV) with diamond cutter, and recovery is effected using the mother ship's crane. This method does not require a large pipelaying vessel.

All together, removal would take about 108 vessel days using reverse laying, plus about 250 vessel days to recover pipe sections from the seabed.

Delays due to weather, estimated at 80 days from the statistics, must also be expected. Since operations of each type can take place at the same time, the total duration of the operation could be about 300 vessel days (ETPM 1998). To avoid waiting on weather the work would be scheduled over two years.

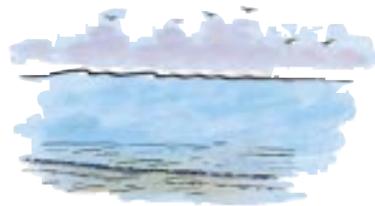


**Figure 50**  
*Recovery of pipeline  
 by reverse laying  
 (top), and by recovery  
 of sections (bottom)*

### 8.1.2 Description of Alternative IIIB – Leave pipelines in-place

All the Ekofisk I pipelines are either buried or covered with the exception of the ends connected to the risers where they approach the installations. The pipelines are buried below 0.8–2.5 metres of sediment or gravel. No special operations are required to leave them, except that the ends must be removed, buried or covered over.

Since the seabed around the Ekofisk Center is still subsiding, there is some chance that parts of the pipelines may ultimately bend and stick out of the bottom (known as «upheaval buckling»). The chance of this happening has been estimated at 2–3 occasions in the next 30 years (DNV 1998-b). Several measures have been suggested to avoid this, and to mitigate the consequences if it does happen. These are described under «Mitigation measures» in Section 11.4. Also, an assessment has been made of the time that will pass before the lines decompose. The sacrificial anodes that protect against corrosion have a lifetime of somewhere between 40–350 years, while full decomposition of the pipelines is expected to take from 1200 to 4400 years.



PNG has also assessed whether leaving the pipelines could create difficulties with regard to laying other pipelines in the area, and concluded this would not be a problem.

## 8.2 Environmental Impacts – Pipeline Alternatives

### 8.2.1 Energy

Removal of all pipelines demands extensive marine operations over a long period. Energy-wise, the recycling of the pipeline materials will not compensate for the added energy consumption of the recovery vessel operations. Compared with leaving the pipelines in-place on the seabed, removal demands 70 per cent more energy in total, see Table 34. In fact, it requires the energy equivalent of the annual energy consumption of 10,000 people.

If left on the seabed, the ends of the pipelines will stick up from the bottom after the platforms are removed. There are several countermeasures:

- Cover pipeline ends with gravel
- Bury pipeline ends below ground
- Cut off and remove pipeline ends

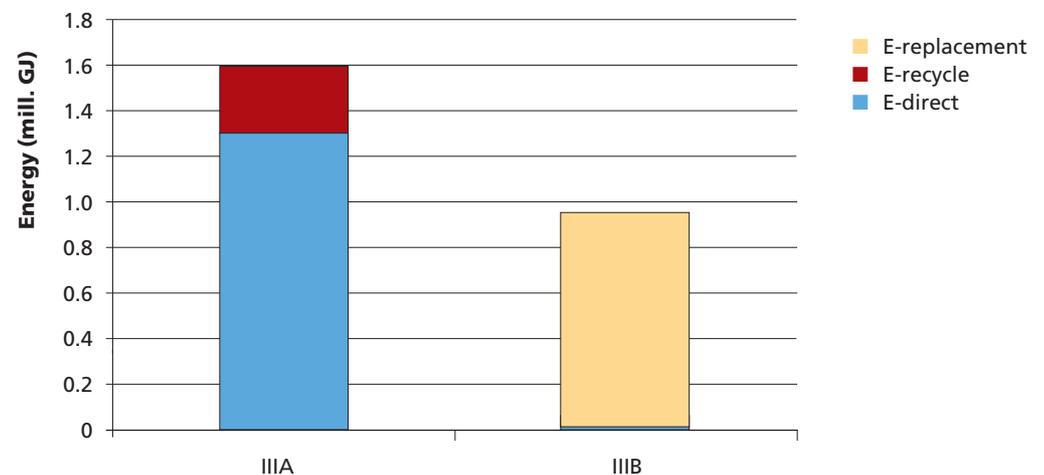
The energy consumption is nearly identical for all three alternative countermeasures. The energy consumption (and Total Energy Impact) for Alternative IIIA (leave in-place and covering with gravel) is given in Table 34, as is the energy consumption and Total Energy Impact for Alternative IIIB (removal of all pipelines).

**Table 34**  
Total Energy Impact for removing or leaving pipelines in-place (GJ).

Operation	Alt. IIIA (Removal)	Alt. IIIB (Leave in-place)
Marine operations	1,200,000	16,000
Demolition	100,000	
Recycling materials	300,000	
Energy cost of virgin production («Replacement Energy»)		912,000
<b>Total</b>	<b>1,600,000</b>	<b>930,000</b>

The results are also shown in graphical format in Figure 51 below:

**Figure 51**  
Total Energy Impact for the Pipeline Disposal Alternatives



### 8.2.2 Emissions to atmosphere

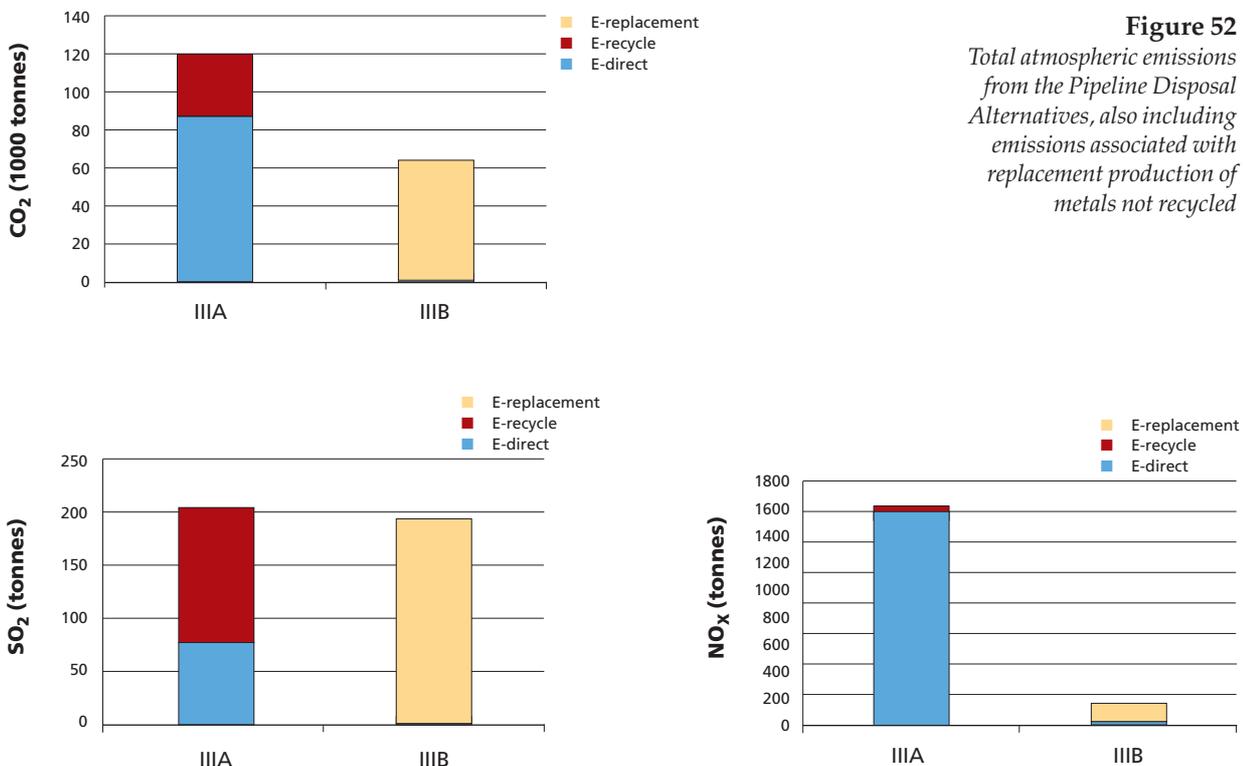
As in the case of energy, the emissions to atmosphere are significantly higher for the removal of pipelines option than the leave-in-place option. CO<sub>2</sub> emissions are about 120 times higher for removal than for leaving in place. (As noted in the previous section, the energy – and hence the emissions – for leaving in-place using the three alternative techniques are almost identical.)

Table 35 provides the emissions figures for these activities.

Operation	CO <sub>2</sub>	NO <sub>x</sub>	SO <sub>2</sub>
<b>Removal (Alt. IIIA)</b>			
Marine operations	90,000	1,600	80
Recycling metals	30,000	60	130
<b>Total</b>	<b>120,000</b>	<b>1,700</b>	<b>210</b>
<b>Leave in-place(Alt. IIIB)</b>			
Marine operations	1,000	20	1
<b>Total</b>	<b>1,000</b>	<b>20</b>	<b>1</b>

**Table 35**  
Emissions to atmosphere from removal and leaving pipelines in-place (in tonnes)

In addition, calculations have been made of the estimated total emissions from the two Pipeline Alternatives, together with estimated indirect emissions from replacement of materials not recycled (see Figure 52 below). The results show that, even considering theoretical «replacement emissions», Alternative IIIB – leave in-place – has the lowest emissions for all gases. The differences are largest for NO<sub>x</sub> and least for SO<sub>2</sub>.



**Figure 52**  
Total atmospheric emissions from the Pipeline Disposal Alternatives, also including emissions associated with replacement production of metals not recycled

### 8.2.3 Discharges to sea, water or ground

Relevant issues identified and explored in this analysis are:

- Re-suspension of bottom sediment and release of contaminants as pipelines are recovered
- Leaching of metals and other substances from pipelines, in the short and long term, in case of leaving in-place
- Environmental risk of discharge of small oil residues.

#### **Alternative IIIA – Remove pipelines**

Removal of the pipelines means flushing and purging them before recovery. This is common to all options, is part of the decommissioning operations and thus is not a part of this Impact Assessment<sup>15</sup>. Removal of the Ekofisk I pipelines and environmental impacts thereof have been studied specifically by ETPM (1998-b).

Recovery of the pipelines would cause the surrounding bottom sediments to swirl up. In a purely operational sense the recovery of the pipelines is envisaged using a ditching device (such as «Jet Prop») to remove overlying sediment. The system has two fans that blow the sediment backward and into a funnel. They can then be pumped to the surface vessel or deposited beside the trench, about 2–10 metres away (F. Bost, ETPM, personal communication). This increases the particulate content of the water for a brief period. The sediments around the Ekofisk Center are also considered to be lightly contaminated from hydrocarbons and contain contamination from certain metals: cadmium (Cd), lead (Pb), iron (Fe), zinc (Zn), copper (Cu), and barium (Ba) (see Section 5.2). All told this will degrade the quality of the water close to the recovery site for a limited period. Certain local acute effects resulting from the heavy particle load and dispersion of various hydrocarbons can be expected. Non-mobile and slightly mobile organisms close to the swirl site will be most susceptible. Sedimentation of the swirling particles will also tend to exacerbate the impact since it will bury some of the bottom-dwellers. No acute effects are foreseen due to spreading of the metal components. Still, certain of the metals have the potential to accumulate in the food chain, although in this context the scale of the problem is considered limited.

A re-suspension of the sediments due to pipeline recovery could, for example, spread hydrogen sulphide, methane, carbon dioxide, lighter hydrocarbons which are readily soluble in water, and some metallic components. The pipelines cannot be removed completely up to the installations while the latter are in-place. Therefore the potential problem of cuttings piles and the potentially most contaminated sediments – up close to the installations – will be avoided. Removal of the final parts of the lines can be done after the cuttings have been dealt with, see Section 10 on Cuttings. The scale of the dispersion as outlined above will therefore be limited.

There are no plans to discharge anything into the sea, water or ground as a result of onshore demolition and recycling of the pipelines, which would conform to applicable regulations (see descriptions of demolition operations earlier).

<sup>15</sup> However, it should be noted that there may be minor oil residues in some pipelines that were taken out of service in the 1970's. These are buried 2–3 metres under the seabed. The risk of spills (probability and impact) has been assessed in any case (see Alt. IIIB Leave in buried state).

The anticipated scope of the negative environmental impacts caused by discharges into the sea, water or ground as a result of removal of the pipelines is deemed small to moderate. The overall consequences resulting from discharges are therefore characterised as «small negative».

### **Alternative IIIB – Leave in buried state**

The pipelines, once cleaned and purged, will be filled with preservative fluid or seawater before they are left in-place (PPCoN 1998, SFT 1998). Preservative fluid will be used in six of the pipelines (at Cod, Albuskjell, West Ekofisk and Edda) to keep the option open to reuse them. Falling objects and anchor impacts may cause leakage of water/inhibited water which may contain hydrocarbon residues. The inhibitors employed are biocides known as MB-548 (Dyno) and EC 6111A (Nalco/Exxon) (PPCoN 1998-b; PPCoN 1998-c). These contain agents such as formaldehyde, glutaraldehyde, isopropanol and methanol. All are readily biodegraded and have low bioaccumulation, but high toxicity. Formaldehyde is also a compound that can cause cancer (Wachtmeister & Sundstrøm 1986). Biodegrading will cause the biocide concentration inside the plugged pipelines to decline over the years. The biocide concentrations used are designed to ensure that any leakage of the inhibited water into the sea is environmentally sound 10 years after charging into the pipelines. Negative impacts of leakage of inhibited water are thus restricted to the initial 10 years after plugging, and will most likely be limited to acute effects on organisms in the immediate vicinity of the spill point during a very limited time frame. The scale of the ecosystem impacts from such a leak is deemed very small, and it must be emphasised that the chances of a leak are also low.

The anti-corrosion sheath that protects the pipelines is made up largely of tar (approximately 900 tonnes) or asphalt (approximately 500 tonnes). Both these compounds contain hydrocarbons of high molecular weight, such as PAH (polycyclic aromatic hydrocarbons). PAH can have acute effects on marine organisms. PAHs are very persistent in sediments, can bioaccumulate, and may be carcinogenic for marine organisms (Molven & Goksøyr 1992), but do not accumulate in the food chain. It must be stressed however that most PAH compounds have a very low solubility in water, if any at all. Certain lighter compounds normally found in tar can also cause acute effects in marine organisms, such as damage to lipid (fatty) membranes. Contamination from the tar or asphalt in the anti-corrosion sheath will principally be limited to leaching into the sediments enclosing the pipeline, under the bioturbation zone (i.e. under the zone influenced by digging animals) (Knutson *et al.* 1992; DNV 1998-b). The scale of the environmental effects resulting from leaching from the pipeline sheath is therefore deemed small.

Reinforcement steel in the concrete will steadily corrode, causing cavities to develop in the concrete, which will collapse if subject to physical impact. Degradation of the concrete is extremely slow (DNV 1998-b). Rust - iron oxide and oxy-hydroxide – produced from corrosion of steel in water, are almost insoluble in water (NERC 1996), and will gradually precipitate in the sediments around the pipeline. As already discussed, iron is not considered a threat to the marine ecosystem. The scale of the environmental effects caused by leaching from the concrete and reinforcement steel is therefore deemed small.

Sacrificial anodes on steel and coflex pipelines (approx 600 tonnes) are designed to be consumed and have a design life of about 20 years (DNV, 1998-b). Surveys done in 1996 (DNV 1998-b) suggest, on the contrary, that this lifetime is significantly longer. This translates into a residual life for the anodes of some 40–80 years. Some of them can be expected to last as long as 350 years. The anodes are made largely of aluminium and zinc, plus some cadmium (0–0.15 per cent), lead (0–0.005 per cent), and iron. Table 36 gives an estimate of remaining metals in the anodes.

**Table 36**  
*Estimate of remaining amount of metals in anodes on the pipelines*

Component	Zinc (tonnes)	Lead (kg)	Cadmium (kg)
Pipelines	590	30	900

The pipelines include steel-lines, one coflex line, and hydraulic umbilical packages and one electric cable in a 10" pipeline from Ekofisk 2/4 A to the Ekofisk Center. All except one are made of structural steel, totalling 35,000 tonnes. The metals in the pipelines include iron (95–97 per cent), plus some manganese, chromium, copper and silicon. The corrosion rate of bare structural steel buried in sediments is estimated at 0.01 mm per year, while the same steel exposed to seawater is estimated to corrode at a rate of 0.05 mm per year (DNV 1998-b). Leaching of metals from the anodes and structural steel is thus a very slow process. In earlier studies for the disposal of the Odin platform, concentrations from leaching from pipelines and anodes into seawater were modelled at several tens of orders of magnitude below the lowest concentration for observed damage to the maritime ecosystem, see Section 7.3.3 (Asplan Viak, 1995). Unlike this model, the Ekofisk I pipelines are buried in sediment, which means that the leach rate for metals into the water column will be less than in the Odin case. Even so, an increase in concentration of metals in the sediments immediately around the pipelines can be expected. Seen in light of the very local potential impacts, and the fact that the increased concentrations occur below the bioturbation zone (Knutson et al. 1992, DNV 1998-b), the scale of the effects caused by leaching from structural steel and anodes in pipelines is considered small.

All pipelines that became redundant with the change-over to Ekofisk II have been cleaned and purged. As for the pipelines that became redundant in the 1970's, there is some uncertainty regarding their state of cleanliness. Based on measurements taken in 1998 it is assumed that they were only flushed through before being left in-place. Therefore, there may be small oil residues inside them. The ecosystem threat that this represents was studied specifically (DNV 1999-b). This study looked at the probability of a break in the various types of pipeline, and the volume of oil that might be expected to escape following a fracture or damage to the line. Small damage might cause spills in the range of a few litres a day, while full breach of the line might release a few hundred litres of oil a day. Yet, since the pressure in the line is equal to the pressure outside, leakage can only be driven by the differences in specific gravity of the oil and the seawater. Thus the environmental consequences seem to be limited, and the total environmental risk is assessed as small.

The total scale of the effects on the marine environment resulting from discharge into the sea, water or ground due to leaving the pipelines in-place is expected to be small. The total environmental impact is found to be «insignificant».

### 8.2.4 Physical impacts and impacts on habitat

The issue identified and addressed here may be summarised as follows:

- Physical disturbance of the seabed when pipelines are recovered.

#### **Alternative IIIA – Remove to shore for demolition and recycling**

Pipelaying vessels (used in reverse mode), barges and other vessels used to remove the pipelines could damage the seabed to a depth of 0–2 metres with their anchors, albeit over a very small area. The sand will soon even out again, and restitution of the benthic community is expected to happen fairly quickly. The scope of this effect of physical disturbance is therefore expected to be small.

When pipelines are recovered the protective sand and rock will have to be removed or pushed aside (see Section 8.1.1). Some of the lines are buried 2–3 metres below the seabed. Removing them could therefore leave considerable depressions and undulations along the route. Sand and fine particles will soon slide into the trench and the bottom will even out, whereas unevenness due to backfill rocks will persist for a long time. The new structure of the bottom may attract a range of organisms, including fish. The scale of the effects of this physical disruption is believed, in this context, to be small.

The total scale of the effects caused by removal of the pipelines is deemed small to moderate. The total environmental impact resulting from these disturbances is therefore expected to be small.

#### **Alternative IIIB – Leave in buried state**

Gravel and rock left in-place, as at present, will represent structural undulations on the bottom. The natural bottom over most of Ekofisk is sand. Undulations will, as hitherto, attract certain types of organisms, including fish. The situation will remain as it has been in the operating phase thus far. The scope of the effects caused by this physical structure is deemed small. The total environmental impact resulting from physical effects from leaving the pipelines in-place is expected to be «insignificant».

### 8.2.5 Aesthetic effects

Aesthetic effects identified are mainly related to noise during demolition of the pipelines.

#### **Alternative IIIA – Remove to shore for demolition and recycling of materials**

The Ekofisk I pipelines are either buried or covered, and thus have no marine growth of significance on them. An exception may be the exposed ends (about 150 metres). Recovery should not, therefore, result in any significant malodours.

Noise would be generated when cutting up the pipelines, during possible crushing of the concrete that forms the sheaths, and during separation of the components for recycling. The concrete sheath probably can be peeled off

(Taraldrud 1998), and this is not expected to cause much noise. It is perhaps more usual to use small explosive charges to loosen the concrete sheath from the pipeline, or chip it off with a pneumatic or hydraulic jack-hammer. However, there is very little experience in this field. Experience from other types of demolition operation has shown that noise from a demolition yard in normal operation using hydraulic shears will be about 50–55 dBA with maxima in the range 55–85 dBA at a distance of 200–10 metres from the source. It is not known if noise from demolition of the pipelines will be in the same range. If it were, the potential negative impact is «large». However, it must be assumed that noise standards according to the «Guidelines for Abatement of Noise in Industry etc» would be observed. The choice of demolition location – in relation to such factors as residential areas, other resources like recreation areas, and topography – as well as noise-abatement measures, could significantly reduce this potential.

Crushing concrete into fine aggregate may cause dust. The scope of the problem would depend on the volume broken up, the method, and containment measures. With sufficient use of water or salt this could be controlled.

Storage of the pipelines onshore prior to demolition would be temporary and is not expected to cause negative visual effects.

Depending on the initial natural beauty of the demolition site, the total scale of the aesthetic impacts might be «large negative». But if a location of low aesthetic value is used, and if noise-abatement measures are implemented, then the scope of the aesthetic impacts will be considerably reduced, thus producing consequences that are «small».

### **Alternative IIIB – Leave in buried state**

This Alternative will not cause any impact due to noise, smells, or visual pollution.

### **8.2.6 Waste/Resource utilization**

If the pipelines are left in-place, the flexible parts of the lines close in to the installations can be removed. The waste volume these represent is very modest (about 2 per cent). Therefore no further evaluation has been made of any waste from them.

The remainder of this discussion relates therefore to removal and demolition of the pipelines.

#### **Steel**

There is 35,000 tonnes of steel in the pipelines. It can be recycled. For further details of the fate of the steel, see Section 6.2.6. But there are some special factors that need to be examined in connection with recycling steel from offshore pipelines, and they are described below.

Production tubing and oil pipelines may contain to greater or lesser extent internal low-radioactive deposits. If steel containing these deposits is sent for melting down without first cleaning, then radioactive dust and slag may result. In Germany there are facilities for melting down uncleaned scrap metal contaminated with natural radio-isotopes, mercury, and organic compounds. Based on trials with small volumes of scrap metal from the oil

industry, Stadge & Kreh (1998) have estimated that 98 per cent of the radium activity ( $^{226}\text{Ra}$  and  $^{228}\text{Ra}$ ) remains in the slag, while about 1 per cent is trapped in the dust filters, and 1 per cent remains in the metal. At activities exceeding 100 Bq/g, this means that the radioactivity in the metal can exceed the threshold of 1 Bq/g as the purity standard after cleaning that a number of countries have established for free sale. Due to the high temperature of the melting process (1300–1400 °C), a large amount of the radioactive lead ( $^{210}\text{Pb}$ ) will be released as dust and – depending on particle size – will be trapped in the dust filters or released to the surroundings. According to Stadge & Kreh (1998), only 7 per cent will remain in the slag, while only tiny amounts will remain in the metal.

No quantitative estimates have been made for scale deposits in the Ekofisk I pipelines, but the radioactivity has been measured and it is low. It is presumed that all waste – including scale, fumes, dust and slag from the scrap furnace – would be handled according to the established guidelines at the foundry.

### Concrete

Concrete on the pipelines makes up 51,000 tonnes. This can be expected mainly to be recycled. Further details on disposal concrete is given in a separate report (DNV 1999-c).

### Anodes

The anodes on the Ekofisk I pipelines amount to 600 tonnes. Their main constituents are zinc and aluminium. Offshore anodes are typically almost exclusively sent for recycling the material. For further details, see Section 7.2.6.

### Coal tar and other compound on pipelines

The Ekofisk I pipelines are coated with various protective compounds, of which three main types have been identified:

- Multi-component coating consisting of primer coated with coal tar (minimum 2.38 mm thick layer) and fibreglass, followed by a coating of coal tar and asbestos
- Somastic coating consisting of 16 per cent asphalt, 84 per cent mineral aggregate (presumably sand), and 0.1–0.15 per cent fibreglass
- EPDM compound consisting of ethylene-propylene-monomer rubber (elastomer)

In addition there are believed to be coatings of polyamide and PVC on the coflex tubing and hydraulic umbilicals.

The organic plastics and plastic-like compounds (EPDM, PVC, Polyamide, rubber and primer) consist of an estimated 80 tonnes. The amount of coal tar is an estimated 910 tonnes, while the amount of asphalt is estimated at almost 530 tonnes. The amount of fibreglass and asbestos is about 60 tonnes and 90 tonnes, respectively.

Special disposal of coatings on pipelines will depend on whether the coating must be removed from the line before the pipe is scrapped. For coatings consisting of coal tar, asbestos or fibreglass, this will be required in order to process these materials properly.

A thin coating of primer or plastics on steel piping can, as for paintwork described earlier, cause difficulties when the steel is melted down, and it is useful to remove it for separate processing wherever possible. However, primer is applied in thin coats on pipelines, and its removal is held to be difficult except by grit-blasting. This, as already noted earlier, is considered a very sub-optimal solution due to its environmental and economic cost in such a context.

If the organic substances in the coating on the pipeline are removed, they usually can be disposed of like other plastics discussed earlier. This means a split between recycling for material and recycling for heat, with some residues being consigned to the dump. Primer is believed to be comparable with paint, and can be dealt with in the same way. A rough estimate suggests that 20 per cent of the plastics will be recycled for the material, 70 per cent for their energy content, and 10 per cent will be discarded.

Coatings consisting of coal tar, fibreglass and asbestos, or asphalt and fibreglass, will be difficult to handle due to the composite mix of several harmful substances and materials. Handling, cutting, sorting and recycling all hold a risk of formation of asbestos or glass dust, and the release of harmful organic compounds like PAH in coal tar. Therefore recycling of these materials seems unlikely.

As mentioned earlier (Section 6.2.6), asbestos materials will be discarded. The same goes for waste containing PAH. Coal tar and asphalt will have to be treated as special waste and discarded in accordance with the applicable guidelines for disposal of such waste. This means a total of about 1,600 tonnes of special waste will need to be disposed.

### 8.2.7 Littering

The litter potential of the Pipelines Disposal Alternatives is identified as coming from:

- Loss of small sections during recovery
- Upheaval buckling and exposure of pipelines left in-place
- Exposed pipeline ends
- To leave something behind that was not naturally there

#### **Alternative IIIA – Remove to shore for demolition and recycling of materials**

During recovery of the pipelines, pieces of the concrete sheath may break off and remain on the bottom. These pieces may be spread over the seafloor, for instance by a bottom trawl, and gradually become buried beneath the sand. The concrete pieces in question will represent a very small total volume and the littering effect is deemed insignificant. It is not to be expected that any of the chunks will damage the marine environment.

#### **Alternative IIIB – Leave in buried state**

Leaving the pipelines will largely avoid any littering of the seabed. The exception is in the case of a pipeline protrusion caused by upheaval buckling

combined with an event such as fishing implements getting caught on it. Upheaval buckling of pipelines is caused by strains in the pipelines imposed by horizontal movement of the seabed, which in the Ekofisk Area are in turn caused by subsidence. The pipeline sections that may be bent up in this way will be removed or buried/covered over after a certain time. The pipeline segments are mainly of steel and will involve short sections (about 30 metre long).

Exposed pipeline ends will be dealt with (removed, buried, covered). The environmental impacts are therefore deemed negligible.

Leave the pipelines in-place is accorded low weight in the context of littering, since the pipelines are buried/covered.

### 8.3 Social Impacts (Pipeline Alternatives)

#### 8.3.1 Impacts on fisheries

With the exception of certain stretches of pipeline which have been back-filled with rock and the chances that pipeline sections may gradually buckle in the subsidence zone, the Ekofisk I pipelines do not overall represent any great impediment to fishing in the Ekofisk Area as they lie today (DNV 1998-b). Since all pipelines are buried the issue of area occupation is not considered relevant. The most interesting problems are related to:

- Possible obstacles to fishing (damage to catch and gear) in a short and long term perspective
- Greater vessel activity during possible removal period.

#### **Alternative IIIA – Remove to shore for demolition and recycling of materials**

Removal of the pipelines will not mean taking up the gravel used to cover them. Therefore any removal of the pipelines will not produce a significant improvement in the conditions for the local fisheries. Removal of redundant pipelines may, nonetheless, have positive implications for the fisheries and fish consumers.

The actual removal operations are expected to take about 300 vessel days, spread over two seasons. This activity will progress according to a specified and preannounced plan, under which marine operations will only take place in limited areas at any time. The marine operations during removal operations for the Ekofisk I pipelines are not expected to hinder fishing.

Removal of the pipelines also leave traces on the seabed in the form of trenches, depressions, and mounds in the sedimentary bottom. These will only be small in nature and comparable with natural topographical variation on the seabed. The situation will thus be very similar to today's. Therefore it is not expected to cause any serious difficulty for bottom-trawls or other bottom equipment.

Removal may also cause parts of the concrete sheathing to fall off, for instance. The scope of this potential is assessed as small.

The aggregate effect of removing all Ekofisk I pipelines is believed to cause no significant changes to the fisheries in the Ekofisk Area. The main reason is

that the pipelines are already buried in the sediment and therefore pose no threat where they lie.

### **Alternative IIIB – Leave in buried state**

Effects on fisheries of pipelines on the seabed are mainly associated with the risk of snagging and damage to fishing equipment, and damage to or loss of catches. This problem is greatest for trawlers, since they tow a bottom trawl. The Ekofisk I pipelines are either buried in the sediment, using a trenching machine, or back-filled with sediment. Some of them are also covered with gravel. Leaving the pipelines in-place means therefore that no parts of them will be exposed above the bottom.

Trenching and back-filling leaves the seabed reasonably smooth and without foreign objects, and is considered a good solution for fisheries (DNV 1998-b). Gravel dumping on the other hand is deemed to represent a problem, since trawling over gravel strips can tear the trawl bag and damage the catch. This has been confirmed by scientific trials (Soldal 1997). Gravel dumping, however, is limited to such a small area that the total effects on the fisheries is expected to be small (DNV 1998-b). In any case, the gravel dumping has already been done, and therefore is not affected by any of these alternatives. If any further cover is needed, an evaluation must be made of whether fine gravel can be used instead of broken rock, thereby reducing the negative effects for trawlers.

In the subsidence zone around the Ekofisk Center, parts of the pipeline may protrude the surface of the seabed due to curvature, and thus present a snag to bottom implements. The likelihood of this is very small, however, and limited to a small area. Inspections will also identify any visible pipe ends, and measures will be taken to mitigate their impact, either by removal, burial, or covering. The chances that curvature can conflict with fisheries is therefore deemed minimal (DNV 1998-b).

No significant changes are anticipated in the status of the Ekofisk Area for fisheries in the future. More effective, specialised and improved gear on future vessels may help reduce the difficulties of snagging and contact with foreign objects on the seabed, and increase the chances of exploiting the fish resources in areas where the risk of damage to gear and catches is now great (DNV 1998-b).

A total evaluation of leaving the Ekofisk I pipelines in-place is that this operation will not cause significant negative impacts on present-day or future fishing (DNV 1998-b). Proposals for how to mitigate potential negative impacts are discussed in Chapter 11.4.

## **8.3.2 Impacts on free passage (Pipeline Alternatives)**

### **Alternative IIIA – Removal of pipelines**

The operational phase of removal of pipelines would last for two seasons and would represent more than 300 days of activity. Geographically the task would cover the area from Cod in the north to Edda in the south, over 180 km. The scope of the activity is deemed small, and the impacts on free passage similarly small.

This final solution will not have any impact on free passage.

### Alternative IIIB – Leave pipelines in-place

Leaving the pipelines in-place will not have any impact on free shipping passage.

### 8.3.3 Impacts on personnel safety

#### Alternative IIIA – Removal of pipelines

Operations connected with removal and demolition of the pipelines are described in Section 8.1.1.

Table 37 shows the risk to personnel of removal of the pipelines.

Activity	PLL
Activity connected with lay-barge	0.07
Activity connected with subsea cutting	0.03
Transport of pipeline sections to shore	< 0.01
Demolition of pipeline sections on shore	< 0.01
<b>Total</b>	<b>0.10</b>

**Table 37**  
*Risk to personnel of removal of pipelines*

### Alternative IIIB – Leave pipelines in-place

The pipelines are normally buried in the seabed or covered with gravel. When leaving the pipelines in-place they will have ends that stick up out of the seabed. These parts, making up about 1 per cent of the total length, must be removed or covered so as not to present a hindrance or risk to fisheries. Removal of the ends can be done by remote-operated underwater cutters. Covering can be done either by dumping gravel on them, or by burying them in the bottom sediment. All alternatives: cutting and removal, gravel cover, and burial, have a probable loss of life of less than 0.01.

### 8.3.4 Costs and national supplies (goods and services)

Removal of all pipelines using a «reverse laying» technique would require costs of about 2.6 billion kroner. The costs of leaving the pipelines in-place and covering them with gravel where needed are estimated at about 30 million kroner.

Table 38 below gives the costs and Norwegian content for each of the two pipeline Alternatives.

**Table 38**

*Ekofisk I pipelines: costs and Norwegian content of Disposal Alternatives for pipelines broken down by cost components, (mill. NOK, 1998 costs (rounded))*

Components	Full removal of pipelines	Norwegian content %	Leave in place and cover with gravel	Norwegian content %
Project admin. and engineering	80	70	0	70
Preparation	100	5	0	
Removal or gravel cover	1,750	5	32	50
Demolition and recycling	680	100	0	
<b>Total</b>	<b>2,600</b>	<b>32</b>	<b>32</b>	<b>50</b>

The Norwegian content of the total goods and services input for removal or leaving the pipelines will reach about 30 and 50 per cent, respectively, provided the pipelines are taken to shore for demolition and recycling in Norway. If the demolition contract goes to a foreign contractor, the Norwegian input will be significantly less, at about 5 per cent of the total input.

The cost estimates apply to a solution where the installations are removed.

### **Project administration and engineering**

This includes input from both field operator and contractor. The Norwegian content will depend on how much Norwegian contractors are involved in connection with the Disposal Alternatives for the pipelines in the Ekofisk Area. Since much of the costs involved are connected with the marine operations, and the Norwegian content of such operations is expected to be very low, the total Norwegian content must be estimated accordingly.

Engineering includes inspection and analysis. Before removal can take place it will be necessary to verify the exact position and depth of burial of each individual pipeline. Also necessary will be planning and calculations in connection with the operations involved. There are Norwegian companies that could do the engineering design.

The Norwegian content is estimated at 70 per cent.

### **Preparation**

Before the pipelines are removed they must be disconnected, flushed, and cut into segments. Since they are buried below sediment, this must be removed before recovery can proceed. One option is to use a system that jets away the sediment. Cutting the pipelines on the seabed will probably make use of remote-controlled diamond cutters. The Norwegian content will be slight, and is estimated at 5 per cent.

### **Removal or covering with gravel**

The removal operation can be done using a lay-barge supported by an auxiliary ship. The pipelines will be cut into sections of 12 or 24 metres. Once lifted they will be moved to Norway or another country for demolition and scrap. The job will most probably go to an international ship operator. There are many likely candidates, including French, Swiss and UK operations. Only an insignificant part of these marine operations could be sourced in Norway, about 5 per cent.

By contrast both Norwegian and international shipping operators could take on a contract to cover the pipelines with gravel if they are left in-place. The Norwegian content in this case is estimated at 50 per cent.

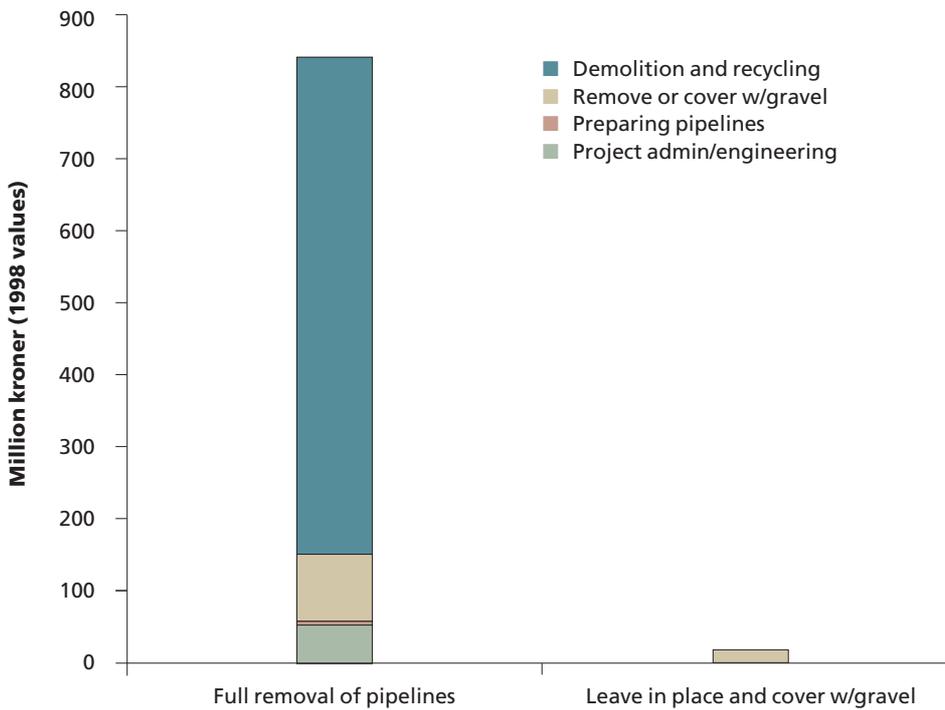
### **Demolition and recycling**

It is not clear if the pipeline sections would be transported to Norway or some other country. Landfall must certainly take place somewhere where there are special facilities for receiving piping for demolition. There are several such sites along the Norwegian coast. Many locations abroad could also accept the Ekofisk I pipelines.

Suppliers of marine operations would probably work jointly with relevant demolition contractors who can organise the recycling. Whether a Norwegian or international demolition contractor is chosen will depend on the alliance that is awarded the contract.

Before demolishing the steel pipeline sections, the concrete sheath around the pipe must be removed, as must its reinforcement steel, asbestos and rubber. Steel scrap will be taken for melting down, possibly in Mo i Rana (Norway) if the sections are landed in Norway. Special waste, like asbestos, must be disposed of in a landfill. The Norwegian content is put at either 100 per cent or zero.

Figure 53 below shows the Norwegian content broken down by cost components for the two alternatives for the pipelines. The total Norwegian input may reach more than 800 million kroner for the removal solution, and about 15 million kroner for the gravel-dumping solution where the pipelines are left in-place.

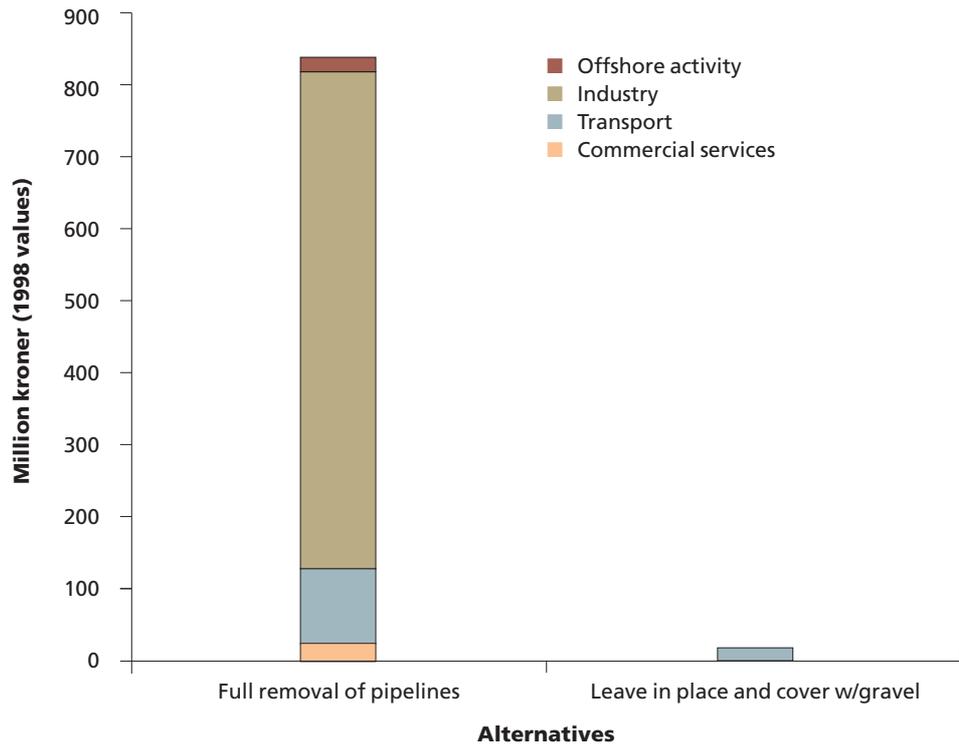


**Figure 53**  
*Ekofisk I pipelines:  
 Norwegian content broken  
 down by cost components  
 for Disposal Alternatives,  
 (mill. NOK, 1998 costs)*

It is mainly in connection with demolition and recycling of the pipeline sections that Norwegian industry may receive contracts. These contracts may be worth 600–700 million kroner in value.

Figure 54, shows the industries that can accept direct contracts in connection with removal or leaving of the pipelines in-place.

**Figure 54**  
 Ekofisk I pipelines:  
 Norwegian supplies  
 (first level) broken down  
 by industry for Disposal  
 Alternatives,  
 (mill. NOK, 1998 costs)



The contracts for demolition and recycling the pipelines will mainly go to the heavy engineering industry (yard industry). If contracts are signed with an overseas company to do the demolition and recycling, the Norwegian content will be reduced by about 600–700 million kroner.

The table below gives a summary of the types and volumes of materials in the pipelines that are susceptible to recycling and resale. This will bring revenues to the project depending on market price of the scrap at the time in question.

**Table 39**  
 Ekofisk I-pipelines –  
 materials for  
 recycling (tonnes)

Material	Steel	Copper
Pipelines	35,000	2*

\* Copper from the cable between the Ekofisk Center and Ekofisk 2/4 A

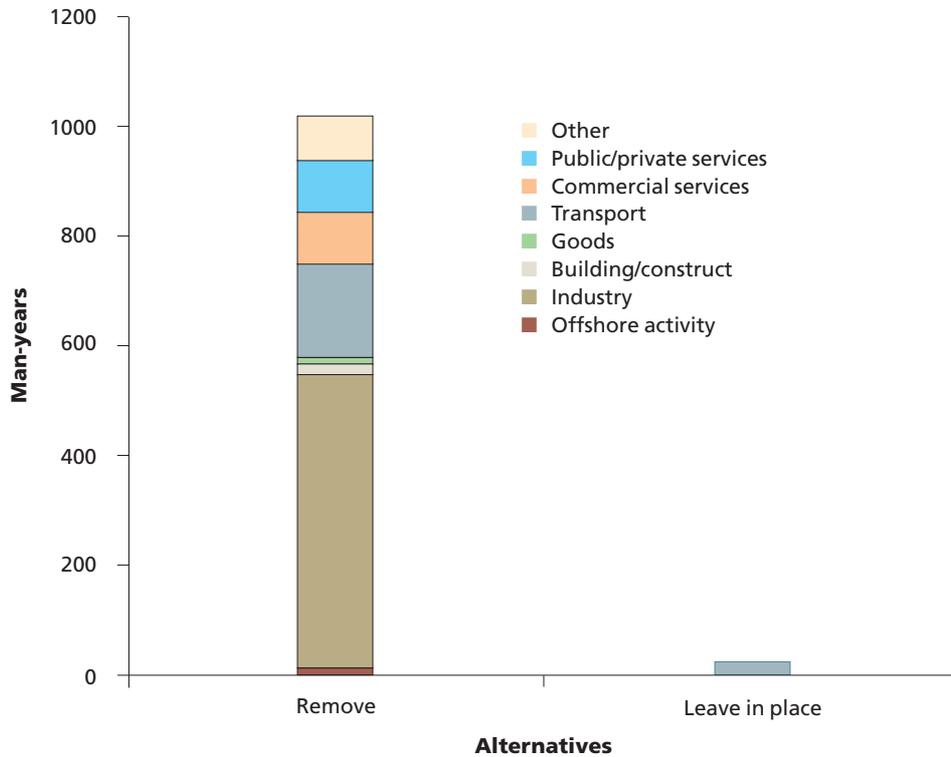
With a price of 300–500 kroner per tonne recycled steel from the Ekofisk I pipelines, this will give an income in the range of 11–18 million kroner.

### 8.3.5 Employment effects

Based on the breakdown of industries that can be expected to take the Norwegian input, the national employment effects have been calculated. If the pipelines are broken and recycled in Norway, then removal of all pipelines at Ekofisk I can mean about 1,000 man-years of labour in production effects. These will result from direct and indirect goods and services supplied from Norwegian industry. The national employment effects will largely accrue from demolition and recycling of the pipeline sections and will come in heavy engineering.

Simply leaving the pipelines will result in about 30 man-years of input to cover them with gravel. In addition to the production effects there will also be

consumer effects, which are estimated to represent an increment of 50 per cent to the employment effect.



**Figure 55**  
*Ekofisk I-pipelines – national production effects broken down by industry (man-years)*

The total employment effects can reach about 1,500 man-years if the pipelines are recovered, then scrapped and recycled in Norway. Leaving in-place can result in collective employment effects equivalent to about 50 man-years.

The production effects of the removal will largely come within industry in connection with scrapping and recycling. If these contracts are placed abroad, the total production effects in Norway will be about 800 man-years less.

## 8.4 Summary for Pipelines

### 8.4.1 Environmental Impacts

The environmental impacts for the two options are summarised below.

	III Pipelines	
Issue	Alternative A Remove to shore for demolition and recycling of materials	Alternative B Leave in buried state
Energy consumption (million GJ).	1.6	None/insignificant
Tot.Energy Requirement (million GJ)	1.6	0.9
CO <sub>2</sub> -emissions (1000 tonnes)	120	1
Disch. to sea, ground, water	Small negative	None/insignificant
Phys./habitat effects	Small negative	None/insignificant
Aesthetic effects	Moderate negative	None/insignificant
Waste/resource util.	Small positive	None/insignificant
Littering	None/insignificant	Small negative

**Energy and Atmospheric Emissions**

Removal and demolition of pipelines requires significant energy consumption, while leaving them buried requires very little energy. The Total Energy Impact for these Alternative is very large, differ 44 per cent in favour of «leave buried».

**Discharges, physical/habitat effects**

If the pipelines are left in-place, sporadic indirect releases may occur, for instance from leaching of metals from the structural components or sacrificial anodes over the years. All in all, this is found to have «none/insignificant» consequences. Removal of pipelines, on the other hand, could cause some swirling up of sediments and leaching of possible contaminants.

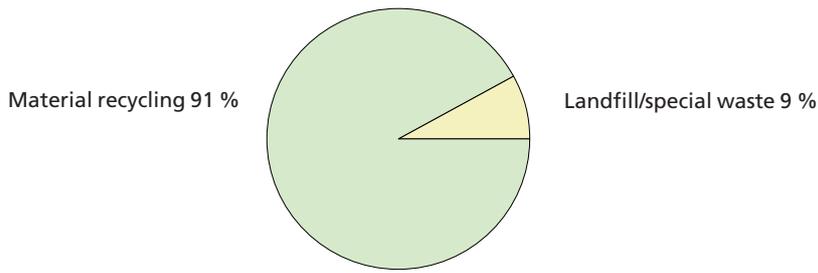
Recovery of the buried pipelines can affect bottom fauna and habitats. The environment is however expected to regain its original standing within a few years, and the impact is assessed as «small negative».

**Aesthetic effects**

Removal and demolition of the pipelines has a potential for negative effects on the work force from cutting and separating the different materials the pipelines are made of. The knowledge about this is limited, but the issue is given high weight, and the impact is considered «moderate negative».

**Waste/resource utilization/littering**

Removal of the pipelines for scrap produces large volumes of waste in relation to the volume of steel available for recycling. The total impact is therefore assessed only as really «small positive» impact.



**Figure 56**  
*Percentage share of recycling and disposal for pipelines if brought to shore for demolition*

The «leave buried» option for pipelines has a potential for littering, although realistically the potential is deemed negligible. The only factor considered is therefore that «something is left that was not there before».

### 8.4.2 Societal Impacts

The impacts on society for the two Alternatives are summarised below.

	III Pipelines	
Issues	Alternative A Remove to shore for demolition and recycling of materials	Alternative B Leave in a buried state
Impacts on Fisheries	None/insignificant	None/insignificant
Impacts on free passage	None/insignificant	None/insignificant
Personnel Safety(PLL)	0.10	<0.01
Costs (bill. Norw. 1998 kroner)	2.6	0.03
Norwegian Content, bill. Norw. 1998 kroner (%)	0.2–0.8 (32)	0.015 (50)
Employment (man-years)	300–1500	50

#### Consequences for fisheries

Since the pipelines are buried, there is no potential for interference with fisheries from leaving pipelines in situ. Pipeline ends will be gravel dumped to avoid any hindrance. Possible trenches in the seabed after removal will rapidly disappear, and removing the pipelines will not have any significant impacts on fisheries.

#### Personnel Safety

Removing the pipelines for demolition and recycling has a potential for loss of life at 10%. Leaving the pipelines in-place involves little manpower, thus having a very low PLL.

#### Costs and employment effects

The cost of removing a the pipelines is a bout 2.6 billion kroner. Leaving the pipelines has a cost at 32 million kroner. The Norwegian content of work will

be in the order of 32 per cent for removal, i.e. maximum 0.8 billion kroner. The associated number of man-years will be 300 – 1,500 for removal depending on work will find place in Norway or abroad.

#### **8.4.3 Comparative Assessment**

From the summary above it can be seen that leaving the pipelines in-place is the best option based on environmental considerations. The possible positive effect from recycling the materials can not justify the negative impacts from removal. Leaving in-place also has only insignificant impacts. Also, looking on the safety and cost aspects, the leaving in-place option is without any doubt considered the preferable option.

# 9 IMPACT ASSESSMENT FOR THE DRILL CUTTINGS DISPOSAL ALTERNATIVES

## 9.1 Description of the cuttings piles

### 9.1.1 History

During years of drilling operations on the Ekofisk fields, piles of drill cuttings accumulated on the seabed below several of the Ekofisk I installations. Cuttings are bits of rock broken up by the bit as it penetrates the rock. The bit is lubricated and cooled using one or several types of drilling mud, which also flushes out the cuttings and balances the downhole pressure. Mud is generally comprised of a base fluid such as water, oil, or synthetic oil, plus additives such as barite or polymers.

The majority of the drilling mud used on Ekofisk I (around 93%) was water-based. Records show that from 1991 around 7% of the Ekofisk I drilling mud used were synthetic based. All releases occurred in accordance with discharge permits from the Norwegian authorities. Cuttings with oil-based mud were not released from the Ekofisk I installations.

Water based drilling fluids commonly contain various additives. The most common material used to increase the density of drilling fluid is barite (granulated barium sulphate). In some wells requiring a very high density, barite can constitute as much as 35% of the drilling fluid by volume. Barite is not only desirable as a weighting material, it is also inert and can be added to fluids with no chemical reaction (Dames & Moore 1999).

Many of the piles have remained dormant for 10 to 15 years. As a result they have changed character significantly through natural erosion, degradation, natural settling, and have gradually become more like the surrounding seabed.

### 9.1.2 Magnitude of cuttings piles in the Ekofisk Area

Throughout the summer of 1998, drilling histories for the Ekofisk I installations were reviewed. The review revealed that drill cuttings had been discharged from seven Ekofisk I installations, and thus it was anticipated that these would have drill cuttings piles at their base. The seven installations are Ekofisk 2/4 A and 2/4 B, Cod 7/11 A, Albuskjell 1/6 A, Albuskjell 2/4 F, Edda 2/7 C and West Ekofisk 2/4 D. The results of the study are presented in two reports prepared by Rogaland Research («RF»), a consulting firm.

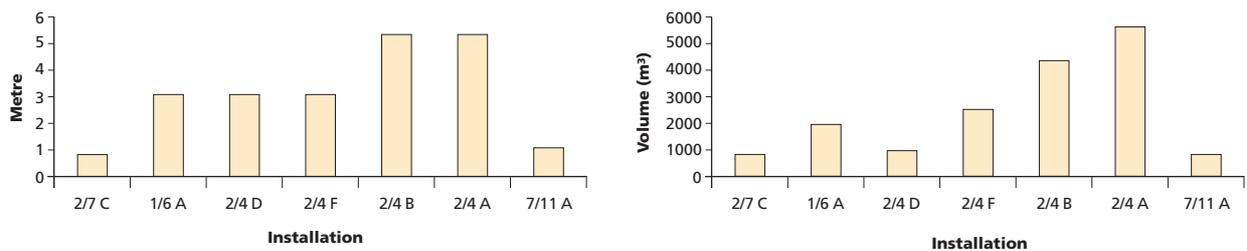
As part of the above-referenced study, RF mapped the piles to determine their relative size and position. The results of the RF mapping study show that the piles around the installations vary a great deal in height and extent (see Figure 57). The height of the pile relative to the normal seabed level

varies from one installation to the next, but is generally from 0.8 to 5 metres. An example of the lateral extent of one of the larger piles (2/4 A) is given in Figure 58.

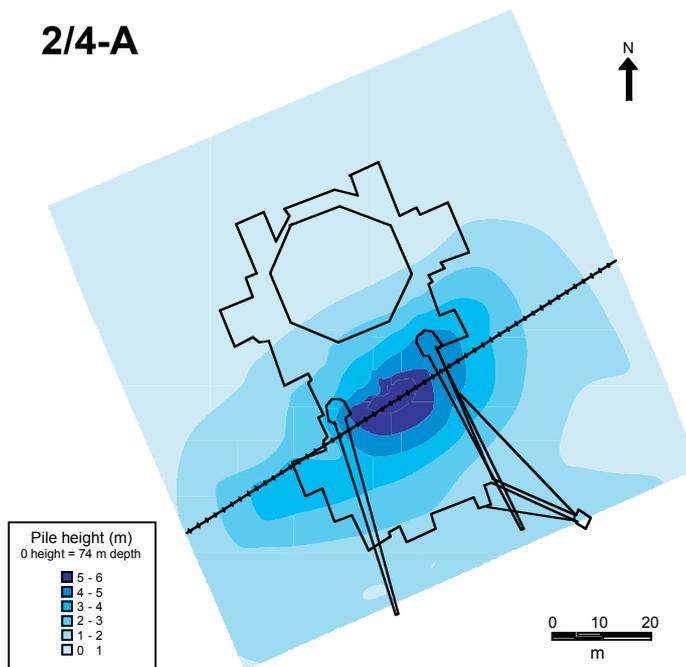
The study found that Ekofisk I drill cuttings piles are generally smaller than the average of what has been found elsewhere in the North Sea (Andersen *et al.*1996; Bell *et al.*1998). The piles have a slight gradient, and it is difficult to determine the pile edge since the pile material is visually consistent with the natural seabed.

The review of the drilling history records indicated that roughly 175,000 cubic meters of cuttings materials (drilling fluids, additives, and cuttings) were discharged from the seven Ekofisk I installations (Dames & Moore 1999). Investigations of the piles in 1998, however, showed that only about 10% of the discharged volume remains in the piles beneath the installations. It was also concluded that natural erosion will dissipate the remaining material during the term of the Ekofisk license. The total volume of cuttings from all seven piles is approximately 17,000 cubic meters (RF 1999) (see Figure 57).

**Figure 57**  
 Volumes and heights of cutting piles (from RF 1999)



**Figure 58**  
 Height of cuttings pile beneath and around Ekofisk 2/4 A



The results of the cuttings piles studies (RF 1999) show that the piles vary in size, composition and condition. Therefore, the optimal solution for one pile is not necessarily the best for another, and the ecosystem impacts at one site may be different from those at another site using the same solution. This results in a very complex situation.

Some older piles appear to have eroded and degraded, while others (with more recent discharges) are larger and contain elevated levels of contaminants within the piles, but few contaminants at their surface.

### 9.1.3 Chemical and physical characteristics of the cuttings piles

Review of the Rogaland Research study results (RF 1999; RF 1998) show variations in composition and content not only between different piles, but within a single pile as well.

The explanations are rooted in the dates of drilling, the drilling mud used, the quality of the barite blended into the mud, etc. The time since drilling ceased is also important, particularly in regards to erosion of the piles. The piles are diminishing with time.

No criteria exists with which to evaluate the quality of the drill cuttings piles, and thus this impact assessments used Norwegian Pollution Control Authority (SFT) guidelines for classification of environmental quality in fjords and coastal waters<sup>16</sup> (SFT 1997) for general comparative purposes. In addition, comparison was made to reference data obtained from the offshore environmental monitoring work in the Ekofisk Area and OLF's quality criteria for barite.

A summary of results for metals (grab samples) and hydrocarbon (mean values from the bioturbated zone 0–30 cm) is given in Table 40. The table shows the median and maximum concentrations of three of the heavy metals (cadmium, mercury, and lead) in the piles. A review of these results shows that the surface grab samples from the periphery contain median concentrations corresponding to SFT Class II or below. Maximum concentrations fall within SFT Class III or below, and also fall within OLF's criteria for barite quality. The maximum concentration for lead in the pile under 1/6A falls within SFT Class IV, but appears to be an isolated incident caused by local debris.

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<sup>16</sup> The system is designed for coastal waters and not suitable for the open sea. Still, it remains the only official set of criteria available, and a comparison with it for the open sea will be conservative.

**Table 40**

Concentration of selected heavy metals, oil, and PAH (from upper 30 cm) in cuttings piles (source: RF 1999) as generally compared with Norwegian Pollution Control Authority classification (SFT 1997) and other references. All figures in mg/kg

	SFT kl I	SFT kl II	SFT kl III	SFT kl IV	SFT kl V	Reference values (Ekofisk area)	Quality criteria for Barite
Cadmium	<0.25	0.25–1	1–5	5–10	> 10	0,008	<5
Lead	<30	30–120	120–600	600–1,500	> 1,500	6.0–8.2	< 1,000
Mercury	<0.15	0.15–0.6	0.6–3	3–5	> 5	0.05	< 5
THC (oil)	–	–	–	–	–		
PAH (16 EPA)	<0.3	0.3–2	2–6	6–20	>20		

<b>Results at different installations. Metals show Median concentration with Maximum in brackets. THC og PAH concentrations are mean values</b>						
	2/4 A	2/4 B	2/4 D	2/4 F	1/6 A	2/7 C
Cadmium	0.46 (1.12)	0.64 (3.38)	0.20 (0.76)	0.15 (0.54)	0.19 (2.49)	0.17 (0.22)
Lead	59 (265)	85 (442)	38 (116)	47 (296)	39 (744)	32 (74)
Mercury	0.12 (0.75)	0.22 (1.86)	0.05 (0.15)	0.04 (0.20)	0.16 (1.19)	0.11 (0,86)
THC (oil)	19,700	157–22,500	120–4405			
PAH (16 EPA)	1.0	0.2–1.2	0.1–6.5			

Table 41 shows the median and maximum concentration for cadmium, mercury, and lead in core samples from piles under the 2/4 A, 2/4 B, and 2/4 D installations. Cadmium, mercury, and lead results show median concentrations of SFT Class III or below in the core results. Maximum concentrations which are elevated (some approaching Class V, 2/4 B) are from samples collected deeper in the pile.

**Table 41**

Concentrations of heavy metals in Type 2 piles from sampling with corer. All figures in mg/kg.

Installation	Sample	Cadmium		Mercury		Lead	
		Median	Max.	Median	Max.	Median	Max.
2/4 A	Virbo core	0.38	1.16	0.06	0.39	37	256
2/4 B	Vibro core 1	0.89	12.40	0.15	6.15	221	1,489
	Vibro core 2	0.77	10.,52	0.32	2.82	143	1,291
2/4 D	ROV core	1.64	9.38	0.35	5.71	267	1,505

The elevated metal concentrations are generally from barite and other additives used in the drilling mud, however some originate from the reservoir. A review of the reference values (Table 40) established from sediment monitoring in the Ekofisk Area, shows that levels of metals in the piles are significantly higher than levels of metals normally found in the sediment in the region. The levels of metals found in the pile are comparable to the levels of metals found in barite. This was determined by reviewing metals concentrations from barite, which was previously approved for use as an additive in drilling muds. This indicates that barite is the main source of metals in the piles. Most of the heavy metals from the muds are bound within the barite, and the possibility of leaching and also bio-availability is considered to be low. The metals found within the piles are not uniformly distributed in the piles. Generally it was found that, for the larger piles, elevated metals are found buried beneath the surface and no serious surface contamination is found.

The SFT classification does not include oil (THC), but the values found in the piles can be characterised as elevated. The source of the hydrocarbon is not apparent since records do not indicate use of oil based drilling fluids, however it is possible some of the hydrocarbon is from surfactants or lubricants periodically added to improve drilling performance. Hydrocarbon concentrations are most elevated at 2/4 B. The source of hydrocarbon here appears to be from a neighboring platform (outside this cessation) which in the past discharges oil based cuttings.

Several piles contained PAH concentrations at the surface of the pile which fell within SFT Class II, and some measurements showed peak PAH concentrations that fell within SFT Class III. Table 40 shows the mean values for THC and PAH in the upper 30 cm of the piles.

It appears that the light oil fractions are found nearer to the surface of the pile, which indicates these may be migrating upwards. Natural biodegradation is assumed to be occurring at the surface of the piles, but not deeper within the piles. If the piles are diminishing with time, probably due to natural erosion, it is possible a systematic natural remediation process is taking place. Recent studies on biodegradation have also shown that hydrocarbon can be degraded under aerobic and anaerobic conditions.

## 9.2 Description of Drill Cuttings Disposal Alternatives

Many disposal options for drill cuttings have been discussed and evaluated (RF, 1999). The following four Disposal Alternatives remain:

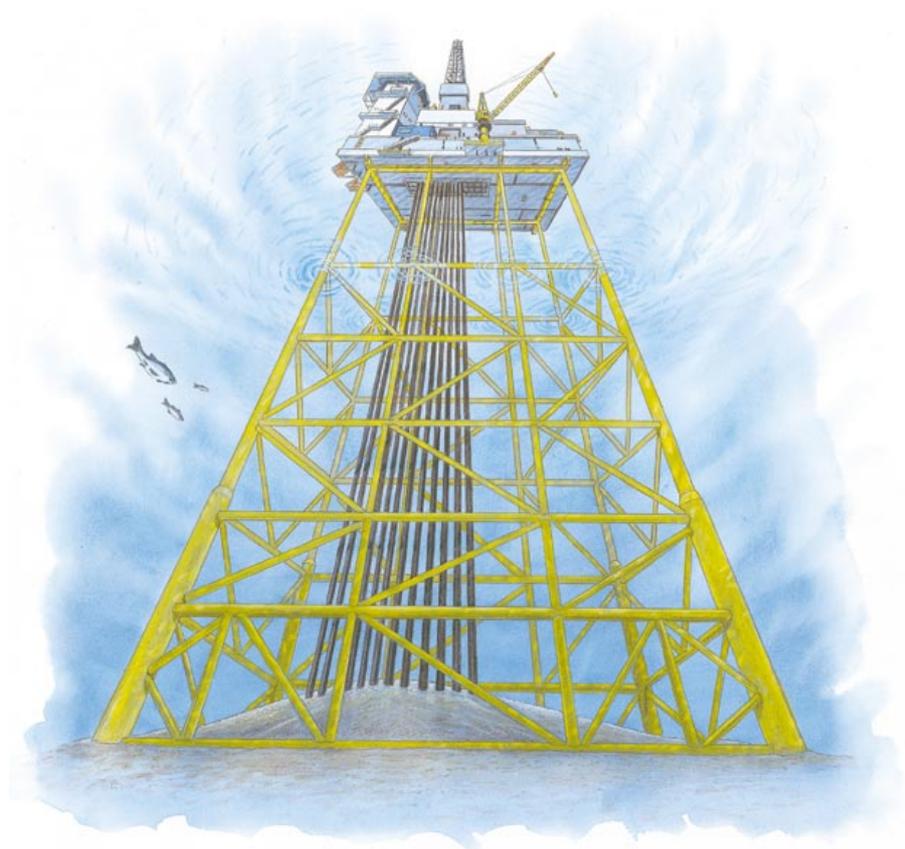
Alternative IVA	Retrieve the cuttings from the seafloor, slurrify and re-inject into a disposal well
Alternative IVB	Retrieve the cuttings from the seafloor and transport to shore for treatment and disposal
Alternative IVC	Leave the cuttings in-place on the seafloor
Alternative IVD	Cover the cuttings with gravel and leave in-place

These Disposal Alternatives are illustrated in Figure 59. Figure 60 depicts a pile under an installation.



**Figure 59**  
*Disposal Alternatives for drill cuttings: removal, leave temporarily in-place under steel jackets, and leave in-place with gravel cover.*

**Figure 60**  
*Cuttings beneath  
 steel jacket*



### 9.2.1 Alternative IVA – Remove the cuttings for re-injection

This Alternative requires that cuttings material be pumped from the seabed to the installation or a floating unit. This would require a permit from the SFT in accordance with the Pollution Control Act. The material would then be slurrified and pumped back into a waste well deep in the bedrock.

It is important to emphasize that, at present, no retrieval technology exists for removing drill cuttings piles in an environmentally acceptable manner.

### 9.2.2 Alternative IVB – Remove the cuttings for onshore treatment

Pumping the cuttings from the seabed according to this Alternative would be the same as for Alternative IVA. Pumping equipment could be deployed from the installation or a surface vessel. The volume retrieved would possibly contain a substantial degree of water, which would need to be separated (either offshore or onshore). The retrieved cuttings material would be shipped to shore in containers on a barge or as bulk. There are several technologies and facilities for treatment of fresh cuttings onshore. Cuttings removed from the seabed, however, would contain chlorides, seawater, a mixture of different mud additives, etc. This would represent a greater challenge to the processing facility. At present, the oil industry is undertaking a study to look into the possibilities, limitations and impacts associated with processing old drill cuttings onshore. When processed, the cuttings volume would still be significant, and this waste would have to be disposed of onshore in a suitable landfill.

### 9.2.3 Alternative IVC – Leave the cuttings in-place

This Alternative means leaving the cuttings piles as they lie below the steel jackets after the jacket is either removed or toppled. Many of the piles beneath the platforms have not received discharges for some time, and likewise are undergoing natural erosion and degradation (only 10% of discharged cutting volume remains).

### 9.2.4 Alternative IVD – Cover the cuttings with gravel and leave in-place

This Alternative could be carried out after the steel jackets are removed. Covering the cuttings piles means that gravel or sand is dumped onto them to protect from outer forces. Gravel-dumping is a technique in the offshore industry used for such applications as adding protective covering to exposed pipelines or other structures on the seabed. The method involves dumping material, such as small gravel, from surface vessels, normally through a fall-pipe. Gravel is preferable to boulders because of the reduced risk of damage to the pile and consequent re-suspension; however some re-suspension should still be expected even if gravel is used.

## 9.3 Environmental Impact Assessment of the Drill Cuttings Disposal Alternatives

### 9.3.1 Energy Consumption and Total Energy Impact

No calculations have been attempted of energy consumption associated with the various Disposal Alternatives. This was deemed less important in this context.

Nevertheless, it is obvious that energy consumption would be highest for solutions requiring intensive use of marine vessels. In addition, pumping for re-injection and onshore treatment would require some energy. Alternatives IVA and IVB are thus evaluated as having «small negative» impacts on the energy issue. Leaving in place (Alternative IVC) would not require any energy. Gravel-dumping (Alternative IVD) is assumed to require limited energy consumption for the gravel-dumping operation.

### 9.3.2 Emissions to air

As for energy, no quantification of atmospheric emissions has been attempted. However, emissions will follow the same pattern as energy (above), with Alternative IVC having the best performance.

### 9.3.3 Discharges to sea, water or ground

The most relevant environmental issues are identified as:

- Swirling/re-suspension of fine particulate matter and contaminants
- Leaching of pollutants (by natural means)
- Discharges/environmental detriments during treatment/disposal on shore.

### **Alternative IVA – Injection of cuttings in disposal well**

As mentioned above, there are no methods available for retrieving/removing drill cuttings from beneath an offshore platform that adequately addresses environmental concerns. The biggest concern is re-suspension or dispersion of contaminated material during retrieval operations. A significant portion of the contaminants may not be recovered by the dredging mechanism and could be rapidly spread into the surrounding environment. This is considered when evaluating the overall environmental impact of this Alternative. In addition and as described below, re-injection raises issues concerning capacities, methods, and regulations.

Some of the cuttings piles have a fairly soft surface and consistency (Bell *et al.* 1998), and the sediments therefore may easily be re-suspended by physical disturbance. Re-suspension of these anaerobic sediments may release gases – among them methane, which is not water-soluble and whose bubbles will rise to the surface. The bubbles may contain variable volumes of other gases (like CO<sub>2</sub> and H<sub>2</sub>S). These gases will dissolve in water and their concentration will decrease as the bubbles rise to the surface. Similarly, fractions of readily-soluble hydrocarbons would spread through the water masses. This would also be the case for some metallic components. Particulate matter would gradually re-settle on the bottom and would have the potential to contaminate adjacent areas. The augmented particle content of the water and the pollutants present could trigger acute effects in marine organisms in the vicinity for a limited time period. It is likely that the effects would mainly impact the immobile or slightly mobile organisms close to the cuttings piles. This is because the occurrence of any marine organisms in or on the piles themselves is very limited (Cripps *et al.* 1998). It is further expected that a greater level of leaching of pollutants to the water body would occur as the contaminated sediments were uncovered during the collection process. The scope of effects caused by recovery of the sediments would be related to the history of the pile and the level of disturbance. It would therefore be advantageous to assess each pile's surface and contamination level before choosing a recovery method.

Water will accompany the cuttings recovered for slurrification. The cuttings-and-water mix to be injected into the well (slurry) would consist of 70–80 per cent water. This means that water accompanying the cuttings could be used to form the pumpable slurry. Any extra water could be pumped into the injection well. It is expected that the surface installation or equipment would be designed so that any soilage from slurrification and injection would be kept to a minimum. Therefore, no discharge of any environmental significance is anticipated into the sea in this connection.

The evaluations by Rogaland Research (RF 1999) determined that different methods of removal could cause anything from large to small environmental impacts. Removal by mechanical means was considered to have large negative consequences, as it potentially could cause extensive re-suspension and dispersion of the sediments. Suction-dredging methods were assessed to result in somewhat less negative environmental impacts.

According to Rogaland Research (RF 1999), re-injection is generally a solution with small environmental impact, although the recovery process itself is fraught with technological uncertainty and is assessed to have the potential for releases in large quantities by re-suspension and dispersion of

particles and pollutants. The Alternative is thus assessed as having «moderate negative» impacts.

### **Alternative IVB – Remove for onshore disposal**

The environmental issues associated with removal of the drill cuttings from the seabed are the same as those for Alternative IVA (see above).

The water volume accompanying the cuttings may be a larger problem for onshore treatment and disposal than is the case with re-injection. The cuttings that are pumped to the surface would be collected in containers for transportation to shore. The cuttings would sink to the bottom of the tank in which they are stored, while an oily layer may form at the top of the water. The oily layer could be removed by employing skimmers, while some of the water could be released to the sea. The water discharged to the sea would typically have a hydrocarbon content of less than 40 mg/l, and the discharge will be subject to permit from the Norwegian Pollution Control Authority (SFT). Such a discharge is not expected to have measurable impacts on the environment. Another solution might be to collect the liquids before transport to shore and send them through the offshore installation's processing facility for produced water. Due to the large quantities of drill cuttings that would be retrieved, it is uncertain whether this would be feasible in practice.

Overall, Alternative IVB – removal for onshore disposal – was assessed to have «moderate negative» impacts.

### **Alternative IVC – Leave the cuttings in-place**

Re-suspension and release of suspended substances could occur in connection with removal or toppling of the jackets. Use of explosive charges, or removal of sediments around the legs/pilings before they are cut, could also cause re-suspension of the deposited material. Effects from re-suspension will be as described for Alternative IVA. The scope of this re-suspension if the cuttings are left in-place, however, is assessed to be small.

A gradual leakage of hydrocarbons and metals from the cuttings piles into the water body and the underlying and near-by sediments could also occur. Studies done at the Heather A platform (ERT 1993) suggest that hydrocarbons in the cuttings piles migrate toward the pile surface, as is also supported by Rogaland Research's study of Ekofisk (RF 1999). A laboratory test done by Delvigne (1995) concludes that the leach rate is largely predicated by the molecular weight of the hydrocarbon. According to this study, the leach rate declines with increasing molecular weight. The leach rate was below measurable limits after 21 days. However, there is limited knowledge about the factors that determine the leach rate from cuttings piles. One study (RF 1999) evaluated the environmental impacts of the various proposed Disposal Alternatives for Ekofisk I cuttings. The study estimated that the leaching of organic components and metals from the cuttings piles will be small and will decrease over time, but believed the effects will vary depending on the history of the cuttings pile in question.

Some of the cuttings piles are almost fluid or soft on the surface. This means that if a fishing implement or anchor is pulled across them it could cause re-suspension of contaminated sediments. This would affect primarily

finer particles, would result in a local reduction of water quality for a limited period, and cause release of hydrocarbons and metals or their compounds. A study done by Petersen *et al.* (1994)<sup>17</sup> shows that metal-contaminated, oxygen-starved sediments which are re-suspended due to anchor operations were quickly reoxidised in the water column. As much as 5 per cent of the particulate-bound Cd, Cu, Pb and Zn was re-mobilised from the sediments.

The results of the Rogaland Research study (RF 1999) also indicate that considerable natural erosion occurs on these piles where they lie. It is not known whether metals are slowly dispersed in the water mass or are buried further down in the sediment as the pile flattens with time. If dispersed to the sea, it is likely to occur as a very gradual release of contaminants to the water body and perhaps a spreading of the particulate matter. Organic components will thus quickly be subject to decomposition, while metals will be spread or re-deposited.

Metals bound within the barite matrices, with the low possibility of leaching and low bio-availability, combined with a limited total quantity and concentrations under SFT's Class V, result in Alternative IVC (leave in-place) being evaluated as having «insignificant» to «small negative» consequences from potential discharges and erosion. Studies show that since barite has a low solubility in water, only small quantities of metal will leach out, if any at all (Sintef, 1996). It is also known that metals are in general less detrimental to the environment in seawater than in fresh water.

The evaluation of leaving the cuttings piles in-place is thus a question of how large an environmental risk it involves. The risk depends on the content of the pile and the distribution of the pollutants within it, but also in particular the activities relating to disposal of the steel jackets. A program for monitoring has been suggested to increase the industry's general knowledge on drill cuttings (see Section 11.4).

The steel jackets protect the cuttings piles from external disturbances, at the same time that the piles naturally erode. Thus the timing of removal of the steel jackets has an impact on the drill cuttings and their environmental impacts.

If jackets are removed soon, then leaving of the cuttings in-place is believed to cause negative consequences of «moderate» scope.

If the steel installations over the cuttings piles can be left for an extended period («cold phase»), then the Rogaland Research results suggest that the piles will erode naturally, and thus, ultimately, will represent a smaller environmental problem than is the case today. This simultaneously reduces the environmental risk of Alternatives that involve digging and/or mixing the cuttings (for example for removal or covering, see above).

An effect of the cold phase for the steel jackets is thus that the cuttings piles can lie undisturbed for a number of years. This means at the same time that there is no need to dispose of the cuttings as waste somewhere else. The direct environmental risk connected with the solution is deemed limited, since the steel structures will serve to stop foreign objects (e.g. trawls) from encountering the piles, and thus prevent any sudden release occurring from the pile. The steady release of leachants following from natural erosion is assessed as relatively less harmful to the environment.

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<sup>17</sup> Cited in Bell *et al.* 1998

The impact of leaving the drill cuttings with removal of the steel jackets in the period 2015–2018 is assessed as resulting in «insignificant» to «small negative» impacts. An earlier removal of the jackets, before the piles are significantly eroded, would give a more negative impact.

#### **Alternative IVD – Cover cuttings with gravel or rock**

It is expected that dumping stone or gravel on the cuttings could cause some re-suspension of contaminated sediments from the piles. Effects from re-suspension would be as for Alternative IVA. The scope of the biological effects in this context would largely depend on the level of contamination of the cuttings pile and the scope of the re-suspension. The material dumped, as well as the dumping technique employed, would also affect the degree of re-suspension. An assessment by Cripps et al. (1998), concludes that gravel would cause less re-suspension of sediments as it hits the cuttings pile than rock. Positioning chutes (fall pipe), which are fitted on most dredging and dumping vessels, should be used. According to Cripps et al. (1998), the chutes would clearly reduce the chance of re-suspension of the sediments compared with use of a method involving dumping from the surface.

Once covered, the cuttings only represent an «insignificant» environmental risk. There remains uncertainty, however, regarding how large a release one can expect from the actual operation of dumping the gravel onto the cuttings pile. The overall impact is considered «small negative».

### 9.3.4 Physical impacts and impacts on habitat

#### **Alternative IVA – Inject the cuttings in disposal wells**

Removal of the cuttings will obviously change the local habitat at the site. As described for Discharges (above) re-suspension may occur, resulting in fine particles settling on the seabed, covering immobile marine organisms and changing the local seabed condition.

This is considered a local effect but of some magnitude. The overall impact is thus evaluated as «small negative».

#### **Alternative IVB – Remove the cuttings for onshore disposal**

The physical impacts will be as for Alternative IVA.

#### **Alternative IVC – Leave the cuttings in-place**

No physical impacts are identified associated with this Alternative.

#### **Alternative IVD – Cover the cuttings with gravel or rock**

Despite the fact that the cover materials would cause changes in the local fauna, the cover itself will constitute a new, clean substrate. This can be argued to represent a «small positive» effect. The scale is very small, and the consequences «insignificant».

### 9.3.5 Aesthetic effects

#### **Alternative IVA – Inject the cuttings in disposal wells**

Cuttings retrieved from the seabed may contain some gases (e.g. H<sub>2</sub>S) which could give some bad odours. This would only take place offshore, and the impact is considered «insignificant».

#### **Alternative IVB – Remove the cuttings for onshore disposal**

The impacts of retrieval of the cuttings would be the same as for Alternative IVA.

Cuttings would be brought onshore in bulk or in containers on ships, and would be temporarily stored at the quayside or at a similar location. Such storage has a certain potential visual impact, though its impact is assessed as having little importance.

Processing the cuttings and further handling the various waste streams could also result in some negative aesthetic impacts to the local environment. The overall aesthetic impact is assessed as «small negative».

#### **Alternative IVC – Leave the cuttings in-place**

This Alternative would result in no aesthetic impacts.

#### **Alternative IVD – Cover the cuttings with gravel or rock**

This Alternative would result in no aesthetic impacts.

### 9.3.6 Waste/Resource utilization

#### **Alternative IVA – Inject the cuttings in disposal wells**

Removing the drill cuttings would create waste that would have to be disposed. Reinjection is therefore considered as having a «small negative» impact.

#### **Alternative IVB – Remove the cuttings for onshore disposal**

The total volume of cuttings in all Ekofisk piles is probably over 17,000 cubic metres (some 30,000 tonnes). By comparison, in 1997 a total of 25,000 tonnes of cuttings were delivered for treatment at the existing treatment facilities in Norway (SFT 1999). The annual capacity at the two largest treatment plants is some 40,000 tonnes combined. Thus the plants seem to be capable of handling the capacity that Ekofisk cuttings would require. In any case, this Alternative would have an effect on the capacity for treating fresh cuttings.

Ash, which remains after incineration of cuttings, would be disposed in a landfill. The cuttings, whether treated or untreated, could also possibly be deposited in a landfill. Once deposited, these have the potential to release substances into the run-off water. Current requirements governing operation of landfills should counteract this potential.

Overall, the waste issue for this Alternative is considered as having a «small negative» impact.

**Alternative IVC – Leave the cuttings in-place**

No waste would be generated by this Alternative.

**Alternative IVD – Cover the cuttings with gravel or rock**

No waste material would be generated by this Alternative. However, the Alternative would utilize some resources (i.e. gravel). The volume of gravel required would be modest, and the overall impact is considered «small negative».

9.3.7 Littering

**Alternative IVA – Inject the cuttings in disposal wells**

Removal of the cuttings would not result in any littering impacts.

**Alternative IVB – Remove the cuttings for onshore disposal**

Removal of the cuttings would not result in any littering impacts.

**Alternative IVC – Leave the cuttings in-place**

Cuttings are not «litter» in a normal context. Nevertheless, cuttings are a waste product resulting from the offshore operations, which are discharged in accordance with Authority permits. According to this Alternative these cuttings would be left when the rest of the field operations have terminated. In this context the impact is considered «small negative».

**Alternative IVD – Cover the cuttings with gravel or rock**

The littering impacts would be similar as for Alternative IVC.

**9.4 Societal Impacts – Drill Cuttings**

9.4.1 Impacts on fisheries

The fisheries issues considered relevant in connection with cuttings piles are as follows:

- Contamination of fish in short and long term
- Pollution (soiling) of fishing gear

**Alternative IVA and IVB – Remove cuttings for reinjection or onshore disposal**

Both Alternatives involve removing the cuttings from the seabed, and both are therefore expected to have roughly the same repercussions for fisheries.

During the removal operation any toxins present (including heavy metals) can be expected to be released from the cuttings, leading to toxic effects on

local fish populations. In particular, if such an operation were carried out during the spawning period or soon after, it would cause a local increase in mortality rates among larvae and fry. However, this is not expected to attain such a proportion that it would affect fish populations, and by extension the fisheries in the area.

Adult fish and prey animals living in the area could also assimilate some ecotoxins, or substances that spoil («taint») the taste, that would be released when the drill cuttings are disturbed. However, it is expected that adult fish would be scared away during such an operation, and thus they would largely avoid exposure to re-suspended components. The short duration and local area affected by this would also limit the probability that large quantities of fish would be affected. The potential for spoilage of the quality of fish stocks, thus negatively affecting the fisheries, is therefore deemed negligible from removal of the Ekofisk I cuttings.

Removal of cuttings from the seabed would ultimately help eliminate a risk of pollution of fishing implements and catches during trawling operations. Cuttings associated with the Ekofisk I installations do not represent a major obstacle to fishing, and therefore the area that would be released for fishing by removal would not have any noticeable effects on fisheries. Removal of the cuttings from the seabed still means that the availability of the areas to fishing are improved, and the total change is thus deemed to be a «small positive» effect on fisheries.

### **Alternative IVC – Leave the cuttings in-place**

If the cuttings piles are left in-place, and if the platform jackets that protect them are removed or if the safety zone is lifted, then they may come into conflict with various bottom-going fishing implements in various ways. In the immediate future the potential conflict would be greatest when the outlying platforms are removed and the no restricted areas are relinquished to fishing. If the safety zone around Ekofisk II is lifted at some time in the far future, the problem may again become relevant for cuttings under the Ekofisk I installations which are now covered by the Ekofisk II safety zone – but natural erosion will limit the potential impact.

Cuttings usually consist of broken rock of variable size, ranging from dust to sand to small stones 1–2 cm in diameter (McFarlane & Nguyen 1991). Several of the cuttings piles considered in this study contain some hydrocarbons and some heavy metals (see Section 9.1). Surveys have shown that the surface of such cuttings piles is generally soft, not encrusted as was earlier believed (Bell *et al.* 1998). This seems also to be true for cuttings piles for the Ekofisk I installations (RF 1999). Direct tear damage or snagging of fishing implements on cuttings piles left in-place is not considered likely, since the bits of rock are so small (usually less than 2 cm across). What could represent a concern, however, is that hydrocarbon residues and other components in the cuttings could pollute the catch and perhaps soil the implements, if they drag over the cuttings piles left on the seabed. This may mean that areas where cuttings remain on the seabed are avoided by fishing vessels which operate with bottom implements. Leaving in-place in this fashion could thus result in a small reduction in the area available to fisheries.

Theoretically, one possible negative impact of leaving the cuttings in-place might be that fish congregating there would be unsuitable for human

consumption due to bad taste («tainting») from hydrocarbons. The concentration of hydrocarbons at Ekofisk I, however, is so low that it is not expected that detectable tainting from leaching of the cuttings piles affecting fish congregating nearby will be found.

Leaving the cuttings in-place on the seabed has been assessed overall to result only in a «small negative» impact on fisheries. The negative impacts of this solution are linked to the risk of pollution (soiling) of fishing implements and the fish catch during trawling, which in practice may cause fishermen to avoid this locality, thus effectively reducing the grounds available to them.

With a later removal of the jackets, or if artificial reefs are established, then these negative effects will gradually tail off or be averted.

### **Alternative IVD – Cover with gravel/sand**

Covering the cuttings piles will further raise the height of the piles over the surrounding bottom. Depending on the size of the rock, gravel or sand used, the cover may potentially cause damage to trawling implements, catches and equipment if the trawl door snags or stones enter the bag. Outside the safety zone around Ekofisk II, and at outlying platforms (if removed), fisheries using bottom implements may perhaps want to steer clear of covered cuttings piles, or at least avoid fishing over them. The piles should nonetheless be shaped to be «over-trawlable», and gravel should be preferred to rock to avoid potential damage to implements and catches. The cover would only occupy small areas (for example, 50 x 50 metres, or about the area that the jacket occupies on the bottom), at seven of the Ekofisk I installations. The probability that a trawl will contact such a pile is therefore statistically small. Covering the cuttings piles is therefore considered a very limited obstacle to fisheries, and the consequences of such a solution are deemed «small negative».

#### **9.4.2 Impacts on free passage**

The various solutions for removing or leaving the cuttings piles will only affect free passage of shipping during the operational phase. Leaving the cuttings in-place requires no operational activities and therefore there are no impacts on shipping. Other solutions would require the use of some vessels, but both the scope and consequences of the operations would be small.

#### **9.4.3 Impacts on personnel safety**

The impacts on personnel safety of the various Disposal Alternatives for the drill cuttings were not assessed in detail. However, since leaving in-place does not require any operations, this Alternative would have no impacts on safety. For the other Alternatives, the safety risks will generally increase with increasing man-hours. This means that the Alternatives requiring removal for onshore disposal and for re-injection have the highest risk levels. Based on the scope of work related to these Alternatives, a PLL in the region of 0.01 for those Alternatives was estimated.

Some of the older cuttings piles contain some residues of oil and other substances possibly harmful to health. The correct use of protective safety equipment would therefore be important if handling cuttings for re-injection (Alternative IVA) or for onshore disposal (Alternative IVB).

#### 9.4.4 Costs and national supplies (goods and services)

The costs are estimated at some 20 million kroner for leaving in-place and covering with gravel (Alternative IVD); about 670 million kroner for removal and onshore disposal (Alternative IVB); and about 710 million kroner for slurrification and re-injection (Alternative IVA).

The Alternative of leaving the cuttings piles in-place without covering them further has no costs attached, and thus has no impact on national goods and services.

Table 42 below shows the costs of the drill cuttings Disposal Alternatives broken down by cost component:

**Table 42**

*Cuttings – costs and Norwegian content broken down by cost component, million Norwegian kroner (1998 values)*

Activities	IVD:Cover with gravel		IVB:Remove		IVA:Reinject	
	Mill.kroner	Norw. cont. %	Mill. kroner	Norw. cont. %	Mill. kroner	Norw. cont %
Project admin./engineering	0		6	80	8	80
Preparation	0		7	100	7	100
Remove or cover with gravel	22	50	390	5	450	5
Transport	0		150	5	100	5
Landfill	0		120	100	150	100
<b>Total</b>	22	50	670	23	710	26

The Norwegian content of the total goods and services input is expected to be relatively modest. Slurrification and reinjection, or removal for onshore disposal, could result in a Norwegian input equivalent to about 25 per cent of the total goods and services supplied.

##### **Project administration and engineering**

Project administration comes both from the field operator's and the contractor's personnel. Engineering covers planning the operations and will again be done by both operator and contractor personnel. It is likely that Norwegian engineering consultants could be given these tasks if they were competitive.

The Norwegian content is estimated at 80 per cent.

##### **Preparation**

Before any cuttings piles could be removed or covered, they would have to be examined to determine their height and footprint. The costs of these activities fall in the category preparation costs. These activities could presumably be done by a Norwegian contractor, and therefore the Norwegian content is put at 100 per cent.

##### **Removal or covering with gravel**

Removal is assumed accomplished by pumping the cuttings up to a surface vessel. Suitable<sup>18</sup> dredging vessels would most likely come from countries outside Norway. Norwegian input could consist of minor supporting roles.

Dumping of gravel onto the cuttings piles is something both Norwegian and international ship operators can do. The Norwegian content is put at 50 per cent.

<sup>18</sup> Again note that today there are no known commercial technologies available for environmentally acceptable removal. A large research program has however been initiated by the British Offshore Oil Association (UK00A) and among other issues, they are evaluating removal technologies.

**Transport**

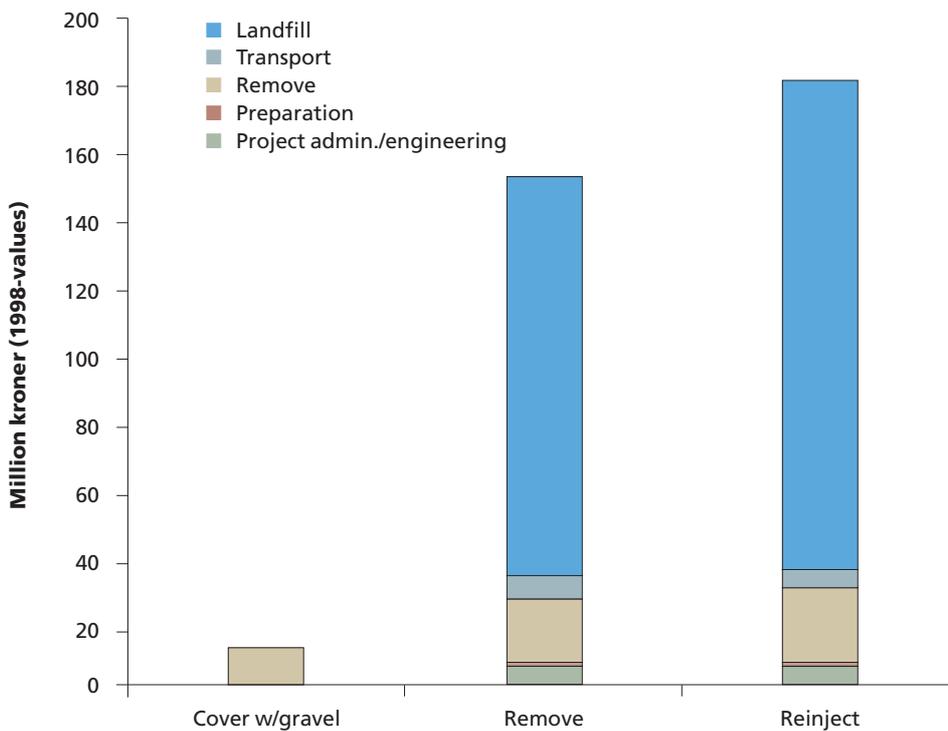
The cuttings would probably be transported to shore in the same dredger that pumps the cuttings to the surface. Here the Norwegian content is put at 5 per cent.

**Onshore Disposal**

If the cuttings were taken to shore they would most likely be taken to Norway, where there are 3–4 receiving facilities that are capable of processing the spoil to separate the oil from the rock or combust it. The Norwegian content is expected to be 100 per cent.

Reinjection of the slurrified cuttings into a disposal well at Ekofisk is something the field operator would do and the Norwegian content is put at 100 per cent.

Figure 61 below charts the Norwegian content of the various cuttings Alternatives, broken down by cost component.



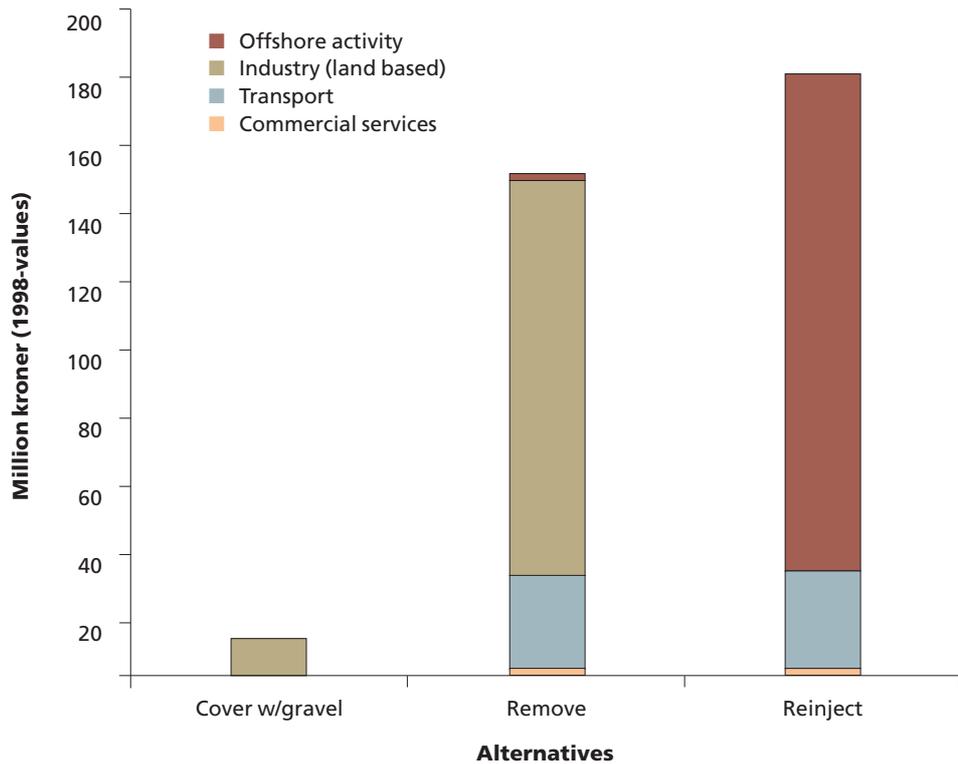
**Figure 61**  
*Cuttings – direct Norwegian supplies broken down by cost components for alternative solutions, million kroner (1998 values)*

Norwegian supplies in connection with the solution for cuttings may run to 10–15 million kroner for placing a gravel fill on the cuttings piles, 150 million kroner for removal, or 180 million kroner for slurrification and reinjection.

The waste would either be disposed in a landfill or reinjected into a disposal well on Ekofisk II. The greatest national input would come from waste disposal (see Figure 61).

Figure 62 identifies the industries that are poised to receive direct contracts for processing the cuttings piles on Ekofisk.

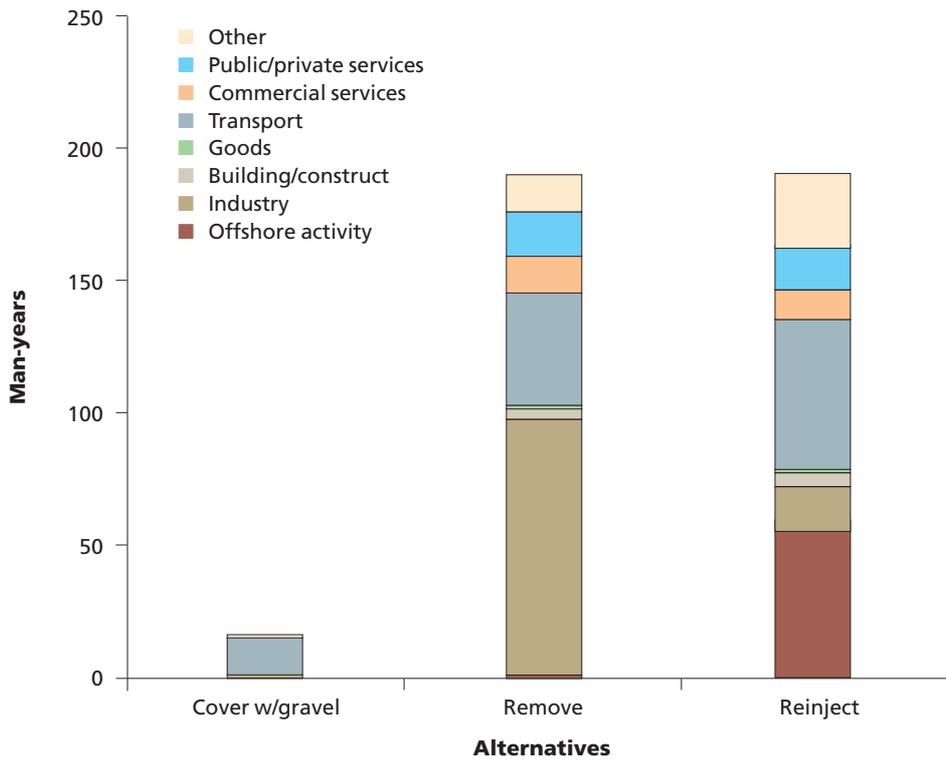
**Figure 62**  
 Cuttings –  
 Norwegian supplies  
 (first level) broken  
 down by industry for  
 alternative solutions,  
 million kroner (1998  
 values)



Removal of the cuttings and processing in an onshore treatment plant would result in contracts for Norwegian industry. Supplies from the offshore industry include the field operator’s work in connection with reinjection of the cuttings in Ekofisk II.

#### 9.4.5 Employment effects

A breakdown by industry of the national goods and services input forms the basis for our employment estimates. The national deliveries would have direct and indirect production effects at the national level. It is expected that a production effect of about 20 man-years would accrue in connection with gravel-cover, and about 200 man-years in connection with removal and reinjection. In addition there would also be consumer effects estimated at 50 per cent of the production effects.



**Figure 63**  
*Ekofisk cuttings – national production effects broken down by industry (man-years)*

The total employment effects are estimated at 30 man-years for covering with gravel and about 300 man-years for removal and reinjection (see Figure 63).

The national production effects may represent about 100 man-years in industry if the cuttings are removed and processed onshore. Work in connection with reinjection into a disposal well can result in about 50–60 man-years on Ekofisk. Otherwise, all Alternatives would result in contracts for Norwegian ship operators in connection with transport and marine operations.

## 9.5 Summary of the assessments of the Drill Cuttings Disposal Alternatives

### 9.5.1 Environmental Impacts

The environmental impacts of the Alternatives are briefly summarized below:

	<b>IV Cutting Piles Alternatives: Summary of Environmental Impacts</b>			
<b>Issue</b>	<b>IVA</b> Removal and reinjection	<b>IVB</b> Removal to shore for disposal	<b>IVC</b> Leave in-place	<b>IVD</b> Cover with gravel
<b>Energy Consum. (million GJ)</b>	Small negative**	Small negative**	None/insignificant	None/insignificant
<b>Tot. Energy Requirement</b>	Small negative**	Small negative**	None/insignificant	None/insignificant
<b>CO<sub>2</sub>-emissions</b>	Small negative**	Small negative**	None/insignificant	None/insignificant
<b>Discharges to sea</b>	Moderate negative	Moderate negative	Small negative*	Small negative
<b>Phys./habitat effects</b>	Small negative	Small negative	None/insignificant	None/insignificant
<b>Aesthetic</b>	None/insignificant	Small negative	None/insignificant	None/insignificant
<b>Waste/Resource</b>	Small negative	Small negative	None/insignificant	Small negative
<b>Littering</b>	None/insignificant	None/Insignificant	Small negative	Small negative

\* A later removal of steel jackets will reduce the negative consequences.

\*\* Assumption, as no calculations carried out.

### Energy and Atmospheric Emissions

The energy consumption associated with the different Disposal Alternatives was not calculated. Nevertheless, it is clear that the Alternatives with the highest involvement of vessels would consume most energy. Similarly, those Alternatives would result in the highest atmospheric emissions.

### Discharges to sea, water and ground, Physical Impacts and Effects on habitat

Removal of the cuttings could result in different levels of discharge or release of pollutants into the water body. However, this topic involves many uncertainties, especially regarding the technical solutions and even the feasibility of removal. The level of discharge is therefore rather uncertain, but the summary below is based on an analysis of available knowledge. The removal methods studied were found to result in considerably larger releases than would result from natural erosion resulting from leaving the cuttings piles in-place

Removal of cuttings could result in disturbance of the local seabed and bottom-dwelling creatures due to dispersion and re-sedimentation.

### Aesthetic effects, Waste/resource utilization, and Littering

Onshore treatment of the drill cuttings could result in negative aesthetic effects in the form of odours and visual pollution. These effects were assessed as having «small negative» consequences.

Removal of cuttings would generate a large volume of waste that would have to be disposed.. Covering the cuttings would require a significant volume of gravel for the operation. In sum, these were assessed as having «small negative» impacts from a resource utilization point of view.

Leaving the cuttings piles in-place on the seabed could be called littering, but it is the same as the present situation and thus results in no negative impacts relative to today. Postponement of removal of the steel jackets would eliminate any littering effect

### 9.5.2 Societal Impacts

The impacts on society are briefly summarised below:

	<b>IV Cutting Piles Alternatives: Summary of Social Impacts</b>			
<b>Issue</b>	<b>IVA</b> Removal and reinjection	<b>IVB</b> Removal to shore for disposal	<b>IVC</b> Leave in-place	<b>IVD</b> Cover with gravel
<b>Impacts on fisheries</b>	Small positive*	Small positive*	Small negative*	Small negative*
<b>Impacts on free passage</b>	None/insignificant	None/insignificant	None/insignificant	None/insignificant
<b>Safety (PLL)</b>	0.01	0.01	0	None/insignificant
<b>Costs (bill. Norw. kroner 1998 values)</b>	0.7	2.0	3.2	0.02
<b>Norwegian content (bill kroner and %)</b>	0.2 (26%)	0.2 (23%)	–	0.01 (50%)
<b>Employment (man-years)</b>	300	300	0	30

\* Later removal of steel jackets means the fishing industry will not be affected by drill cuttings. All alternatives will then result in «none/insignificant» consequences.

Cuttings left on the seabed represent some risk that bottom equipment and catches could be soiled. The consequences for fisheries, however, are dependent on the disposal and disposal timing of the steel jackets. The disposal solution for the jackets is also considered more important for fisheries than the disposal solution for the cuttings piles. A later jacket removal would mean that any issues related to the cuttings piles would disappear.

None of the options have any impacts on free passage of shipping.

With respect to costs, the removal Alternatives are far more costly than the leave in-place Alternatives.

### 9.5.3 Comparative assessment

In evaluating the drill cuttings Disposal Alternatives, it is essential to emphasize that no environmentally acceptable retrieval technology has been identified. In sum, based on current knowledge, leaving the cuttings piles in-place is found to be the best environmental Alternative. This conclusion is especially true when considered in combination with a later jacket removal. When considering the cost aspects associated with the various Alternatives into consideration in addition, the results is an even stronger justification for the leave in-place Alternative.

# 10 IMPACT ASSESSMENT FOR SEABED DEBRIS

## 10.1 Description of Alternative

Offshore operations sometimes result in the loss of items, large or small, from ships or installations in extreme weather or due to accidents during operations. Each year therefore, under the direction of the Norwegian Petroleum Directorate, a clean-up operation is conducted on specified parts of the continental shelf.

Once operations terminate on a field it is natural to expect to find various foreign objects cluttering the seabed. Their extent – number, size and nature – is difficult to predict.

After disposal activities in the Ekofisk Area are complete, the sea bed in the area will be surveyed so that identified debris can be removed. The latest data from the NPD clearance work suggest that a combined survey and clearance operation is envisaged. This could be done after termination of Ekofisk II in the case of the Ekofisk Center and after each steel jacket is removed in the case of the outlying platforms. In all the campaign is expected to take about three weeks on the Ekofisk Center, with about three days being used for each outlying field.

The area will be cleared so that no impediments remain that can snag fishing gear.

## 10.2 Environmental Impacts

No negative environmental impacts are anticipated from clearance of the seabed. The measure is by its nature a positive contribution to the environment as it eliminates a potential source of litter.

Energy consumption and emissions to atmosphere from the vessel will be limited as the operations will only last a total of a few weeks and only involve a single vessel.

## 10.3 Societal Impacts, seabed debris

### 10.3.1 Impacts on fisheries

As mentioned in the assessment of leaving the pipelines in-place, foreign objects, debris and rubbish on the seabed represent a risk of snagging fishing implements and damaging them. Clearance of debris on the seabed at Ekofisk is therefore considered an exclusively positive measure in relation to fishery interests in the Ekofisk Area.

### 10.3.2 Impacts on free passage

Clearance of debris on the seabed will mean that one (or more) vessels are working in the area where the installations have been removed for a short period (days or weeks). The consequences of this for free passage are deemed «none/insignificant».

### 10.3.3 Impacts on personnel safety

Impact on safety from removal of debris is considered «insignificant».

### 10.3.4 Costs and national supplies (goods and services)

After the fixed installations and, as the case may be, the pipelines and cuttings are removed from Ekofisk, the debris – trash and scrap left lying on the seabed – will be recovered using suitable recovery vessels. The total costs of this clean-up operation are estimated at about 66 million kroner.

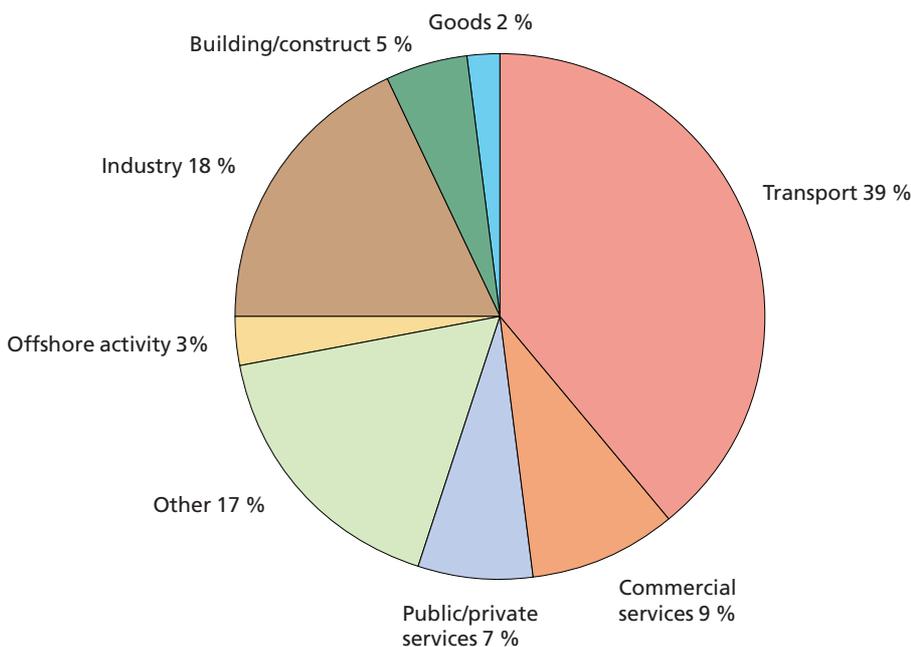
Cost Components	Total investment	Norwegian content %
Project adm. and engineering	3	100
Removal of debris	63	100
<b>Total</b>	<b>66</b>	<b>100</b>

**Table 43**  
Seabed debris removal: Costs and Norwegian content broken down by cost component, (mill. NOK, 1998 costs)

It is anticipated that the work of cleaning up the seabed is done by Norwegian vessels.

### 10.3.5 Employment effects

Clean-up of the seabed can provide a basis for about 60 man-years of employment measured in production effects. In addition there are the consumer effects, to that the total employment may be about 100 man-years.



**Figure 64**  
Clean-up of seabed – national production effects broken down by industry (man-years)

Clearing up the seabed will largely result in production effects within Norwegian ship operators.

### 10.4 Summary for Seabed

As there is only one solution for debris on seabed a comparative assessment is meaningless.

Removal of debris has no significant negative environmental consequences.

Also from a societal viewpoint, the impact of such an action will be only viewed as positive. A short summary of the consequences follows below:

Issues	V Debris on seabed
Impacts on fisheries	Small positive
Impacts on free passage	None/insignificant
Costs (billion Norwegian kroner 1998 values)	0.07
Norwegian content (bill. kroner and %)	0.07 (100%)
Employment (man-years)	100

# 11 BASIS FOR THE RECOMMENDED DISPOSAL SCENARIO

## 11.1 Description of the Recommended Disposal Scenarios

The recommended Disposal Scenario, comprised of the selected Disposal Alternative for each Entity (Figure 65) and the corresponding timing of each disposal activity (Figure 66), is the result of an overall evaluation of the technical, safety, environmental, social and economic aspects of each Alternative, as well of the needs of other users of the sea and the physical and operational limitations in the Ekofisk Area.

The PNG recommends the Disposal Alternatives highlighted in colour below.

**Figure 65**  
Recommended Disposal Alternatives are shown in colour

Entities	Alternatives Assessed				
<b>I Topsides</b>	<b>A</b> <i>Jacket Topsides:</i> Lift and Transport to shore for recycling <i>Tank Topsides:</i> Lift and transport to shore for recycling		<b>B</b> <i>Jacket Topsides:</i> Lift and transport to shore recycling <i>Tank Topsides:</i> Remove at shore & recycle after tow to shore on substructure		
<b>II Substructures</b>	<b>A</b> <i>Jackets:</i> Reef in-place  <i>Tank:</i> Reef in-place	<b>B</b> <i>Jackets:</i> Reef at Tank  <i>Tank:</i> Reef in-place	<b>C</b> <i>Jackets:</i> Remove for onshore recycling  <i>Tank:</i> Leave in-place	<b>D</b> <i>Jackets:</i> Remove for onshore recycling  <i>Tank:</i> Refloat and Deposit deep water	<b>E</b> <i>Jackets:</i> Remove for onshore recycling  <i>Tank:</i> Refloat and recycle
<b>III Pipelines</b>	<b>A</b> Remove to shore for recycling of materials		<b>B</b> Leave buried in-place		
<b>IV Cutting Piles</b>	<b>A</b> Remove, slurrify and reinject in waste well	<b>B</b> Removal to shore for disposal	<b>C</b> Leave in-place	<b>D</b> Cover with gravel	
<b>V Seabed</b>	Remove Debris				

The recommended Alternatives are based on the use of proven North Sea technology. Due to the large volume of work, disposal activities are divided into four campaigns: (1) Ekofisk Center North Topsides, (2) Ekofisk Center South Topsides, (3) Outlying Field Topsides, and (4) Jackets. Each campaign will have a duration of about 3–5 years (see Figure 66 below):



- Provision of a moderate and long term work load.
- Provision of a flexible framework to which additional platforms from Ekofisk which become redundant may be added to the disposal program (such as 2/4 W, 2/4 K and 2/4 C).
- Extends window of opportunity for further or other use, in-place or at another location.
- Allows time for development of new or improved removal methods and tools.

## 11.2 Reasons for the Recommended Scenario

The main reasons for selecting the chosen Disposal Alternatives and the recommended timing for each Entity are summarised in the following Sections.

### 11.2.1 Topsides Facilities

#### Reasons for the recommended Disposal Alternative

The PNG recommend that the topsides be taken to shore for disposal, where components will be reused and recycled to the extent possible. As OSPAR Decision 98/3 does not generally allow in-place disposal of topside facilities, no other Alternatives have been assessed.

The PNG also concludes that removal by reverse installation is at present the preferred method and will not pose extreme difficulties.

The module support frame (between the jacket and topside modules), which, according to OSPAR Decision 98/3, also forms part of the 'topside', will likewise be taken to shore for disposal.

The concrete deck on the Tank is a cast in-place concrete construction forming an integral part of the substructure. It would be difficult and costly to remove the structure without damaging the remaining parts of the substructure, and therefore it is recommended to be left in-place as part of the substructure.

The steel deck stiffens the columns supporting the concrete deck and cannot be removed without reducing the structural integrity of the concrete deck. Further, the steel deck supports the bridges, which may be used to strengthen the Screen Wall in-fill panels, thereby extending the time which the Screen Wall can be safely used to support the navigation aids. For these reasons, it is therefore recommended to leave this deck on the Tank in-place.

#### Reason for the recommended timing

The topsides are recommended removed between 2003 and 2015 in 3 separate and continuous removal campaigns. The amount of work per campaign allows some scheduling flexibility. The scheduling flexibility gives the following benefits:

- Implementation of new (single lift) technology on topsides.
- Co-ordination with other disposal projects in the North Sea.
- Regulation of overall activity volume and hence costs.

The topsides technically could be removed earlier than recommended. This, however, would compress schedules and increase costs. Compressed schedules would also in general have a negative impact on safety. The



topsides could also be removed later than recommended if the subsidence rate decreases. An ongoing review of cold phase maintenance costs may also affect the composition or scheduling of the identified campaigns.

An early removal of the topsides in separate campaigns prior to removal of the jackets will enable the configuration of the cement grouted jacket piles to be investigated, thereby improving the cost efficiency of jacket cutting operations in the subsequent jacket removal campaign.

The bridges on Ekofisk Center South cannot be removed before 2012 because of the need for access to 2/4 W, an Ekofisk II platform, via 2/4 C, 2/4 Q and 2/4 FTP.

### 11.2.2 Jacket Substructures

#### Reasons for the recommended Disposal Alternative

After a thorough evaluation of the relevant Alternatives in accordance with the identified assessment issues and criteria, the PNG recommend the jackets be taken to shore for disposal by reuse or recycling. The presently preferred method is by subsea sectioning and retrieval by crane vessel.

The only short-listed Alternative to onshore disposal is use of the steel jackets as artificial reefs. The reef Alternatives are considerably less costly than the onshore Disposal Alternative and result in less energy consumption, a lower Total Energy Impact, and fewer atmospheric emissions. The benefits and success of artificial reefs varies throughout the world. Predominantly, artificial reefs are used for fisheries management and enhancement. In such areas as Japan, they are frequently used to increase fish production and fishing efficiency. Other countries, such as Italy, have used the benefits of artificial reefs in the area of habitat protection. Successful artificial reef building and use has existed off the east coast of the United States and the Gulf of Mexico since the mid-1950's. The use of platform jackets as reef further popularized the idea in these areas, and today, jackets re-used as artificial reefs are seen often to increase fish stock and promote recreational activities. However, the short and long-term benefits to the fishing industry in the North Sea are uncertain at this time due to lack of presently available data. Further, trawl fishers do not support artificial reefs, as they view reefs as a hindrance to trawling. Line fishers are more positive to artificial reefs, but constitute a smaller proportion of the Norwegian fishing industry. The future liability issue for artificial reefs is also uncertain.

#### Reason for the recommended timing

All the jackets are recommended removed in one removal campaign in 2015–2018, following the completion of the final topside removal campaign. The jackets will be marked with navigation aids for long periods of time after the topsides have been removed.

A separate removal campaign for the jackets has the following justifications:

- The leg pile configuration will be known; once the topsides are removed, the configuration can be determined and jacket cutting and removal operations planned for accordingly.
- More time will be available for implementation of new technology, which specifically can be designed for jacket removal.
- More time will be allowed for gathering knowledge on fishing reef alternatives if desired by the Authorities or fishing organisations.



- The drill cutting piles, which are diminishing with time, will be smaller and less dispersion of potential contaminants is therefore foreseen during removal of jackets.
- Jacket removal possibly can be co-ordinated with removal of other license group's redundant jackets

### 11.2.3 Concrete Substructure (2/4 Tank and Barrier)

#### Reasons for the recommended Disposal Alternative

Based on an overall evaluation, the PNG conclude that leaving in-place is the best Disposal Alternative for the concrete substructure. The technical risks, risks to personnel and property, environmental impacts and costs were of particular importance in the evaluation.

Through comprehensive studies the PNG have identified a potentially theoretical method of *total* removal of the Tank. However a combined refloat would involve untried methods, high risks and very high costs. An alternative method – reverse installation by three separate refloat operations – was found to be more weather dependent and represented additional and greater risks for the Ekofisk II installations than combined refloat.

A combined refloat would require formation of a watertight connection at the base between the Tank and the Barrier. It would not be possible to obtain an acceptable confidence level that a refloat attempt would succeed until the end of the preparatory phase, and after two billion kroner had been expended on engineering, inspection, measurements, testing and trials.

Even after all the preparatory work and expenditure, studies performed by DNV conclude that the probability of failure after lift-off due to lack of watertightness would remain high. The DNV risk studies conclude that the probability of failure after lift-off due to lack of water-tightness has an estimated order of magnitude (even after application of risk reducing measures) of 1 in 500, mainly due to the difficulties associated with material verification. Construction defects in the Barrier Wall (laminations) contribute to the failure probability.

The high probability of failure would limit the possibility of using personnel on board to service ballasting equipment during lift off, and would substantially increase the risk for those personnel who must be on board during the refloat attempt.

The proposed method of removal has never before been attempted. The effect of a large leak during lift-off as well as aspects associated with subsequent tow-away may, despite all efforts to minimise risk, also affect the nearby Ekofisk II platforms, with potentially very large negative consequences for personnel, Ekofisk production and facilities, and the environment.

Despite the implementation of risk reducing measures in all phases of the refloat and removal operation, it has not been possible to reduce the technical risk to an acceptable level.<sup>19</sup>

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<sup>19</sup> As a result of the extensive and severe consequence of an event affecting Ekofisk II, the acceptance criterion for probability of occurrence for such an event is set to  $10^{-5}$  (1 in 100,000). This is somewhat more severe than the criterion set for an event which only affects the concrete substructure which is  $10^{-4}$  (1 in 10,000) with loss of life, and  $10^{-3}$  (1 in 1000) without loss of life. These criteria are in line with current offshore practice.

The cost of removing the concrete substructures by refloat would be substantial. Removal of the Tank could also reduce the operating lifetime of the 2/4 C platform, which is shielded from waves from the north by the Tank structure. Depending on the subsidence rate, a removal of the Tank-Barrier would result in 2–6 years lost production at 2/4 C due to the increased wave heights.

The Impact Assessment concludes that disposal in-place of the concrete substructure has a far better environmental profile than total removal by refloat for reuse, recycle or deep sea deposit. The PNG's recommended Disposal Alternative for the Tank has the best Total Energy Impact of all the Tank Disposal Alternatives, approximately 50% less than the refloat Alternatives (1.2 million GJ for leaving the Tank in place vs. 2.4 million GJ for refloat and recycle, and 2.5 million GJ for refloat and deep sea deposit). The recommended Disposal Alternative for the Tank will also result in the lowest atmospheric emissions of all Alternatives, even when one considers indirect emissions from replacing steel not recycled from the Tank. The solution has 50% lower CO<sub>2</sub> emissions than the refloat/removal options (92,000 tonnes for leave in place, 180,000 tonnes for deep sea disposal, and 195,000 tonnes for recycle onshore). Leave in place also has an even more significant effect on the NO<sub>x</sub> emissions, due to the high NO<sub>x</sub> emissions associated with marine operations: leaving in place results in 93% lower NO<sub>x</sub> emissions than removing and recycling (190 tonnes for leave in place and 2800 tonnes for remove and recycle onshore). Onshore recycling of the Tank would result in «large negative» aesthetic impacts due to odours (from marine fouling), noise and especially spread of dust (from onshore demolition and crushing of the concrete). In the case of recycling the Tank, the concrete will probably not have any commercial value. Crushed concrete may be recycled, however, most probably it will need to be consigned as waste.

The conclusion is that in-place disposal is clearly more favorable than a refloat.

Leaving the Ekofisk Tank in place will have no effect on shipping or fisheries until at least the end of Ekofisk II operations in 2028 or beyond, as the Tank is located close to the active Ekofisk II installations and thus within an established safety exclusion zone. After termination of Ekofisk II operations, the Impact Assessment concludes that the recommended substructure Disposal Alternative results in release of 24 out of a total of 25 sq.km, with only the Ekofisk Tank remaining as a limited risk to shipping. However, the configuration of the proposed left in-place structure will take into account the need for continued safe access to navigation aids, in particular navigation aids to assure safe navigation for passing ships as well as aviation warning lights on the Screen Walls for helicopter traffic to Ekofisk II operations. The latest subsidence predictions indicates a dramatic reduction in subsidence rates, and indicate that the Screen Walls (where the navigation aids are located) will remain intact beyond the end of Ekofisk II operations. If the Tank or Screen Wall can no longer be safely accessed, navigation lights will be provided on buoys around the structure. The Impact Assessment concludes that the recommended Disposal Alternative for the Tank – leave in place – represents a small to moderate risk of collision (one collision every 90,000 years), and thus an overall «small negative» impact on free passage. The effect of leaving the Tank on fisheries has been assessed as being more of a physical nuisance than a significant economic detriment.

In an earlier stage of the short-listing process, the PNG studied *partial*

removal of the Tank by in-place demolition studied as an alternative to complete removal. Partial demolition using explosives is theoretically possible, but should not be attempted until after the end of Ekofisk II operations. Based on the current lack of experience with these techniques, this method was considered at present unproven, and thus not assessed further.

#### **Reason for the recommended timing**

After removal of the topsides from the Ekofisk Tank, the Screen Wall (the upper part of the PBW) and in-fill panels will, if necessary, be maintained to prevent a structural failure affecting the safety of operations at 2/4 C, and the integrity of the 2/4 C bridge link to 2/4 H and/or 2/4 W. Navigation aids will be maintained on the Screen Wall and/or concrete deck for as long as safe access is ensured. The revised subsidence forecasts indicate that this will be possible at least to the end of Ekofisk II operations (i.e. after 2028). Floating navigation aids are premised after safe access to the Screen Wall and/or decks can no longer be assured.

### **11.2.4 Pipelines**

#### **Reason for the recommended Disposal Alternative**

There are no significant negative aspects associated with leaving the pipelines in-place. The pipelines are cleaned and buried by 1m or more and will remain buried and eventually degrade. They represent no impediment to shipping or fishing activities, nor any physical environmental impacts, impacts on habitat or aesthetic effects.

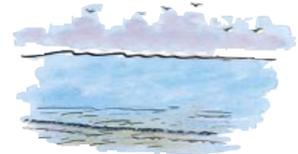
Removing pipelines, on the other hand, has many negative effects. The Total Energy Impact for removal and recycle of the pipelines is much higher than for leaving the pipelines in-place, and removal would cause 120 times the amount of CO<sub>2</sub> emissions than leaving the pipelines in place. The many man-hours required increases the overall PLL («possible loss of life») from essentially zero for the leave in place Alternative to 10%. The removal operations would cause «small negative» discharges to the sea due to re-suspension of sediments and «small negative» physical impacts due to disturbances of the seabed. Removal would also result in generation of substantial quantities of waste, and the costs are significantly higher than the leave-in-place Alternative.

Once the jackets are removed, fishing vessels can trawl over the area, and therefore the PNG recommends the pipeline ends be covered with gravel in order to avoid interference with potential trawling operations.

#### **Reason for the recommended timing**

The PNG recommend the pipeline ends be covered with gravel after jacket removal, since the safety zones will remain in force until the jackets are removed.

Upheaval buckling of the pipelines (due to subsidence) could occur near the Ekofisk Center as long as the Ekofisk Field is in operation. Since the Ekofisk Center is in a «no trawl» zone, any buckled pipelines protruding the sea bottom prior to the end of the field's lifetime will not have any detrimental effects on fishing. Once production ceases, subsidence will stop, thus eliminating the buckling effects. The PNG recommends any buckled pipeline sections be covered with gravel after the area is no longer classified as a «no trawl» zone. The PNG will perform inspections of the pipelines in the subsidence area at regular intervals through the Ekofisk II lifetime.



### 11.2.5 Drill Cuttings

#### Reason for the recommended Disposal Alternative



Environmentally acceptable techniques for retrieving the drill cuttings have not been identified. The environmental effects of retrieving drill cuttings using today's techniques are negative, and costs of removal are very high (estimated cost of 700 million Norwegian kroner). Based on today's knowledge, the environmental consequences of leaving the drill cuttings in place is assessed as a good disposal solution. The PNG thus recommend the drill cuttings be left in-place.

The PNG proposes that one of the more representative drill cuttings piles (2/4 A) and the surrounding area is monitored to provide further data for research on the subject of drill cuttings. The results of the monitoring will be shared with ongoing drill-cuttings (UKOOA and OLF studies). Based on our knowledge of the Ekofisk I piles, the PNG are of the opinion that the recommended option (leave in-place) will be the best alternative for the Ekofisk I drill cutting piles.

The leave in-place alternative avoids damage to the drill cutting piles, avoids dispersion upon retrieval, and avoids contamination of a final disposal site if the drill cuttings are removed. The risk of an environmental impact from natural erosion of the cuttings piles over a long period is assessed as less than the sudden impact a retrieval would cause. The leave in-place alternative also allows sufficient time for any hydrocarbon present in the piles to biodegrade.

#### Reason for the recommended timing

The drill cuttings need not be disturbed until the jackets are removed. By that time their size will be reduced significantly, probably to the extent that the piles will not represent a technical or environmental problem with the sub-sea cutting operations when the jackets are removed.

### 11.2.6 Seabed Debris

#### Reason for the recommended Disposal Alternative

It is a Norwegian regulatory requirement to clear seabed debris from the seabed.

#### Reason for the recommended timing

To avoid repetition of operations, the PNG recommend the seabed in the vicinity of platforms are cleared of debris after all other disposal operations are completed.

## 11.3 Consequences of the Recommended Disposal Scenario

The consequences of the recommended Scenario are briefly summarised below. There is also a discussion of the solution in relation to the international guidelines and agreements.

### 11.3.1 Environmental impacts

The recommended Disposal Scenario involves the total energy consumption of some 7.6 million GJ, which is 35 per cent above the optimal energy solution, and 35 per cent less than the most energy-intensive solution.

The Total Energy Impact for the Recommended Scenario is 9.7 million GJ, which has the lowest Total Energy Impact of all potential Scenarios (17 per cent below the Scenario with the highest value).

The total emissions of CO<sub>2</sub> are 580,000 tonnes, spread over a period of about 15 years. This is 36 per cent less than the Scenario having the highest CO<sub>2</sub> emissions and 18% more than the Scenario with the lowest emissions.

The corresponding figure for NO<sub>x</sub> is 9,100 tonnes, a saving of 30 per cent relative to the Scenario with heaviest emissions. The Scenario has SO<sub>2</sub> emissions of 970 tonnes, 35 per cent less than the Scenario with the highest SO<sub>2</sub> emissions.

The Scenario will not have any discharges of any size into the sea.

Any effects on habitats and other physical effects are purely marginal.

Aesthetic impacts will largely be caused by noise in connection with the demolition process for the jackets and topsides. Compared with other Scenarios, potential problems associated with dust are avoided, and the scope of noisy activities is reduced.

The recommended Scenario will result in the recycling of about 160,000 tonnes of steel. A total of about 15,000 tonnes of waste will require disposal, about half of which will be marine growth.

Leaving the pipelines buried in-place is not expected to have a genuine litter impact. Disintegration of the gravity base of the Tank left in-place will take place so slowly that no sizeable litter problem is expected to ensue.

Leaving the drill cuttings in-place under the steel jackets has been found to be the best Alternative from an environmental perspective. This is due to the low risk of leaching and spreading of potential contaminants, as well as the lack of any environmentally sound alternatives.

The seabed will be cleared of debris when disposal operations are completed.

### 11.3.2 Societal impacts

For fisheries, the recommended Disposal Scenario results in a substantial increase in available area for fishing. The only remaining Ekofisk I obstacle will be the Ekofisk Tank substructure. The recommended Disposal Scenario is considered overall to be a good solution for fishing.

For shipping, the left in-place Tank will represent the only remaining risk factor. The risk will be very small and the installation will be properly marked with navigation aids to reduce the chances of dangerous situations developing.

The total Potential Loss of Life (PLL) for the chosen scenario is 0.45, which means that there is a 45% probability that life will be lost in the activities connected with removal. Other alternative scenarios have PLLs ranging from 0.68 to 0.37.

The total cost of the recommended Disposal Scenario is 8.0 billion Norwegian Kroner (NOK), which is NOK 3 billion more expensive than the least costly Scenario, and NOK 6.6 billion less costly than the most expensive Scenario.

The recommended Scenario has a Norwegian content of about 41–50 per cent. In fact, all Scenarios have Norwegian contents of roughly 50 per cent.

Altogether, the Scenarios will result in 5,700 man-years of direct or indirect employment effects. Spread over the four disposal campaigns, this translates into an annual employment effect of 200–500 jobs per year.

## 11.4 Legal considerations

The recommended Disposal Scenario was arrived at in compliance with Norwegian petroleum legislation, which requires a case-by-case analysis of all aspects of the Disposal Alternatives. The recommendation is also consistent with international guidelines.

The licensees recommend that the Tank and Barrier Wall be adequately marked to ensure safety of navigation, and that the structure be disposed of in-place. This solution is justified by an overall evaluation of all relevant factors, including environmental, safety, and economic factors, and is thus consistent with the OSPAR Decision 98/3 which, inter alia, allows disposal in-place of concrete installations when the relevant coastal state finds significant reasons for such a solution. The solution for the Ekofisk Tank is also consistent with the advisory IMO Guidelines. To ensure the continuous operation of navigation aids and thus the promotion of maritime safety, a maintenance program will be implemented, satisfying the IMO Guideline maintenance recommendation.

## 11.5 Monitoring, mitigation and follow-up activities.

One of the aims of an impact assessment is to propose measures, based on the identified impact levels, that are designed to mitigate negative impacts and enhance positive impacts, and to propose follow-up and monitoring activities in instances where present understanding of the processes involved is uncertain.

Below is a brief summary of measures and follow-ups that are recommended and will be planned for.

### **Recommissioning, re-use and investment recovery**

The work to market and prepare whole or parts of installations for resale will continue. The goal is to optimise use of existing resources to reduce overall disposal costs, and increase potential economic benefits.

The recommissioning or re-use options will also be reflected in the contract strategy for removal. Resources will be used, for instance, in studies and trials of alternative removal methods that do not rely on heavy-lift technology. Optimisation and disposal schedules are crucial for attainment of cost-effective solutions.

### **OSPAR consultations**

The recommended solution for the Ekofisk Tank makes it necessary to enter into a round of consultations under the OSPAR framework. This process will be directed by the Norwegian State, but technical assistance will be provided by the field operator.

### **Information**

There are plans to follow-up the issues in the public sphere in the form of an open communications strategy. The motivation is found in the Cessation Project goals, which state, in part, that the chosen solution shall be acceptable to the Norwegian and international community. The strategy will thus ensure that correct and adequate information is provided in relation to the needs of society.

### **Onshore demolition**

For demolition, emphasis will be given to the choice of a location with a view to mitigating possible aesthetic impacts. This includes evaluations of noise and proposals for monitoring and abatement. Focus will be placed on such factors in the contract strategy.

Marine growth on jackets will be handled in a manner that avoids problems with odors. Procedures for dealing with growth will therefore be developed.

### **Monitoring pipelines**

Regular visual inspections will be made of pipelines. The aim is to detect exposed sections.

If exposed sections are found, suitable countermeasures will be put into effect. These include removal, burial, and covering. The timing of mitigating actions will be assessed in relation to the location, the safety zone, and other activities in the vicinity.

### **Monitoring cuttings**

A program to monitor the cuttings piles has been established. The drill cuttings pile under the Ekofisk 2/4 A platform was chosen (from among the seven Ekofisk I drill cuttings piles) as this pile was found to be best suited for this purpose. Monitoring started in 1999 and includes 16 stations at 2/4 A. Analyses of the sediment samples include metals, organic content, oil components, benthic fauna and grain size distribution.

The details of the monitoring program will further be developed in consultation with the Norwegian Pollution Control Authority (SFT).

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# APPENDIX A      DEFINITIONS AND ABBREVIATIONS

## Definitions

Some terms in the ECP decision making process have specific meanings. These terms are defined in the following:

### **Ekofisk Center (or Ekofisk Complex)**

The following platforms (tied together with bridges) with associated tripods/flares;

2/4 R, 2/4 S, 2/4 G, 2/4 T, 2/4 P, 2/4 C, 2/4 H, 2/4 X, 2/4 J, 2/4 Q, 2/4 FTP, 2/4 W, North Flare and South Flare

### **Entities**

In this document: Topsides, Jackets, Tank and Protective Barrier Wall (PBW), infield pipelines, drill cuttings, and the seabed debris are referred to as the individual «Entities».

### **Disposal**

A process and/or agreement which brings an Entity to the final location(s) where it is re-used, re-cycled or deposited.

### **Disposal Alternatives (or Alternatives)**

«Disposal Alternatives» are specific disposal solutions for each Entity.

### **Disposal Scenario (or Scenario)**

The «Disposal Scenario» is an overall disposal solution for all of Ekofisk I Entities, covering the recommended Disposal Alternative for each Entity and the recommended disposal timing for each Entity.

### **Disposal Campaign**

A «disposal campaign» covers a collection of the total scope of entities or parts of entities to be disposed of in a given time period.

### **Decommissioning**

Activities relating to bringing the platform from an operating condition to a cold, hydrocarbon free condition (does not, as is sometimes understood, include activities relating to removal or other methods of disposal).

### Selection Issues

The Disposal Alternatives for each Entity are assessed with respect to six main selection issues:

- Safety
- Environment
- Cost
- Public Opinion
- Fishing Industry
- Shipping Industry

### Substructure

The part of a fixed platform installation founded on the sea bed, and supporting the topside over the wave zone.

### Stortinget

Norwegian Parliament

### Abbreviations

ECP	-	Ekofisk Cessation Project
ENGO	-	Environmental non-governmental organisation
FAR	-	Fatal accident rate
FD	-	Ministry of Finance
FID	-	Ministry of Fishery
GBS	-	Gravity Base Structure
HLV	-	Heavy lift vessel
IA	-	Impact Assessment
IR	-	Investment Recovery
KRD	-	Ministry of Local communities and Regional issues
LTA	-	Lost time accident
MPE	-	Ministry of Oil and Energy
MD	-	Ministry of Environment
NGO	-	Non-governmental organisation
NOK	-	Norwegian Kroner
NPV	-	Net Present Value
OLF	-	Oljeindustriens Landsforening
PBW	-	Protective Barrier Wall
PLL	-	Potential loss of life
PNG	-	Phillips Norway Group
PPCoN	-	Phillips Petroleum Company Norway
ROV	-	Remotely Operated (sub-sea) Vehicle
SSCV	-	Semi-submersible Crane Vessel