Frigg Field Concrete Substructures

An Assessment of Proposals
for the Disposal of the Concrete Substructures
of Disused Frigg Field Installations
TCP2, CDP1 and TP1

TOTAL FINA ELF
TotalFinaElf Exploration Norge AS

Frigg Field Concrete Substructures

An Assessment of Proposals for the Disposal of the Concrete Substructures
of Disused Frigg Field Installations TCP2, CDP1 and TP1

6 August 2002

TotalFinaElf Exploration Norge AS

TotalFinaElf Exploration UK PLC

TotalFinaElf Exploration Norge AS, Post Office Box 168, 4001 Stavanger, Norway

Preface

The Frigg Field is unusual in that it spans the border between the Norwegian and UK sectors of the North Sea. One concrete and two steel platforms are located in Norwegian waters and two concrete and one steel platform are in UK waters. In accordance with the principle of adopting a common approach to the decommissioning of the Frigg Field, this document is presented jointly by the governments of Norway and UK to the OSPAR Contracting Parties for consultation.

The licensees of the Frigg Field are proposing to the competent authorities of Norway and UK that, apart from the concrete substructures, all the facilities at the field should be removed and brought to shore for reuse and recycling. This includes: the topsides and substructures of the three steel platforms (one of which was damaged during installation and has no topsides); the topsides and external steel work of the concrete substructures and all the infield pipelines and cables. The three concrete substructures, which it is proposed should be left in place, will be suitably marked.

In reaching this proposal, TotalFinaElf Exploration Norge AS, as the operator of the Frigg Field, has carried out a full and thorough comparative assessment of disposal options for the concrete substructures. The assessment was undertaken strictly in accordance with national regulations and Annex 2 to OSPAR Decision 98/3.

This document summarises the work carried out by TotalFinaElf Exploration Norge AS on behalf of all the Frigg Field Licensees. A full description of all the studies and evaluations supporting this assessment may be found in the Frigg Field Cessation Plan, which is available on the web at: www.totalfinaelf.no/cessation

Roman Gozalo
Managing Director
TotalFinaElf Exploration Norge AS

Contents

1. Introduction

In accordance with the provisions of OSPAR Decision 98/3, this assessment is provided to demonstrate that there are significant reasons why leaving the concrete substructures of Frigg Field platforms TCP2, CDP1 and TP1 in place is preferable to reuse or recycling or final disposal on land.

The Frigg Field lies in both the Norwegian and UK sectors of the North Sea. In accordance with the practice followed during the development and operation of the field, a common approach has been adopted to the decommissioning of the Frigg Field facilities, whilst respecting each nation's legislation. This document therefore assesses disposal alternatives for the concrete substructures located in both the Norwegian and UK marine areas.

This assessment is based upon the information contained in the Frigg Field Cessation Plan submitted by TotalFinaElf Exploration Norge AS, on behalf of the Frigg Field Licensees, to the governments of Norway and the United Kingdom.

The Frigg Field Cessation Plan has been based upon studies carried out in the period from 1999 to 2001. Independent experts from many European countries have provided input to the studies, and have verified the results and conclusions. The studies undertaken have been based upon scientific principles and have been carried out by particularly experienced personnel, using the latest techniques.

An integral part of the studies and assessments has been a process of public consultation and dialogue, which TotalFinaElf Exploration Norge AS has conducted, principally in Norway and UK. This process has allowed an open exchange of ideas and concerns between the Frigg Field Licensees and interested parties in both countries.

Except where specifically noted in the text, the name "TFEE Norge" has been used in this document to mean TotalFinaElf Exploration Norge AS. In accordance with common practice, the abbreviation UK has been used throughout this document to refer to the United Kingdom of Great Britain and Northern Ireland. National flags are used at specific locations in the text to denote the location of the concrete substructure being considered.

2. Summary

2.1 THE FRIGG FIELD

The Frigg Field is a natural gas reservoir, with associated condensate, that extends across the median line between the Norwegian and UK sectors of the North Sea Continental Shelf. The Frigg Field facilities now consist of five fixed installations together with infield pipelines and cables. In addition, the DP1 steel substructure, which was damaged during installation in October 1974, is still in place in the field. Gas production from the field started in 1977 and is expected to be shut down in 2004.

The location of the Frigg Field is shown in Figure 3.1. Three of the Frigg Field installations are located in UK Block 10/1 and three of the installations are in Norwegian Block 25/1. The platforms were installed in the period 1974 to 1977. None of the concrete substructures were designed for removal.

The UK registered installations are:

- Concrete Drilling Platform 1 (CDP1)
- Treatment Platform 1 (TP1)
- Quarters Platform (QP)

The Norwegian registered installations are:

- Treatment and Compression Platform 2 (TCP2)
- Drilling Platform 2 (DP2)
- Drilling Platform 1 (DP1)

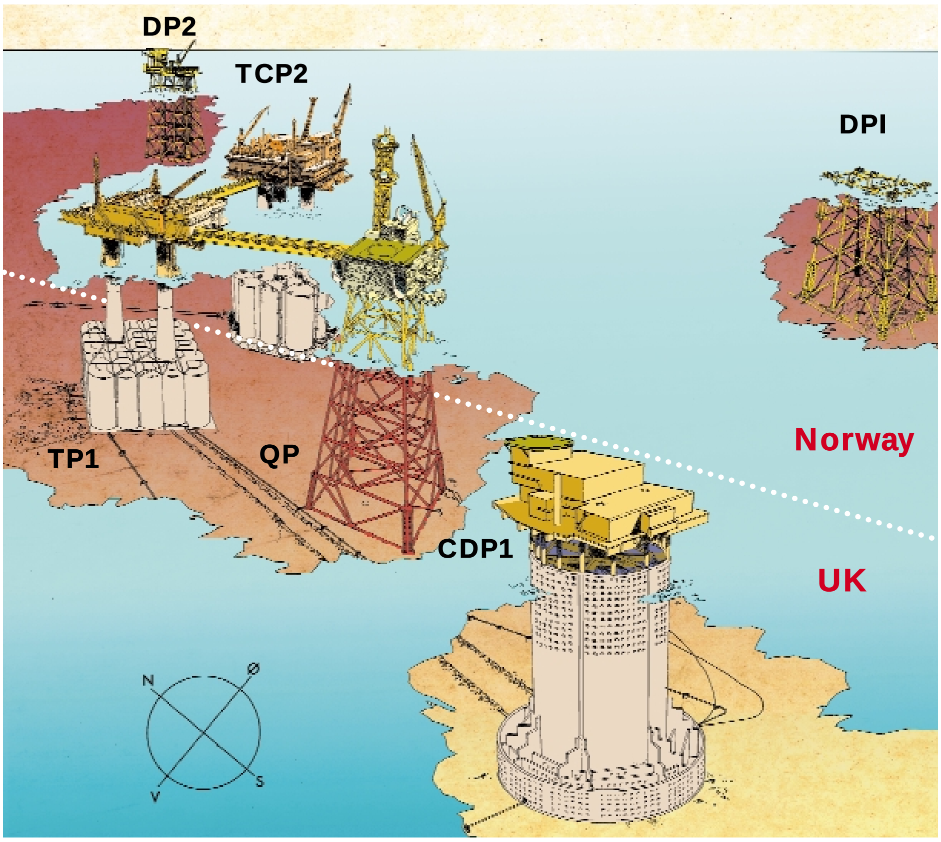


Figure 2.1 Frigg Field Facilities to be Decommissioned with the Border Line Indicated

2.2 DISPOSAL PLAN FOR FRIGG FACILITIES

TFEE Norge, on behalf of the Frigg Field Licensees (see Section 3.1), has prepared a disposal plan for the Frigg Field facilities as a whole, which has been submitted to both the Norwegian and UK governments for consideration. This disposal plan, together with an environmental impact assessment of the various disposal alternatives, has been presented in a common document entitled **"Frigg Field Cessation Plan"** (see first reference in Section 9).

The topsides of all the Frigg Field Platforms and the steel substructures of DP2, QP and DP1 are planned to be removed and transported to shore for deconstruction. The infield pipelines and cables between the platforms are planned to be retrieved and transported to shore. As much as practicable of the materials and equipment brought to shore will be reused or recycled. It is proposed that the drill cuttings within the concrete substructure of CDP1, and on the seabed around DP2 (maximum thickness 20cm), are left in place and not disturbed, apart from where necessary to cut the steel foundation piles of DP2.

It is proposed that, after the necessary preparation (see Section 6), the concrete substructures of TCP2, CDP1 and TP1 should be left in place.

This document contains an assessment of the proposal that these concrete substructures should be left in place. The assessment has been prepared in accordance with the framework set out in Annex 2 of OSPAR Decision 98/3. Each substructure has been individually considered.

The requirements of the 1992 OSPAR Convention and OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations have been fully complied with during the assessment of disposal alternatives and will continue to receive the highest priority throughout the decommissioning work. The studies, which form the basis of this assessment, have been undertaken by independent specialists and have been the subject of peer review by experts from a number of European countries (see Section 9).

2.3 PUBLIC CONSULTATION AND DIALOGUE

In 1999 TFEE Norge initiated a process of consultation and dialogue with stakeholders, which has included many different activities, as described in Section 5.1.3. This process has been similar in Norway and UK whilst respecting the particular national regulations. Particular efforts have been given to seeking the views, and sharing information with, different stakeholder groups. The comments and suggestions of stakeholders have been very useful in determining the content and direction of the studies and in assessing the results. Information will continue to be provided to stakeholders throughout the decommissioning work.

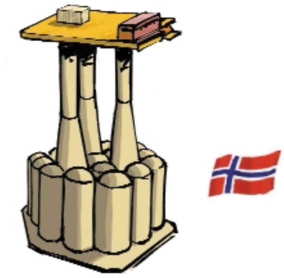
2.4 COMPARATIVE ASSESSMENT FINDINGS

Overall Conclusion

Based upon an assessment conducted in accordance with the provisions of OSPAR Decision 98/3 (see Section 5), it is concluded that there are significant reasons why leaving the concrete substructures of TCP2, CDP1 and TP1 in place is preferable to reuse or recycling, or final disposal on land.
The main reasons for reaching this conclusion for the concrete substructures are detailed below.

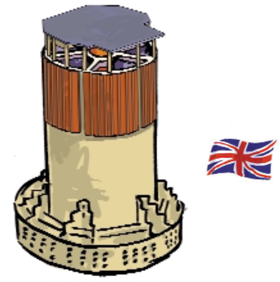
Technical Feasibility of On Land Disposal of TCP2

There is a significant degree of uncertainty regarding the strength and integrity of the concrete substructure of TCP2 and the ballast pipework during the refloating operations. There are also a number of significant uncertainties associated with the method of freeing the substructure from the seabed and its movement as it comes free. The probability of a major accident or incident during the refloating operations has been estimated as between twenty to forty times higher than the acceptance criterion for marine operations.



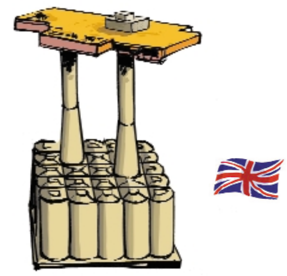
Technical Feasibility of On Land Disposal of CDP1

The main uncertainty relating to the possible refloat and onshore disposal of CDP1 is the water tightness of the substructure. There is a significant probability of leakage, either through the cofferdam (that has to be installed to seal the holes in the outer wall), or through ineffectively closed penetrations, broken pipes or cracks in the walls and base slab of the substructure. The probability of a major accident or incident during the refloating operations has been estimated as approximately three hundred times higher than the acceptance criterion for marine operations.



Technical Feasibility of On Land Disposal of TP1

The main areas of concern relating to the possible refloat of the TP1 concrete substructure are the strength of the inner walls in the base, and the stability and strength of the structure during the separation and ascent from the seabed. The integrity of the ballast pipework is also uncertain. The probability of a major accident or incident during the refloating operations has been estimated as between twenty to fifty times higher than the acceptance criterion for marine operations.



Risk to Personnel

The probability of a fatality during operations to refloat the three concrete substructures, tow them to shore and then deconstruct them has been estimated as 60% (see Section 5.5.1). This is a very high probability and indicates that there are many hazardous operations associated with the on land disposal alternative. The statistically predicted chance of a fatality during preparation work for leaving the concrete substructures is in the order of 6%.

The average Fatal Accident Rates during the refloat, tow and deconstruction of the concrete substructures (as given in Table 5.2) are between 10 and 17 times higher than the rate for production operations on Norwegian platforms and 3 to 5 times higher than the estimated average rate for production and drilling operations in UK waters.

Environmental Impacts

The discharges to the sea for the leave in place alternative are assessed by DNV to be "None/Insignificant" using the system of categorisation described in Section 5.1.2 and Figure 5.2. Diesel fuel, hydraulic oil and methanol used for operational purposes in the columns, will be removed and the equipment and piping cleaned. The concrete substructures have never been used for the storage of crude oil. In the very long term, the water based mud drill cuttings within CDP1 would be released but independent experts have assessed that this would have insignificant effect on the environment (Section 7).

The energy consumed to prepare the concrete substructures to be left in place is significantly less than the energy to remove and deconstruct the three concrete substructures, which is equivalent to running more than 105,000 family cars for one year. The emissions of carbon dioxide, nitrogen oxides and sulphur dioxide to atmosphere are approximately 5% of the equivalent values for on land disposal of the concrete substructures.

During the operations to refloat the concrete substructures DNV has assessed the physical impact on the environment as "Moderate Negative" because a layer of gravel has to be deposited on the seabed around TCP2 before attempting to refloat the substructure. The physical impact of leaving the substructures in place is found to be "None or Insignificant" for the next few hundreds of years. After that time, as the concrete substructures deteriorate further, the physical impact on the environment will be similar to that of attempting to remove them, i.e. "Moderate Negative".

The onshore deconstruction of the concrete substructures is predicted to have a "Moderate Negative" aesthetic impact due to the visual impact, noise, smell and dust associated with breaking up the concrete onshore. The aesthetic impact of leaving the substructures in place is considered to be "None/Insignificant".

The removal of the substructures is considered to have a "Moderate Positive" impact in respect to fisheries and free passage at sea. If the three concrete substructures are left in place the effect is predicted to be "Small Negative" to "Moderate Negative" due to the substructures causing a potential obstruction to fishing vessels and passing marine traffic.

If a major unplanned event occurred during the refloat operations, the impact on the environment would be considerably greater. A major leak occurring during the refloat operation would result in the substructure falling back onto the seabed. This event together with the subsequent clear up operations would have a significant physical impact on the local environment.

Cost

The cost of removing the three concrete substructures and disposing of them on land is estimated to be 8418 MNOK / £643.6m (€ 1027m) in 2002 money terms. A significantly greater cost would be incurred if there were a major accident or incident during the refloating and towing operations. The estimated cost of the preparation of the concrete substructures to be left in place is 125 MNOK / £9.5m (€ 15.2m).

2.5 PREPARATION OF CONCRETE SUBSTRUCTURES BEFORE LEAVING IN PLACE

After removal of the steel topsides of TCP2, CDP1 and TP1 the steelwork on the outside of the three concrete substructures, such as risers, riser clamps, stairways, landings etc. will be removed (see Section 6.3).

Tanks and pipes containing diesel oil, hydraulic oil and methanol used for operational purposes within the concrete columns will be drained and cleaned in accordance with accepted practice. The glass reinforced epoxy pipework in the TP1 columns and the flexible pipes inside the J Tubes in the TCP2 columns will be removed. Fluorescent lighting tubes in the columns will be removed.

The steelwork within the columns of TCP2 and TP1, and the central shaft of CDP1, will be left in place together with the protective aluminium and zinc anodes. These items are not considered to adversely affect the natural environment but will degrade gradually over time. Working in the columns is particularly hazardous and leaving the steelwork in place will reduce the risk to personnel during the decommissioning operations. Measures will be taken to allow the free flow of seawater water through the columns to ensure equal internal and external pressures and to prevent the stagnation of the water in the columns.

None of the concrete substructures has ever been used for the storage of crude oil. Cleaning operations to remove hydrocarbon deposits within the cells or columns are therefore not required.

All materials and substances removed from the substructures will be transported and disposed of onshore in accordance with relevant national and international regulations.

Navigation aids will be installed on the substructures and regularly maintained. The navigation aids installed on the concrete substructures will be designed to ensure a high level of reliability. They will incorporate back-up systems and parts of the navigational aids system will be changed at regular intervals. TFEE Norge has made contact with the responsible authorities in both Norway and UK and a dialogue has been started to ensure that the navigation aids provided comply with national regulations and international conventions.

In addition, TFEE Norge will take action to ensure that the Frigg Field concrete substructures remain marked on navigation charts. The position of the concrete substructures will be included in the UK "FishSAFE" programme which is a computerised system providing fishermen with information about obstructions or hazards in the fishing grounds. Fishing vessels fitted with the "FishSAFE" equipment receive a visual and audible alarm when they come within 6 nautical miles of an identified obstacle.

Debris on the seabed will be removed within the Frigg Field. A sonar sweep and trawling tests will be undertaken after the area has been cleared.

2.6 IMPACTS OF LEAVING THE CONCRETE SUBSTRUCTURES IN PLACE

After the substructures are decommissioned the only energy requirement will be the navigation aids and the helicopters used for maintaining them. Similarly the only emissions to atmosphere will be from helicopter flying.

The materials that would be left in place inside the columns of TCP2 and TP1 and the central shaft of CDP1 are:

Material	Weight (tonnes)
Reinforced / prestressed concrete	433,068
Steel	2,823
Stone/gravel/concrete ballast	373,633
Cement grout under concrete substructure	19,004
Drill cuttings inside CDP1 (5,600 m^3)	11,300
Anodes (zinc and aluminium)	53
Paint on the internal steelwork	8
Electrical cabling in the columns/shaft	60
Marine growth (estimated)	3,500

The impact of discharges to sea from the materials left in place have been assessed by DNV to be "None/Insignificant". (See Section 7)

In the next few hundred years the physical impact on the environment of leaving the substructure in place is considered to be "None or Insignificant". In the very long term the installations will slowly deteriorate. This will have a similar effect as discharging gravel ballast on the seabed and is judged by DNV to be a "Moderate Negative" impact.

There are considered to be no aesthetic impacts such as noise, smell or dust from leaving the concrete substructures in-place.

After decommissioning the concrete substructures will not generate any waste. Debris on the seabed around the concrete substructures will be removed during decommissioning and thus the potential for littering by decomposition of the substructures in the next few hundred years is considered to be insignificant. It is recognised that leaving the substructures in place may be regarded as littering. The littering impact is judged by DNV to be "Small Negative".

The Frigg area is today regarded as of medium importance to the fisheries. Assuming that this situation is unchanged, the impact of leaving the substructures in place has been assessed by DNV to be "Small Negative" to "Moderate Negative", due solely to their potential obstruction to fishing activity in the area. The Norwegian Institute of Marine Research has noted that after 30 years of operation the Frigg Field installations have become part of the ecosystem. It is therefore their opinion that leaving the three concrete substructures in place will not harm the fishery resources or other marine fauna.

There is a low level of shipping in the vicinity of the Frigg Field, with no major shipping routes passing within 10 nautical miles. The statistical probability of a collision by fishing vessels or passing vessels has been judged by navigation experts to be low. The introduction of more sophisticated navigational equipment such as the Electronics Charts Display and Information System (ECDIS) and higher levels of training for mariners, in accordance with international conventions, is predicted to reduce the probability of collision further.

2.7 MONITORING

At the end of the decommissioning work programme, an environmental survey, including seabed sampling, will be undertaken to document the environmental conditions. A survey of the condition of the concrete substructures and the adjacent seabed will also be undertaken at that time.

The navigation aids installed on the concrete substructures will be designed to ensure a high level of reliability. Regular surveillance will be carried out to check that the navigation aids are operational. It is envisaged that the navigation aids will be designed in such a way as to allow them to be changed from a helicopter, thus obviating the need to man the platforms for this purpose.

A visual check on the above-water condition of the concrete substructures will be undertaken and recorded when the navigation aids are being checked by helicopter. The anticipated condition of the substructures in the coming years is discussed in Section 7, subsection "Physical Impact on the Environment". The implications of any observed deterioration of the substructures, in relation to the safety of users of the sea, will be assessed and any required action determined in consultation with the Norwegian and UK authorities.

The Frigg Field concrete substructures remain the property and responsibility of the Frigg Field Licensees, unless otherwise agreed with the Norwegian and UK authorities.

2.8 FURTHER INFORMATION

References to the many supporting studies undertaken, and the peer review reports, are to be found in Section 9 of this document.

The Frigg Field Cessation Plan, which includes both the Disposal Plan and the Environmental Impact Assessment undertaken by DNV, may be found on the TFEE Norge website www.totalfinaelf.no/cessation

A complete copy of this OSPAR assessment document may also be accessed through the same website.

3. Description of Frigg Field and Surrounding Area

3.1 FRIGG FIELD

The Frigg Field, which was discovered in 1971, is a natural gas reservoir, with associated condensate, that extends across the median line between the Norwegian and UK sectors of the North Sea Continental Shelf. The framework for the joint exploitation of the reservoir was established by the **"Agreement between the Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the Kingdom of Norway relating to the Exploitation of the Frigg Field Reservoir and the Transmission of Gas therefrom to the United Kingdom"**, known as the Frigg Treaty of 10th May 1976.

The Norwegian section of the Frigg Field was developed under Production Licence PL. 024 which expires in 2015. The UK section was developed under Production Licence P.118 which expires in 2016.

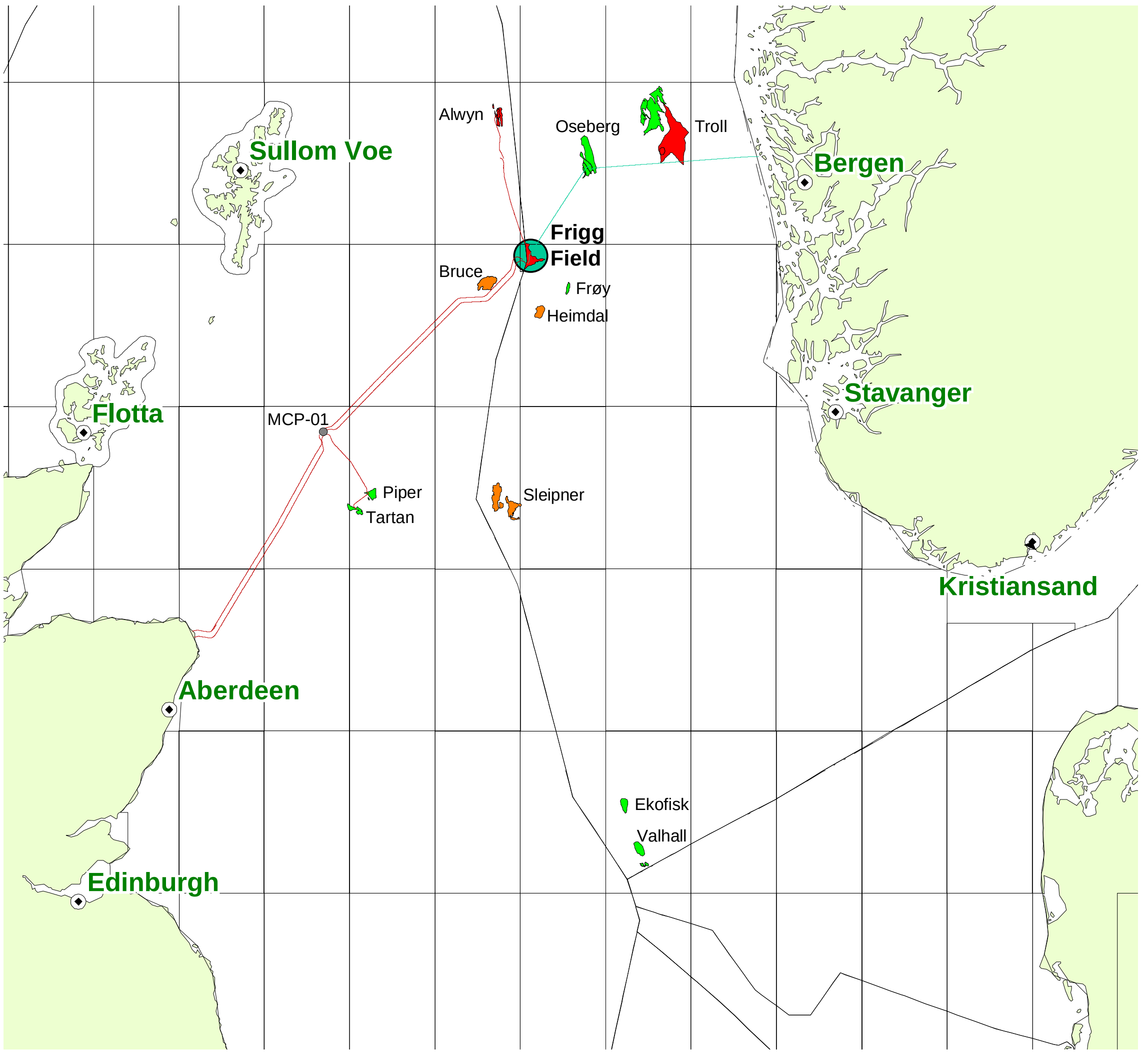


Figure 3.1 Location of the Frigg Field and the Main Pipeline Connections

The Frigg Field Licensees signed a Unitisation Agreement in July 1973 regulating development and operation of the field. Following the merger of the TotalFina Group and the Elf Group in 2000, the current Frigg Field Licensees are:

	Unitised License (%)
• TotalFinaElf Exploration Norge AS (Operator)	28.664
• Norsk Hydro Produksjon a.s	19.992
• Statoil ASA	12.164
• Elf Exploration UK PLC *	26.120
• TotalFinaElf Exploration UK PLC	13.060

*) Under management of TotalFinaElf Exploration UK PLC

Commercial deliveries of gas from the Frigg Field started on 13th September 1977. During the years of plateau production, the annual gas production was 16.5 GSm^3 with an average peak daily flow of more than 60 MSm^3/d. The total gas production of the Frigg Field up to 01.08.2002 was nearly 189 GSm^3.

Cessation of production from the Frigg Field is presently estimated to occur sometime in 2004 depending on the reservoir behaviour. Production from all the satellite fields that were tied into Frigg/TCP2 has already ceased.

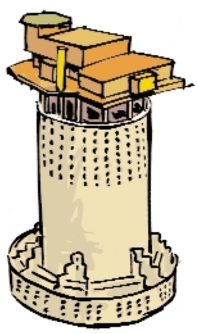
3.2 FRIGG FIELD FACILITIES

The Frigg Field facilities consist of five fixed installations standing in approximately 100m of water, together with infield pipelines and cables. In addition, the DP1 steel substructure, which was damaged during installation in October 1974, is still in place in the field. The Flare Platform (FP), originally located in the field, was removed in 1996 and brought to shore for recycling.

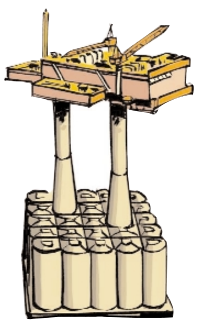
Three of the Frigg Field installations are located in UK Block 10/1 and two of the installations (together with the DP1 wreck) are in Norwegian Block 25/1. The platforms were installed in the period 1974 to 1977.

The UK registered installations are:

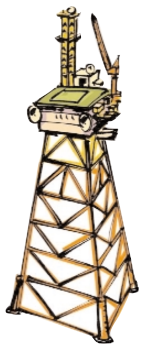
- Concrete Drilling Platform 1 (CDP1)
- Treatment Platform 1 (TP1)
- Quarters Platform (QP)



CDP1



TP1

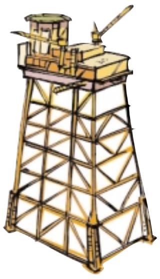


QP

The Norwegian registered installations are:

- Treatment and Compression Platform 2 (TCP2)
- Drilling Platform 2 (DP2)
- Drilling Platform 1 (DP1)

TCP2



DP2

DP1

Three of the platforms, TP1, QP and TCP2, are permanently bridge linked and form what is known as the Frigg Central Complex. The facilities on the Frigg Central Complex have been used to process and export hydrocarbons from the main Frigg reservoir and satellite fields. In addition gas from the North Alwyn field has been routed via Frigg Central Complex into the export pipeline to St Fergus in Scotland.

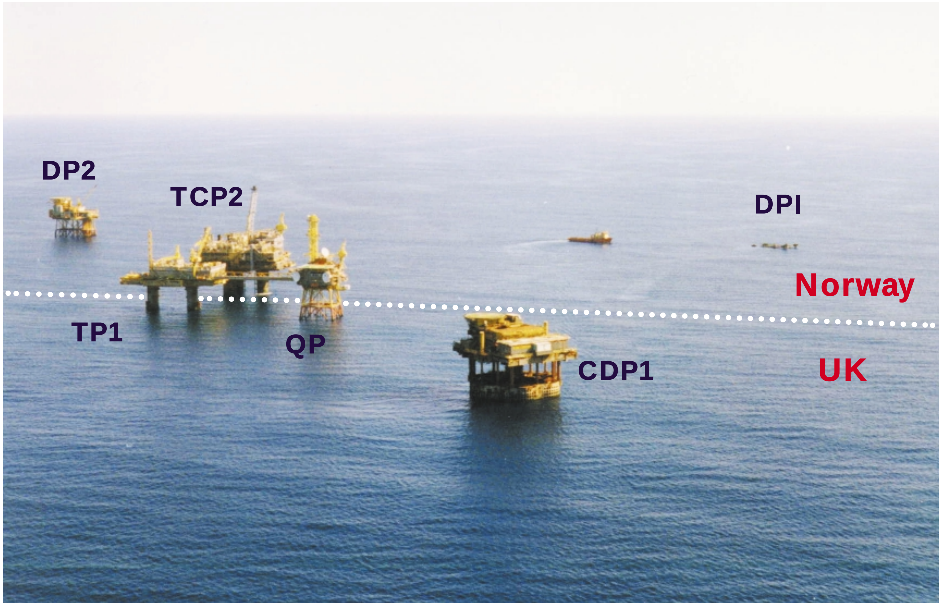


Figure 3.2 Frigg Field Installations (1999), indicating the border between Norwegian and UK Sectors of the North Sea

The meteorology and oceanography of the Frigg Field area are described in detail in Section 6 of the Environmental Impact Assessment, which forms Part 2 of the Frigg Field Cessation Plan.

3.3 FRIGG AREA ENVIRONMENT

3.3.1 Seabed

The water depth in the Frigg area is approximately 100 meters. The bottom sediments consist mainly of olive-grey coloured fine sand (83.7 - 92.5%) with small amounts of pelite (silt and clay) and medium sand. The organic matter content of the sediments in the region varies between 0.63 and 0.90%.

Environmental monitoring has been conducted in the area of Frigg on a regular basis for a number of years. It has therefore been possible to monitor changes in hydrocarbons, heavy metals (in sediment) and the benthic community over time.

When the wells were drilled on DP2 (the drilling platform in the Norwegian Sector) the cuttings were deposited on the seabed mainly under the platform. Water-based mud was used for drilling all the wells apart from side-tracking two of the wells where low toxicity oil based mud was used. A total of 120 m^3 of low toxicity oil based mud was brought ashore for treatment and disposal. Drill cuttings containing 116 m^3 of low toxicity oil based mud were cleaned on the platform so that they contained less than 10% oil, before being discharged to sea. Surveys have been conducted to monitor and map the drill cuttings deposits and to identify contaminants.

In the period from mid 1980s to 1992 there was an increase in hydrocarbon content in the local sediments. Around DP2 elevated THC (Total Hydrocarbon Concentration) levels were found with values ranging from below background level (7.0 mg/kg) to 10 mg/kg dry sediment. Only one of the stations had a THC content above 10 mg/kg.

The survey in 1997 however showed a reduction or no change in the hydrocarbon content. Core samples showed an almost uniform THC down to a depth of 6 cm below the seabed.

The survey in 2000 showed that the average THC in the sediments had increased slightly from 6.6 mg/kg dry sediment to 7.5 mg/kg since 1997. For an offshore petroleum field in this part of the North Sea such values are low. The only elevated concentrations of THC were found near DP2 and these are thought to be associated with the removal of drilling facilities which took place on the platform during this period.

Metal concentrations are generally found comparable with Class I (slightly polluted) or Class II (moderately polluted) of the sediment quality classification system for fjords and coastal waters produced by the Norwegian Pollution Control Authority (SFT). For such contamination levels there is no environmental benefit in undertaking remedial actions. The highest metal concentration of lead (Pb), zinc (Zn), copper (Cu) and cadmium (Cd) were found near the DP2 platform, where the highest hydrocarbon content was also found.

The 1997 survey showed a reduction in the benthic fauna at the field stations compared to 1992. The number of individuals has decreased at most stations while the number of taxa has increased at some stations, and the diversity has generally increased. The 2000 study does show that the faunal disturbance has increased in intensity since 1997.

Based on the monitoring results it can be concluded that the Frigg area, as a whole, can be classified as relatively undisturbed (i.e. Group A[1]).

1 Relatively undisturbed communities, with low dominance (no species present in very high numbers) and a wide range of species from a variety of taxonomic groups, including molluscs, echinoderms and crustacea. Moderate species numbers and total abundance, high biomass.

3.3.2 Water Quality

The International Council for the Exploration of the Sea (ICES) and the Joint Monitoring Programme (JMP) Laboratories reviewed data on trace metals in the North Sea during 1985-1987. The conclusion from that programme was that there are low levels of cadmium (Cd), copper (Cu), lead (Pb) and mercury (Hg) in the central areas of the North Sea as compared to the southern areas.

Water column monitoring related to offshore activities has been undertaken in the region during the last few years. No signs of contamination have been reported, and the produced water discharge from Frigg is very low. As there are no significant point sources of organic material, nitrogen or phosphorous in the Frigg Field area, the level of nutrients in the water masses is at normal background level for the central North Sea.

In conclusion, the water quality in the Frigg Field area is considered to be good in relation to heavy metals, organic contaminants and nutrients level.

3.3.3 Marine fauna

The fauna in the Frigg area is well described in the Regional EIA for the Norwegian Sector of the North Sea. This report therefore only contains a short summary description of the most relevant aspects.

Plankton

Plankton organisms are small plants and animals passively drifting in the water. Phytoplankton is a microscopic, freely suspended, normally single-celled algae. They exist mainly in upper layers of the sea (30-40 m), where light supports photosynthesis. In open water phytoplankton are the only contributors to the primary production. The primary production in the central North Sea Area is reported by the North Sea Quality Status reports to be 100-150 gr. C/m^2/year.

Fish

Fish species like mackerel, saithe, herring, cod, whiting and Norway pout are present in the central and northern part of the North Sea, at different life stages at different times of the year. The north and central parts of the North Sea represent the most important spawning area for the North Sea mackerel. There are important spawning areas for cod along the east coast of Scotland and in the central parts of the North Sea (i.e. south-west and south of Frigg). Saithe spawns during January-April, along the shelf edge north and east of Frigg. Herring and Sandeels may also occur in the ocean areas near Frigg.

Marine Mammals

The population of marine mammals found in the Frigg area is composed principally of many species of whale. The abundance of particular species varies during the year due to their seasonal cycle, which include feeding and breeding. The abundance also varies from year to year as food availability varies. Many species are observed migrating northwards (feeding) during summer and move southward during autumn and winter in a breeding migration to warmer waters.

Seals observed in the area (some of which appear to be resident at some oil installations) will be individuals, most probably common seal (Phoca vitulina) and possibly grey seal (Halichoerus grypus).

Seabirds

Many species of seabirds are recorded in the Frigg area, including common guillemot, razorbill, puffin, little auk, kittiwake, blackheaded gull, great black backed gull, herring gull, great skuas, gannet, storm petrel and fulmar. The density of different species varies throughout the year, as in other parts of the North Sea.

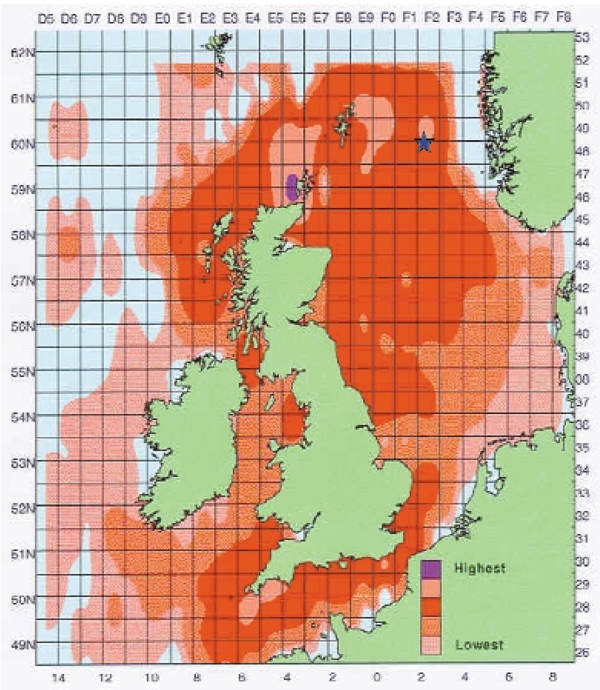
3.4 MARINE ACTIVITY IN FRIGG AREA

3.4.1 Fisheries Activity

The North Sea is of international importance as a spawning, growth- and feeding area for many different fish species. Fisheries in the North Sea can be split into three main groups

- Trawling for bottom living species for direct consumption (mainly cod, haddock, whiting, and different species of flatfish)
- Industrial trawling (Norway pout, sandeel, blue whiting and sprat), and
- Fisheries with pelagic trawl and net gear which exploit species living in the water column (herring, horse mackerel and mackerel)

Compared to the rest of the North Sea, the Frigg area is within an area of moderate importance to fisheries, bordering an area of higher importance as shown in Figure 3.3.



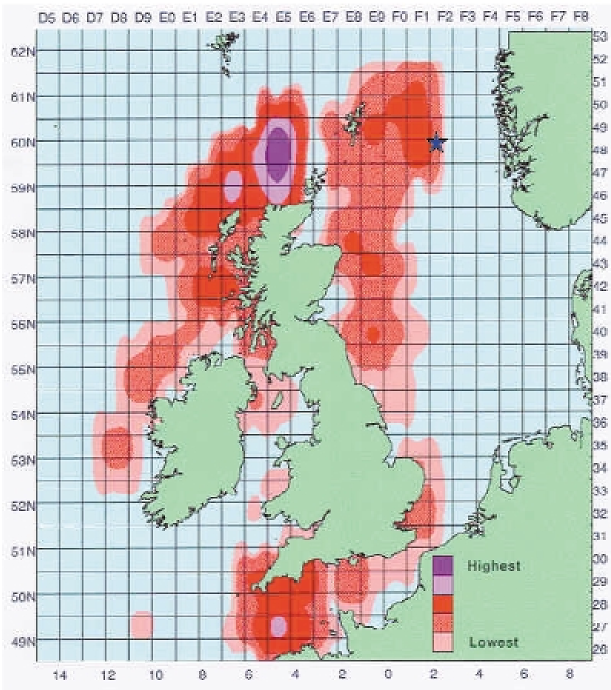


Figure 3.3 Relative value of different areas in the North Sea to demersal fisheries (left) and pelagic fisheries (right), 1996. Frigg position indicated with blue star (Maps modified from UKOOA web pages)

The general picture of the fishery activity in the Frigg area is that there is a considerable Norwegian industrial bottom trawl fishery. Norwegian effort involving net gear is also significant. British fisheries are present in the area, exploiting demersal species (with net and trawl gear) for the consumption markets. However, this effort is limited to modest landings. Based on the low Norwegian and British consumption fish landings, the Frigg area is considered to be of minor importance to the consumption fisheries.

The fishery activity is most intensive during summer, autumn and winter. Norwegian and British fishing vessels are present during the whole year in this part of the North Sea although the catch effort is lower in the first three months of the year. Detailed information on the density of fishing activity in the Frigg area is not available, but is estimated to be in the order of 1.8 vessels per 10,000 km^2, based upon data for the northern North Sea.

3.4.2 Passing Marine Traffic

The current shipping traffic pattern in the vicinity of the Frigg field has been assessed utilising the COAST database (2001 version). This data source contains details of route positions, traffic volumes and vessel type/size distributions for all merchant shipping routes passing through the North Sea. The COAST database indicates a low level of shipping in the vicinity of the Frigg field, **with no major shipping routes passing within 10 nautical miles (nm) of the Frigg Field.**

The shipping routes that were identified as passing within 10 nm of the Frigg Field are presented in Table 3.1 in ascending order of closest point of approach (CPA). The total annual traffic volume on these routes is estimated to be 128 vessels, that is, an average of one vessel every three days.

Route No.	Main Contributor	CPA (nm)	Bearing (°)	Standard Dev. (nm)	Vessels Per Year
1	Baltic-Sullom Voe	4.3	228	2.5	64
2	Statfjord Terminal-Thames	7.7	80	1.5	44
3	Bømlofjorden-Lerwick	7.9	194	0.9	20
				TOTAL	128

Note: Routes passing the location with identical CPA's and bearings have been grouped together, with the name of the largest sub-route shown as the main contributor.

Table 3.1 Routes Passing within 10 nm of Frigg

A plot of the mean route positions relative to the Frigg location is presented in Figure 3.4. It is noted that the shipping route data is the most current available for the Northern North Sea. This has been taken to represent the best estimate for the period 2012 to 2032 (the twenty years after activity at the Frigg Field ends). However, it is recognised that shipping routes and traffic levels may change due to port competition, changes in trading routes, etc.

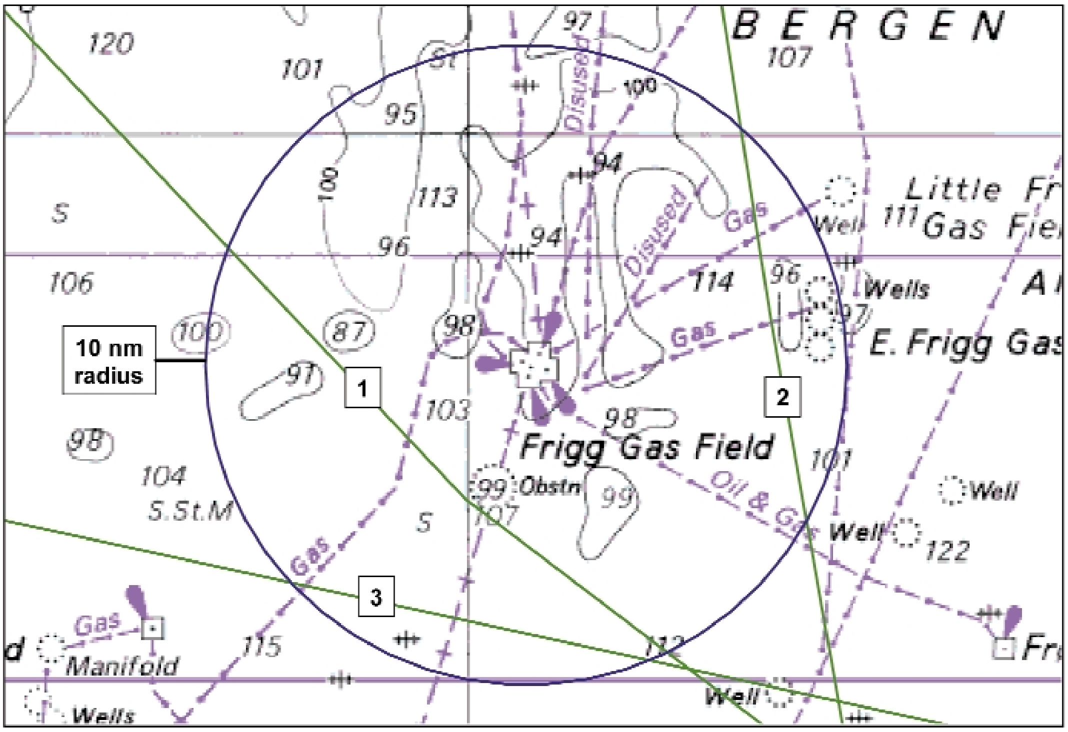


Figure 3.4 Mean Route Positions Passing within 10 nm of the Frigg Field (sea route numbers are defined in Table 3.1)

The majority of the traffic passing Frigg (88%) is large tankers on the Baltic-Sullom Voe and Statfjord Terminal-Thames routes. Merchant vessels on the Bømlofjorden-Lerwick route form the remaining 12% of passing traffic.

4. Description of Concrete Substructures

This section contains a brief description of the three Frigg Field concrete substructures together with key data about their size and weight. None of the concrete substructures were designed for removal. No crude oil has been stored in the concrete substructures.

4.1 PLATFORM TCP2

At present, gas from the Norwegian drilling platform DP2 is processed on TCP2 before being exported to St Fergus in Scotland via the 32” diameter Frigg Norwegian Pipeline (now called Vesterled).

The topsides of TCP2 weighing 22,882 tonnes will be removed and brought onshore where they will be dismantled and the materials and equipment reused or recycled as far as practicable.

The concrete substructure of TCP2 was designed by Norwegian Contractors (now Aker Engineering) and is a typical “Condeep” structure with a base formed from 19 cylindrical cells. The walls of the base cells are generally 0.6 m thick. Three of the cells extend upwards to form the columns supporting the topsides. The diameter of the columns varies from approximately 20 m at the base to 10.4 m at sea surface level. The column walls vary in thickness between 0.5 m and 0.85 m. The platform, which stands in 103 m of water, was installed in 1977.

The cells in the base are filled with seawater.

Subsea pipelines and cables connecting with the platform are routed to deck level inside the concrete columns.

TCP2	Dry Weight (tonnes)		Overall Dimensions		Comments
Concrete Substructure	Concrete (incl. reinforcement and cast-in items)	159,173	Height	129 m	Volume of concrete is 60,000 m^3.
	Ballast in caisson	69,920	Area of hexagonal foundation slab	9,340 m^2	Volume of grout under substructure is 13,725 m^3.
	Cement Grout under substructure	18,254	Maximum width of substructure	116 m	
	Marine growth (estimate)	865	Height of caisson	40 m	
	Steelwork inside columns	1,603	Number of cells	19	
	Steelwork outside the concrete substructure	483	Diameter of cells	20 m	
			Diameter of cells	20 m	

Table 4.1 Key Platform Data for TCP2

Figure 4.1 Concrete Substructure of Treatment and Compression Platform 2 (TCP2)

4.2 PLATFORM CDP1

The concrete substructure of CDP1 was initially intended to be the booster platform at the midpoint of the Frigg pipelines to St Fergus (Platform MCP01). It was converted for use as the drilling platform for the UK sector of the Frigg Field after the loss of DP1 during installation. The water depth at its current location is 96 m.

The substructure, which was designed by CG Doris, consists of a series of concentric cylindrical concrete walls of different heights, connected together by the base slab and radial concrete walls. The main external wall extends from the base to about 8m above water level and the upper section of the wall is perforated to reduce the wave forces on the substructure. Inside the external wall a central concrete shaft runs from the base slab to deck level.

After the concrete substructure was installed in 1975 the space between the main external wall and the central core was filled with sand/gravel ballast to keep the platform stable on the seabed. When the wells were drilled on CDP1 the drill cuttings were deposited inside the main wall on top of the sand/gravel ballast. In 1981 more ballast was added on top of the drill cuttings to give the structure greater stability following the observation of large cracks in some of the radial walls after a period of severe weather.

The deck consists of a series of 4m deep concrete beams that are supported on the central concrete core and a series of concrete filled steel columns mounted on top of the main external wall. The topsides modules and equipment and the supporting steel structures will be removed and brought to shore for reuse or recycling.

In 1989/90 all the 24 wells were permanently plugged and abandoned and the well casings cut approximately 5 m below the seabed. The drilling rig and cranes were dismantled and removed and the platform has been non-operational since 1990. The platform is now only visited for inspection of certain parts of the structure and for maintenance of the navigation aids. The helideck is maintained in operational condition to allow access to the platform.

CDP1	**Dry Weight (tonnes)**		**Overall Dimensions**		**Comments**
Concrete Substructure	Concrete	146,976	Height	107 m	Volume of concrete is 56,263 m^3.
	Sand, gravel and concrete ballast	268,703	Diameter of base slab	101 m	
	Cellar deck modules incl. core cap, skid beams and steel panels	2,024	External wall diameter	62 m	The concrete-weight figure includes deck-beams, reinforcement steel, prestressed steel bars, deck support columns and other steel items integrated in the concrete structure.
	Marine growth (estimate)	1,900	Max. subsea width of substructure	101 m	
	Steelwork inside the central shaft	317	Weight of the largest cellar-deck module	198 tonnes	
	Steelwork outside the central shaft	54			

Table 4.2 Key Platform Data for CDP1

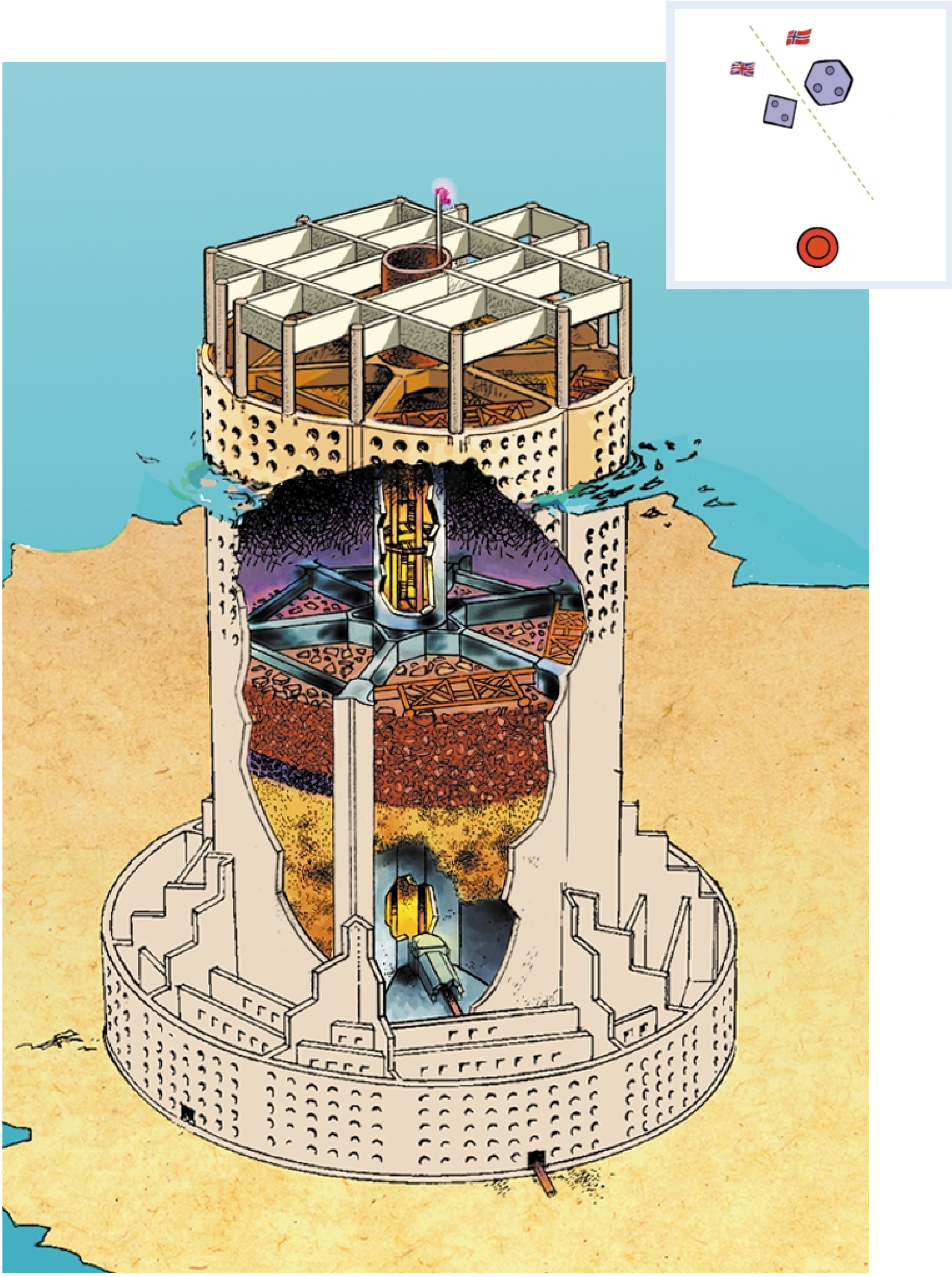


Figure 4.2 Substructure of Concrete Drilling Platform I (CDP1)

4.3 PLATFORM TPI

Gas from CDP1 was originally processed on TP1 before being exported to St Fergus in Scotland via the Frigg UK Pipeline. Since production from CDP1 ceased in 1989, TP1 has functioned as a riser platform connecting the Alwyn gas export pipeline to the Frigg UK Pipeline.

The TP1 platform, which was designed by Sea-Tank, was installed in 1976 in a water depth of 103 m. It consists of a square concrete base made up of 25 cells, two of which are extended to form the two con-crete columns supporting the topsides. The base cells are approximately 13 m square and the walls between the cells are 0.8 m thick. The outside curved walls of the cells are 0.6 m thick. The diameter of the columns varies from approximately 13 m at the base to 7.6 m at sea surface level. The column walls vary in thickness between 0.4 m and 0.8 m. The cells in the base, and the columns, are normally water filled to enhance the stability of the platform.

The topsides, consisting of the steel deck and modules will be removed and brought to shore where they will be dismantled and the materials and equipment reused or recycled as far as practicable.

Most pipelines and cables enter the platform though the bottom part of the structure into the two columns, where they rise up to the topside facilities. One pipeline penetrates directly into one of the concrete columns at the top of the caisson.

TP1	Dry Weight (tonnes)		Overall Dimensions		Comments
Concrete Substructure	Concrete Concrete ballast Cement Grout under substructure Marine growth (estimate) Steelwork inside the two columns Steelwork outside the concrete substructure	126,919 35,010 750 781 880 370	Height Dimensions of base Height of base	126 m 72 x 72 m 49 m	Volume of concrete is 50,000 m^3. The concrete-weight figure includes reinforcement steel, pre-stressed cables and other steel items cast into the concrete.

Table 4.3 Key Platform Data for TP1

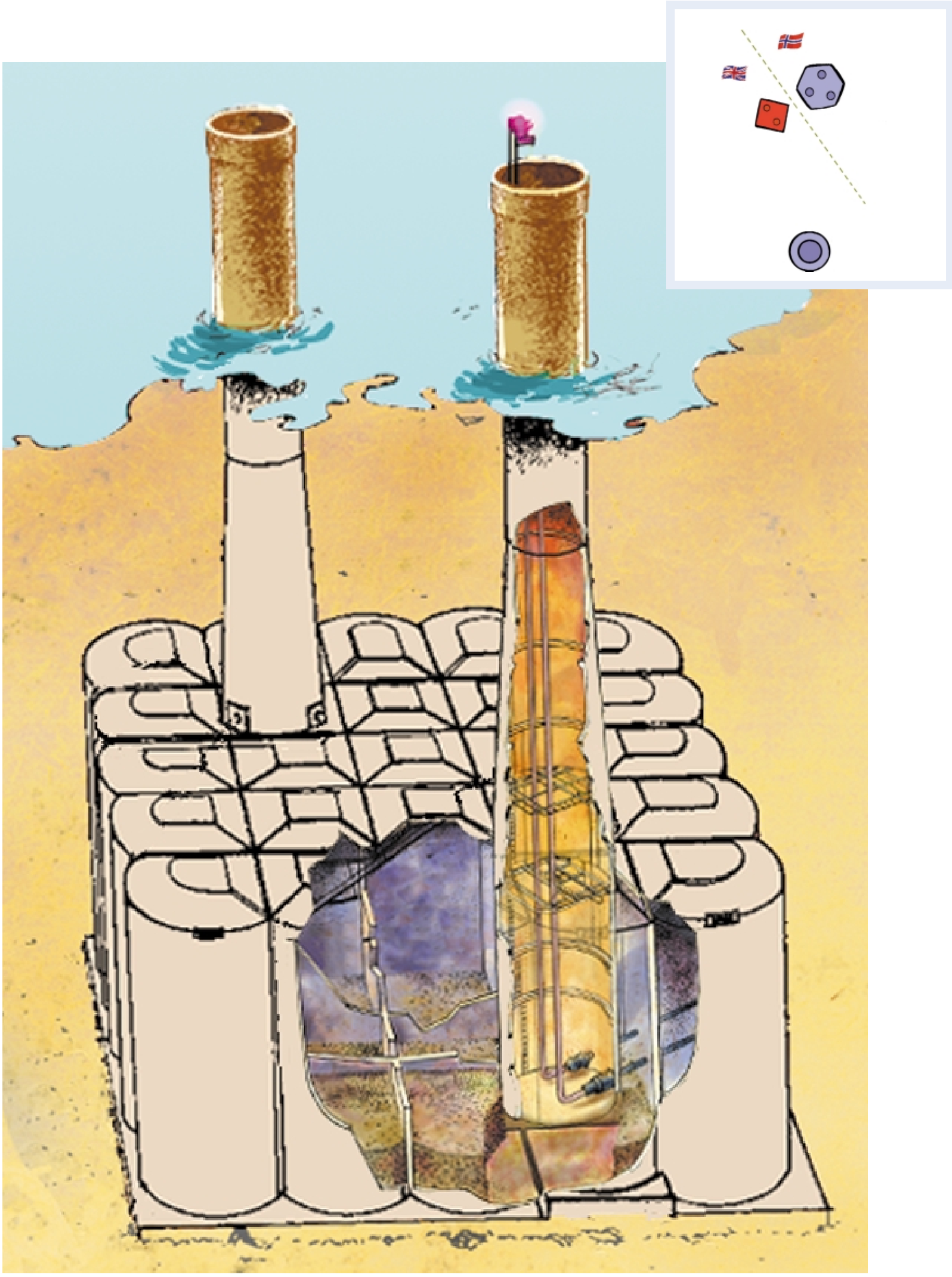


Figure 4.3 Concrete Substructure of Treatment Platform 1 (TP1)

5. Assessment of Disposal Alternatives

5.1 THE ASSESSMENT PROCESS

5.1.1 Principles and Approach

A sequential assessment process has been followed in determining the disposal arrangements to be adopted for the three Frigg Field concrete platforms (TCP2, CDP1 and TP1) when they reach the end of their production life. The assessment process is based upon the waste hierarchy detailed below, which values reuse above recycling, and disposal onshore above disposal at sea.

- Evaluation of the possibility of reusing all or parts of the offshore facilities either in their current location or at another site
- Evaluation of the possibility of recycling all, or parts, of the offshore facilities
- Evaluation of the possibility of disposal onshore
- Evaluation of the possibility of disposal at sea

In accordance with the principle of the waste hierarchy the possible reuse potential of the three concrete platforms, considered jointly, has been assessed as described in Section 5.2. In assessing the reuse potential of the facilities, the technical feasibility has been assessed in the light of existing proven technology and financial viability, evaluated based upon current economics.

The general principle has been adopted that if reuse is not possible, either at the current location, or at another site, then as much of the equipment and materials as practicable will be recycled. This principle has been extensively applied throughout the Environmental Impact Assessment where account has been taken of the energy requirements and discharges during the recycling processes.

As the reuse of the Frigg Field facilities at their current location has been shown not to be viable (Section 5.2), the technical feasibility of refloating the concrete substructures has been studied, and the implications in terms of safety, impact on the environment and other users of the sea and cost have been assessed. The general principle adopted has been that, if possible, all facilities shall be returned to shore where they may be reused, recycled or disposed of in the most effective manner. These studies and assessments are described in Section 5.3.

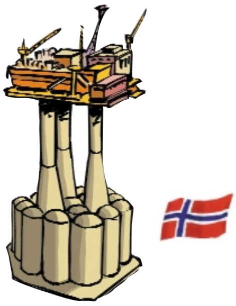
The possibility of disposing of the concrete substructures at sea has also been considered. The alternatives considered have included refloating and sinking at a deep water disposal site, cutting the substructures down to provide a clear shipping draft of 55 m, or leaving the substructures in place on location at Frigg. Consideration of these disposal alternatives is provided in Section 5.4. The assessments provided have been undertaken in accordance with the requirements set out in "OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations". In particular, the content and structure of the assessment has been based upon Annex 2 of OSPAR Decision 98/3 entitled "Framework for the Assessment of Proposals for the Disposal At Sea of Disused Offshore Installations".

The alternative disposal arrangements have been fully studied but, in the following subsections, the main emphasis has been given to an assessment of the on land disposal alternative (see Section 5.3) and the leave in place alternative (see Section 5.4.3).

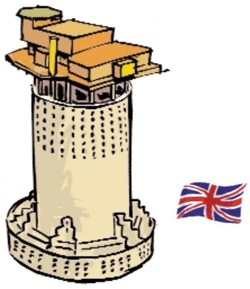
5.1.2 Methodology

Development of Method Statements

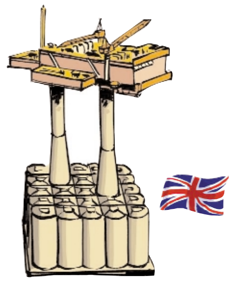
The companies involved in the original design and construction of the three platforms in the 1970s were; TCP2 - Norwegian Contractors (now Aker Engineering); CDP1 - Doris Engineering; and TP1 - Sea-Tank (now Doris Engineering).



TCP2



CDP1



TP1

These companies were engaged by TFEE Norge in 1999 to conduct the initial engineering and feasibility studies for decommissioning the concrete substructures. Different methods were considered and the design companies proposed a recommended method for each disposal alternative based upon technical feasibility and safety considerations. The recommended methods were described in the form of a general procedure or method statement. The method statements were then reviewed and modified as necessary, to reduce or eliminate unacceptable risks to personnel. Additional engineering studies were undertaken to investigate specific areas of technical uncertainty.

The method statements and engineering studies were reviewed and validated by a group of independent experts including representatives from SINTEF (The Foundation of Scientific and Industrial Research, Trondheim, Norway), the Norwegian Geotechnical Institute, Noble Denton, Munich University and Det Norske Veritas.

Assessment Parameters

In assessing alternative disposal arrangements for the Frigg Field concrete substructures the following aspects have been evaluated and considered:

- Technical Feasibility
- Risk to Personnel
- Environmental Impact
- Cost

In this context "Environmental Impact" includes impacts for users of sea and society as well as impacts on the natural environment (see Table 5.1).

Figure 5.1 gives an overview of the various studies and reviews that form part of the overall assessment for the concrete substructures.

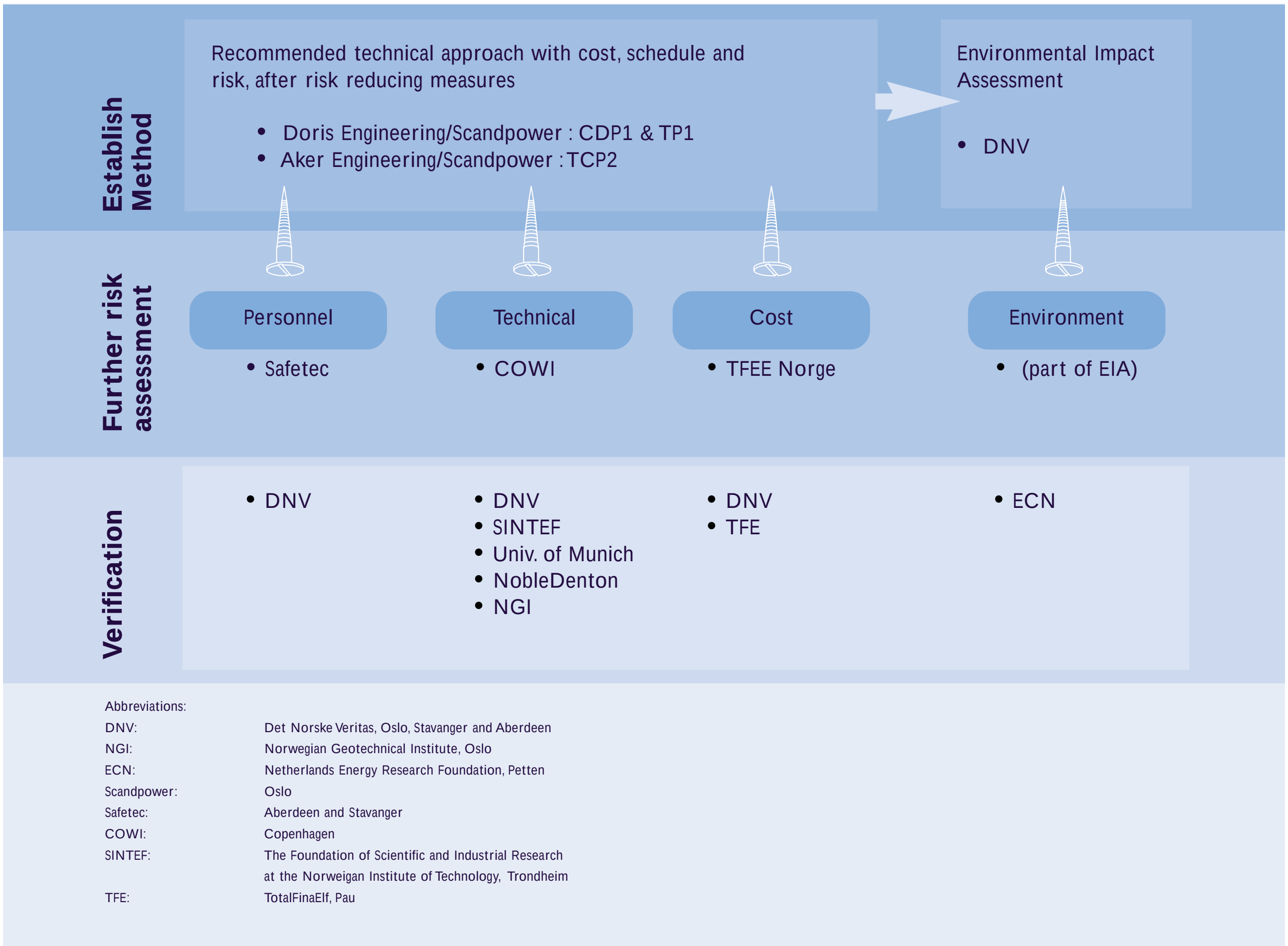


Figure 5.1 Assessment Process for Refloat and On Land Disposal Alternative

Technical Feasibility

The technical feasibility of a disposal arrangement has been judged based upon knowledge of existing equipment and practices, although in some instances the possible extension of existing technology has been included, where this is reasonably foreseeable. In such situations the implication of being unable to develop and test the necessary technology prior to use, has been assessed. Leading independent experts in many different fields have been consulted to provide input to the studies and to verify the conclusions. A major factor in assessing technical feasibility has been the level of uncertainty associated with the activities to be under-taken. This uncertainty particularly arises due to insufficient knowledge as to the exact structural condition of the installations and the behaviour of the structure under the load conditions arising during decommissioning activities. Again, specialist input has been obtained from independent experts in the relevant fields to allow verification of the results and conclusions.

Using the method statements developed by Aker Engineering and Doris Engineering, the technical feasibility of the disposal alternatives has been analysed by the Danish consulting engineers COWI. The risk of being unable to complete the disposal work as planned due to major accidents or incidents was estimated in quantitative terms using state of the art methods. Independent experts from Norway, UK, Germany, Switzerland and France were used to provide specialist input to this technical risk analysis. In addition offshore inspections were carried out during 1999 and 2000 to determine the condition of certain key mechanical systems and structural elements. The results from this inspection and testing provided additional input and validation to the technical risk analysis.

Both the probability and the consequences of major accidents or incidents during the planned disposal activities were estimated. The implication of these "worst case" scenarios has been an important factor in the decision making process.

For a number of years the TotalFinaElf Group has used criteria to limit the risk of asset loss arising from differing levels of damage to offshore platforms. These risk acceptance criteria have been adopted as the basis for determining the acceptability of technical risk during the decommissioning of the Frigg Field facilities.

Based upon these criteria, the maximum acceptable probability of a major accident during the decommissioning operations has been set as 1 x 10^{-3} (1 in 1000).

This figure is in-line with the guidance contained in Part 1 of the "Rules for Planning and Execution of Marine Operations" published by Det Norske Veritas in January 1996. In these rules DNV states that it was not possible to set a definitive acceptable risk level for marine operations at that time, due to the scarcity of data. DNV further states that it will seek further data and that **"A probability of total loss equal to or better than 1/1000 per operation will then be aimed at."** These same rules indicate that during marine operations a probability of **structural** failure ten times less than this (that is 1 in 10,000) should be aimed at. These risk acceptance criteria would be used if TFEE Norge were to install a new platform at the present time. In fact, risk levels considerably lower would be sought in accordance with the general risk acceptance principles defined in TotalFinaElf Group standards.

In the 1970s when the Frigg Field installations were constructed and installed quantitative risk analysis was not in general use and the necessary computational methods and tools were not available to allow a full quantitative assessment of the risks during the installation process. It is therefore not possible to directly compare the risks during the decommissioning phase with those experienced during installation.

Risk to Personnel

Both qualitative and quantitative assessments of the risks to personnel engaged in the removal and disposal operations have been carried out. Current practice has been a major factor in the qualitative assessments together with the expert judgement and experience of many of the personnel who were engaged in the initial design, fabrication and installation of the facilities. Practicable risk reducing measures, identified during the qualitative risk assessment, have been included into the planned activity arrangements.

Quantitative estimates of the risks to personnel have been made based upon the number of man-hours involved for the various tasks and the risk for each task, estimated from both offshore and onshore construction or deconstruction experience. This method is regarded as the best available at the present time but has a tendency to **underestimate the risk to personnel** due to the fact that hazards which are specific to the actual work are not fully included. The degree of underestimation of risk is not possible to quantify, but experts in this field judge that in some situations the actual risk may be up to double the risk estimated solely on the basis of generic historical data.

In common with risk analysis practice the statistically predicted number of fatalities (Potential Loss of Life or PLL)[1] or major injuries (Potential Major Injuries or PMI)[2] have been used as the basis of comparing alternative disposal alternatives.

The physical significance PLL and PMI is somewhat difficult to appreciate, particularly when expressing a fatality or injury level less than one. Accordingly, the probability or "likelihood" of a fatality occurring during the work scope in question has also been calculated, and is expressed either in percentage terms, (such as a 13% chance of a fatality) or in terms of "odds" (such as a 1 in 7 chance of a fatality).

Where appropriate, the Fatal Accident Rate (FAR)[3] for a particular activity, or set of activities, has been presented. Fatal Accident Rate is a statistical parameter that expresses the "likely" number of fatalities that would occur during 100 million man-hours of the activity (or activities) in question. Fatal Accident Rates are commonly used to express the risk associated with particular activities such as construction work, scaffolding, helicopter flying etc. Fatal Accident Rates are also widely used as a way of comparing the risk of different types of activity. Fatal Accident Rates are also sometimes used to express the "average " risk for an operation which includes many different activities, of differing durations, each having different numbers of participants. When used in this way FAR values only give a general indication of the "average" risk. This can be helpful in making relative comparisons between different options, but is not appropriate to use as an absolute decision making criterion.

In accordance with TotalFinaElf risk acceptance criteria, the risk of fatality for an individual shall not be greater than **1×10^{-3} per year** (1 in 1000) and **shall be as low as reasonably practicable.** This criterion is in line with guidance from the UK Health and Safety Executive and is in accordance with generally accepted principles applied by the regulatory authorities in both Norway and UK. 1 in 1000 is the highest risk that can be tolerated and, in practice, a personnel risk level considerably lower than this is sought for all operations, in accordance with the principle that risks should be as low as reasonably practical.

Environmental Impact

The impact of the disposal operations on the environment and society has been estimated using generally accepted methods and principles. The Environmental Impact Assessment has been carried out by DNV.

The purpose of the Environmental Impact Assessment is to :

- Clarify the consequences of the relevant disposal alternatives or the Frigg Field facilities that may have a significant impact on the environment, natural resources and society.
- Present information about possible impacts in a manner that can form a basis for a decision on the disposal alternatives.
- Present proposals for mitigating any damage and nuisance caused by the chosen disposal alternatives.

1 Potential Loss of Life (PLL) is the number of fatalities that are "likely" to occur whilst undertaking a defined amount of work.
2 Similarly, Potential Major Injuries (PMI) is the number of major injuries that are "likely" to occur whilst undertaking a defined amount of work.
3 Fatal Accident Rate (FAR) is the number of fatalities that are "likely" to occur whilst undertaking 100 million hours of a particular activity.

The parameters studied in the Environmental Impact Assessment fall generally into two main categories as listed in Table 5.1.

Environmental Impacts	Social/Community Impacts
• Energy • Releases (emissions) to atmosphere • Releases (discharges) to sea water, or ground • Physical impact on the environment • Aesthetic impact including noise, smell and visual effects • Waste/resources management • Littering	• Fisheries • Free passage at sea • Costs and natioal supply • Employment effects • Other social impacts

Table 5.1 Different Impacts Addressed in the Environmental Impact Assessment

Some environmental impacts can be quantified, but where this has not been possible, qualitative assessments have been used, based upon a method developed by DNV and ASPLAN which categorises the impacts as shown in Figure 5.2.

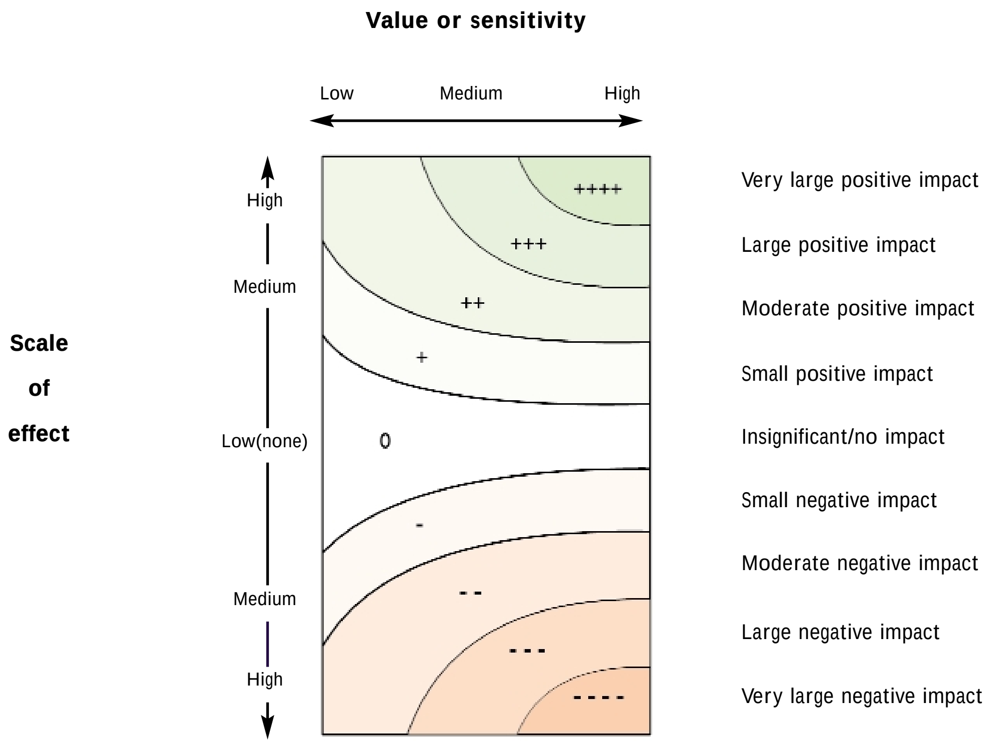


Figure 5.2 Methodology for Assessment of Non-Quantifiable Impacts.

The assessment distinguishes the important impacts from those that are less important. This is done by considering the effect of an impact in the area in which it is occurring (“value” or “sensitivity”), combined with the scope of the effect, to arrive at the total impact. By using this method the same magnitude of effect may then give different impacts depending on the value or sensitivity of the impacted environmental component. Additionally, the same type of effect will give a different impact depending on the sensitivity of the recipient /environment. This is considered by DNV to be a sound basis for assessing and presenting the impacts.

When the terms defined in Figure 5.2 are used in this document they are shown in inverted commas as for example, "Moderate Negative" impact.

The overall environmental impact of a particular disposal alternative has been judged based upon the impact on the individual parameters listed above. The significance of both the overall and the individual impacts has been assessed from both the short term and long term perspective. The Environmental Impact Assessment has been peer reviewed by independent experts in The Netherlands.

Cost

The estimated cost of the various disposal alternatives considered has been based upon studies performed by several different consultants in both Norway and the UK, using appropriate current rates and norms. Independent consultants in the UK, Denmark and Norway have also been used to verify the estimated costs and experts within the TotalFinaElf Group in France have performed additional validation.

The costs presented for the different disposal alternatives are expressed in year 2002 money terms.

Possible increases in the cost of the works have also been estimated based upon the technical uncertainties associated with the disposal alternatives.

5.1.3 Public Consultation

TFEE Norge began planning for the decommissioning of the Frigg Field in 1998 and considered it important to involve stakeholders as early as possible. Thus, in April 1999 a process of public consultation and dialogue was started, involving stakeholders in both Norway and the UK. The consultation process has been similar in both countries whilst respecting the particular national regulations.

In addition to the statutory consultations required by both Governments, efforts have been made by TFEE Norge to identify, and involve, a wide range of stakeholders who have an interest in the decommissioning of the Frigg Field. All identified stakeholders have been kept informed about the development of the project and invited to participate in appropriate events organised by TFEE Norge.

Efforts have been made to ensure that the consultation and dialogue process is open and transparent. Feedback received from stakeholders has been greatly appreciated and has influenced the studies and assessments undertaken and the drafting of the Frigg Field Cessation Plan.

To date, the main stakeholder consultation activities have been:

- Identification of interested stakeholders by placement of advertisements in key national and international publications inviting stakeholders to participate in the consultation process.
- Consultation regarding the scope of the Environmental Impact Assessment (EIA), which was modified in line with the comments received.
- Face-to-face meetings with stakeholders in UK and Norway.
- Stakeholder review of the Draft EIA and incorporation of comments into the document.
- Stakeholder workshop held in London in September 2000 to consider the challenges associated with the decommissioning alternatives for the concrete substructures. This workshop was attended by stakeholders from UK and Norway.
- Visit by stakeholder to the Frigg Central Complex in September 2001.
- Statutory public consultation, 29 November 2001 to 28 February 2002.

Newsletters have been produced regularly and all documents of interest to stakeholders are posted on the Frigg Field Cessation web site (www.totalfinaelf.no/cessation). Two video animations have been prepared by TFEE Norge illustrating the numerous uncertainties associated with attempting to refloat, or cut down the three concrete substructures. These video animations have been used in the consultation process.

A copy of the Frigg Field Cessation Plan was sent to each statutory consultee in both Norway and UK and to a wider group of interested parties. Other stakeholders were notified that the Cessation Plan had been issued and that it was available either on the web site or from the offices of TFEE Norge in Stavanger, Norway. Hard copies of the document were made available for review at public libraries in London and Aberdeen and notices advertising this fact were placed in the UK national press.

During the three-month consultation period the main groups of stakeholders were contacted and meetings held when requested to discuss and explain the reasoning in the Cessation Plan. The responses received from both the statutory consultees and other interested parties have been summarised and included in the Third Draft of the Frigg Field Cessation Plan. A summary of the main matters of concern and the response of TFEE Norge has also been prepared.

5.2 REUSE POTENTIAL

The reuse of the Frigg Field concrete substructures either for oil and gas exploitation or for other purposes has been actively considered. No arrangement to reuse the facilities at their present location has been identified which is both technically feasible and economically viable at the present moment.

The uncertainties inherent in trying to refloat the concrete substructures (as described in later sections) mean that it is not possible to reuse them at another location.

Some of the possible reuse schemes considered are described in the following sections.

5.2.1 Reuse as a Treatment Centre for Adjacent Fields

Since the early 1980s extensive efforts have been made to prolong the operational life of the Frigg Field facilities. These efforts resulted in the development of several satellite fields in the Frigg area. All of these satellite fields have now ceased production and the production equipment has been removed.

Gas from the Alwyn Field is presently exported to UK via the Frigg Central Complex. After the Alwyn pipeline is connected directly to the Frigg UK Pipeline in 2004, there will be no need to retain the platform facilities.

At present there are no other known reservoirs in the area that can be economically developed from Frigg. In addition, the prospect for new developments in the area is limited. The operators of a number of discoveries in the Norwegian and UK sector of the North Sea have also been approached regarding the possible use of the Frigg Field facilities. None of these approaches has lead to the prospect of continued use for Frigg.

It is therefore concluded that the continued use of the Frigg Field facilities as a treatment centre for hydrocarbons produced in the area is neither likely, nor economically viable.

5.2.2 Reuse as a Pipeline Export Centre

Three different export pipelines are connected to Frigg, namely the two 32” gas pipelines to St. Fergus in Scotland (known as the Frigg Transportation System), and the 16” Frostpipe oil pipeline to the Oseberg platform from where the oil is routed to the Sture terminal in Norway. By connecting the Alwyn and Vesterled pipelines directly to the Frigg export pipelines to Scotland they will continue to function without requiring support from the Frigg platforms. The future use of Frostpipe is undecided at present although it is not likely to require the retention of the Frigg Field installations.

5.2.3 Artificial Reef

Four alternative arrangements for an artificial reef formed from the Frigg Field substructures have been considered. The studies show that none of the alternatives are likely to have a great enhancement effect on pelagic fishery, or a significant positive impact on the total marine environment.

The establishment of an artificial reef is only considered to be a favourable option if clearly positive effects can be shown. In view of the findings of the studies, it is concluded that the use of the installations as artificial reefs is not a desirable reuse alternative.

5.2.4 Wind-generators

The aim of the wind-generator study has been to investigate the possibility of utilising the redundant concrete substructures as foundations for offshore wind-generators. The study has shown that it is technically feasible to supply power from wind-generators located at the Frigg Field to other platforms in the same general area of the North Sea.

The price of electricity generated by offshore wind power systems at Frigg has been estimated to be considerably higher than the cost of electricity generated offshore from the combustion of hydrocarbons, even taking account of the tax levied on carbon dioxide (CO_2), emissions in the Norwegian Sector. It is judged that electricity generated by offshore wind-generators located on the Frigg Field installations would not be competitive in the energy market, even if the cost of production could be significantly reduced. The cost uncertainties associated with the conversion and maintenance of the ageing Frigg installations and their logistical support, also mitigate strongly against their use as wind-generators.

It should also be noted that any consumer of wind generated electrical power would need to install and maintain a back-up source of power for times when there is insufficient wind to meet the required power demand.

The export of wind-generated electricity from Frigg to shore is not economically viable due to the high transmission cost (Frigg is 190 km from the Norwegian coast and 360 km from the UK coast).

The reuse of the Frigg concrete substructures as foundations for offshore wind-generators is therefore judged not to be viable at the present time.

5.2.5 Emission-Free Gas-Power Plant

The installation of an emission-free gas-fired power plant on the existing Frigg Field platforms has been studied based upon different gas supply scenarios. It is assumed in the study that the electricity generated would be exported to other platforms in the area by subsea cable. The gas (carbon dioxide/nitrogen) from the power generation process would be exported, via pipelines, to fields in the area for use in reservoir pressure support and enhanced oil recovery.

There are a number of technical uncertainties as the technology is still only at the pilot-scheme stage and thus the capital cost of such a project is uncertain. It also appears likely that there would not be a market for the electricity and gas at the price necessary to ensure commercial viability. There will also be a significant financial risk associated with the continuing maintenance and logistical support of the ageing structures.

Although the concept is emission-free, large quantities of high-temperature cooling water would be discharged into the sea. There is no practical possibility of recovering and using this energy and thus the energy balance for such a scheme is not environmentally attractive.

It has therefore been concluded that this concept does not provide a practicable future use for the Frigg concrete substructures.

5.2.6 Ekofisk Studies

As a partner in the Ekofisk Field, TFEE Norge has reviewed the studies that were carried out during the preparation of the Ekofisk 1 Environmental Impact Assessment, to assess whether the results are applicable to the Frigg Field. Although there are significant differences between the Ekofisk and Frigg installations it has been concluded that none of the schemes considered (and subsequently rejected) for Ekofisk would be economically viable at Frigg.

The possible uses considered included:

- Wave power
- Aquaculture
- Centre of communication and navigation
- Meteorology station
- Training centre for divers
- Launching base for research missiles
- Rescue and standby centre
- Marine research

5.2.7 Possible Reuse at Another Location

A general assessment of the potential reuse opportunities has been carried out and possible scenarios established. One option, that could provide added value to society, is to use the concrete substructures as bridge foundations for fjord crossings. Such a use has the potential to provide cost savings on the bridge construction cost. The concrete substructures could also be incorporated into some form of quay foundation or be used as landfill for industrial purposes.

The feasibility of such schemes depends upon the ability to safely refloat the substructures and on the particular site conditions where it would be reused. As shown in Section 5.3 the risks associated with refloating the Frigg Field concrete substructures are many times higher than acceptable.

5.3 ON LAND DISPOSAL

In the absence of any viable reuse for the three Frigg Field concrete substructures, studies have been carried out to consider the feasibility of refloating and towing them to shore where they can be deconstructed and the materials recycled.

When assessing the on land disposal alternative, similar attention has been given to assessing technical feasibility, safety, environmental impact and cost aspects. The three concrete substructures are each different in design and therefore, different procedures would be needed for their removal and disposal. It has therefore been necessary to describe the technical feasibility of refloating each of the substructures separately. The risks to personnel, the environmental impacts and the costs have been carefully assessed and the results are summarised for all three substructures.

All of the substructures have currently been in place for approximately 25 years and it is likely that some deterioration in their condition has occurred. At the time these platforms were designed and constructed, consideration of the loading during a future removal operation was not included in the design process. In addition, the mechanical systems used in controlling and positioning the concrete substructures during installation were only designed for use during that phase, and were thus abandoned when the platforms were in place.

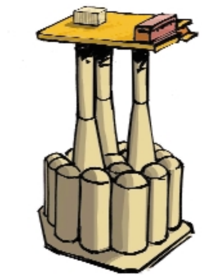
In order to reduce the risk to personnel, the substructures would be unmanned, during the refloat and towing operations. Operation of the deballasting systems when the substructure is unmanned would be by remote control, from an adjacent boat. It might however be necessary to re-man the substructure for a period of time in the event of equipment malfunction.

The reinforced/prestressed concrete cut from the substructures would be crushed onshore to allow recovery of the steel and concrete. The steel would then be sent for re-smelting whilst it is anticipated that the crushed concrete would be reused or disposed of in landfill.

5.3.1 Technical Feasibility TCP2

5.3.1.1 Proposed Method

To refloat the TCP2 concrete substructure it would be necessary to use a combination of buoyancy forces and water pressure beneath the base slab to free the substructure from the seabed. The sequence of operations would be:



- Remove part of the topsides to reduce the load.
- Install deballasting systems, incorporating existing pipework in the base, to allow water to be pumped out of the cells and columns.
- Install the compressed air systems needed to reduce the stresses in the concrete substructure during the refloat operation.
- Install the water injection system including the construction of injection points through the base slab.
- Place a layer of gravel around the substructure to help maintain the hydraulic pressure under the base slab.
- Pump water out of the cells, but maintain a positive load on the seabed.
- Inject water under the base. The hydraulic pressure under the base slab would be the primary force used for extracting the skirts and dowels from the seabed.
  As the platform rises the hydraulic pressure beneath the base would be lost due to outflow of the water to the surrounding sea.
- Pump water out of columns to complete the extraction of the skirts and dowels from the seabed.
- After the substructure separates from the seabed, continue deballasting until towing draft is reached.
- Tow to a sheltered inshore mooring, remove the remaining topsides and deconstruct the concrete substructure.
- Tow the lower section of the substructure into a dry dock to complete deconstruction.

5.3.1.2 Technical Feasibility

During the design of the TCP2 platform no consideration was given to the removal of the concrete substructure at a later date. Accordingly the ability of the structure to resist the loads during a refloat operation was not checked, and no specific features were incorporated into the design to facilitate removal.

It has been estimated that the chance of a major accident or incident during the refloat, towing and deconstruction operations is twenty to forty times higher than the acceptance criterion for marine operations. The aspects with the potential to cause the refloat operation to be aborted are shown diagrammatically in Figure 5.3 and are explained in the following text, using the same headings used in the diagram.

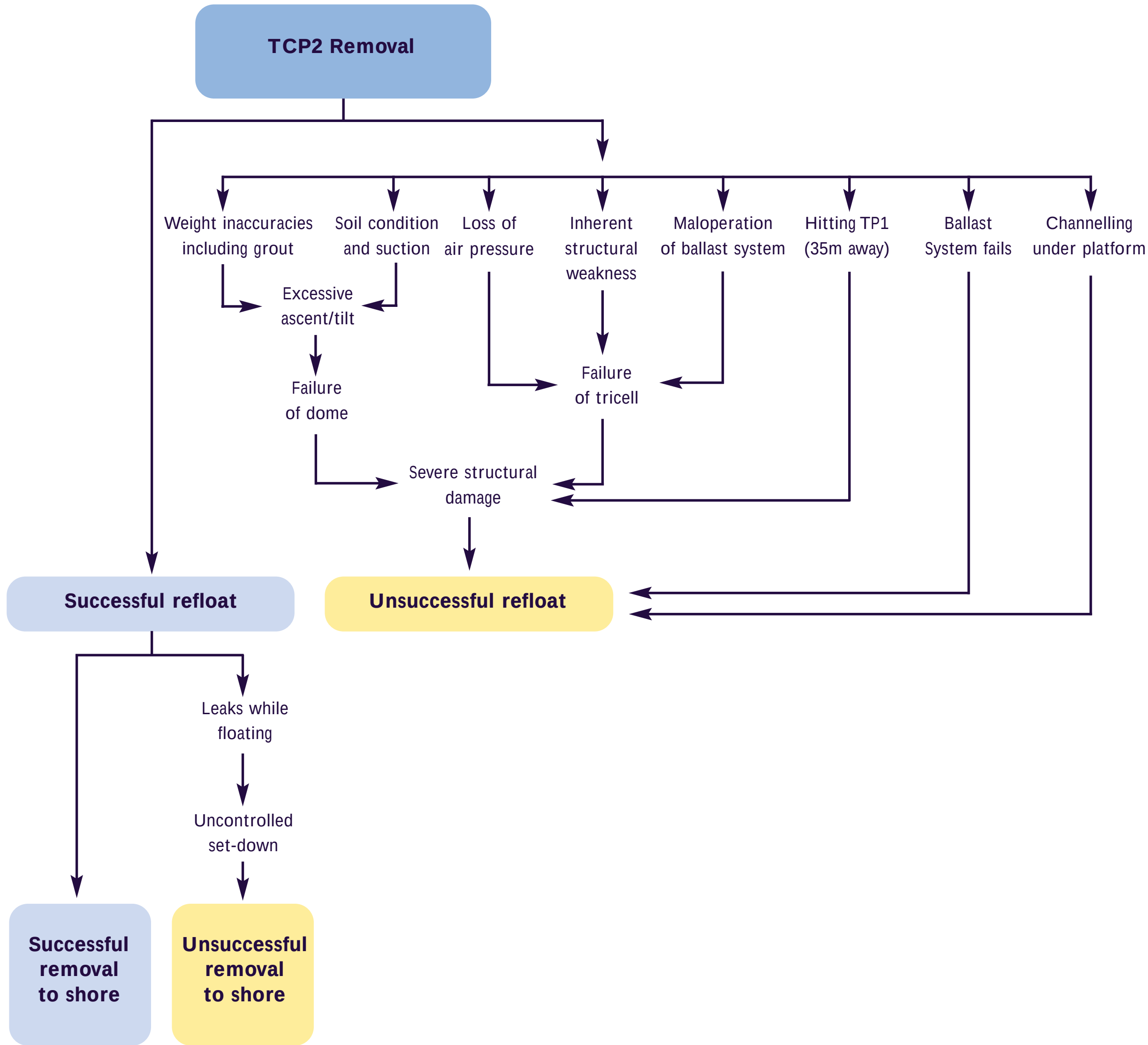


Figure 5.3 Areas of Uncertainty Affecting the Success of the Refloat and Towing of TCP2

- **Weight Inaccuracies Including Grout**
- **Soil Conditions and Suction**
- **Channeling Under Platform**

These are all aspects that have an effect on the success of the operations required to separate the concrete substructure from the seabed.

The substructure has a series of 1.7 m deep "skirts" below the base slab that go into the soil to prevent horizontal movement of the platform when the platform is subject to large wave forces. In addition there are 3 dowels projecting from the bottom slab into the soil. These dowels were used to prevent the platform "skidding" across the seabed during the latter stages of installation.

The base slab is not a flat concrete slab but is formed from the domed ends to the cells in the base of the substructure. After installation the space between these domed cell ends and the soil was filled with cement grout to ensure an even bearing pressure on the seabed.

In order to successfully refloat the concrete substructure it would be necessary to pull the skirts and the dowels, attached to the bottom of the platform, out of the soil. The force necessary to extract the skirts and dowels from the soil is uncertain due to possible **variations in the soil strength**, the **weight**

of the substructure, and any **suction** that might develop under the platform. The uncertainties associated with these aspects are all increased due to the time the platform has been in place.

Pulling the skirts and dowels out of the soil by buoyancy forces alone is not considered to be feasible due to the uncontrolled dynamic effects that could occur when the platform breaks free from the seabed. In such a situation the platform might rise well above its normal floating draft before stabilising. In addition, analysis has indicated that hydrodynamic effects during the ascent from the seabed could cause significant "tilt" of the substructure. These combined effects could result in **severe over-stressing of the domed roof** of the cells and, in worst-case situations, give rise to structural failure and loss of the substructure.

The possibility of an uncontrolled release from the seabed is increased due to **uncertainties in the weight of the structure** as it comes free. The main factors that make the weight less certain than at installation are; marine growth; deposits on the top of the cells and the amount of cement grout that might become detached from the base slab. These factors may adversely affect both the **tilt** and the **maximum ascent** of the substructure after breaking loose from the seabed.

The feasibility of the refloat operation is therefore dependent upon the successful use of adequate, and correctly controlled, hydraulic pressure beneath the base slab to initiate the extraction of the skirts and dowels from the soil.

Studies have indicated that in certain circumstances **channels** could form in the sand under the substructure allowing the water to flow out too easily and thereby preventing the build up of the necessary pressure. This would limit the lifting force generated beneath the platform and would seriously jeopardise the feasibility of the refloat operation.

The placement of a surcharge of gravel on the seabed around the substructure will reduce the risk of channelling in the soil although it is not completely certain that this measure will ensure that the skirts and dowels can be extracted using hydraulic pressure under the base slab. Although extensive evaluation of the soil conditions at the Frigg Field has been undertaken it is known that the soil in the area is rather variable. There is likely to be a significant variation in the soil properties under and around the platform that may affect the efficiency of the hydraulic jacking operations.

Even if it is possible to start the extraction process using hydraulic pressure under the base slab, the amount of extraction possible with this method may be limited due to leakage and the slope of the seabed. If this should occur after limited extraction of the skirt, it would then be necessary to undertake the final extraction of the piles and dowels using buoyancy forces generated by deballasting the base cells and columns. The slope of the seabed and variations in the soil properties are both significant factors in determining how much of the skirts and dowels would be extracted before the pressure under the base slab was lost.

If it were impossible to extract the skirts and dowels by a significant amount using hydraulic jacking, then a relatively high out-of-balance buoyancy force would be needed to pull them out of the seabed. There would then be a very significant risk that the substructure would rise to a level well above its normal floating draft, which would overstress or cause the failure of one or more cell roof domes. In that event, the buoyancy of the substructure would be lost and it would fall back onto the seabed, being severly damaged in the process.

The overload of the upper domes is due to the fact that the cells have to be filled with compressed air at high pressure to prevent damage to other parts of the substructure when it is emptied of water. This is explained further in the following sub-section.

- **Loss of Air Pressure**
- **Inherent Structural Weakness**
- **Maloperation of Ballast System**

The lower part of the substructure is composed of nineteen interconnected cylindrical cells with domed ends. The cylindrical cells are closed and the water level, and pressure, within them may be controlled. The triangular space formed where three cells join is often referred to as a tri-cell. This space is open to the sea at the upper end. Cracking in the tri-cell area has been experienced on other platforms of similar design.

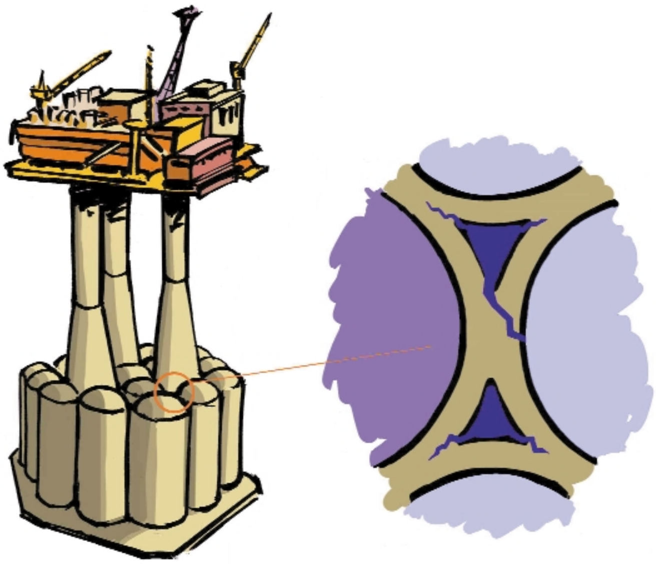


Figure 5.4 Location of Predicted Cracking in the tri-cells

A concrete substructure was lost during deep submersion testing in 1991 due to weaknesses in the design and construction of the tri-cells. As a result, the reinforcement was unable to resist the hydrostatic loads in the tri-cells and extensive cracking occurred which allowed the ingress of large amounts of water.

It is also known that problems occurred with the tri-cells of two other similar substructures during deep submersion testing and installation. Significant repairs to the concrete substructure were needed following severe cracking that occurred when the structures were subject to large hydrostatic pressures.

The TCP2 concrete substructure is similar, although not identical, in design to these other substructures. During de-ballasting operations large forces would be developed on the walls of the tri-cells which could cause severe cracking. The water pressure penetrating into the crack would tend to open the crack further.

In order to limit the forces in the tri-cell walls it is proposed to pressurise the adjoining cells with compressed air. The **air pressure** that can be used in the cells has to be within certain limits. It has to be high enough to prevent overstressing of the structure around the tri-cells when the substructure is resting on the seabed, but not so high that it will cause over-stressing and possible collapse of the cell roof domes when the substructure is at its highest point of ascent after breaking loose from the seabed.

A further aspect that requires consideration when assessing the condition and strength of the tri-cell walls is that during the life of the structure the columns have been pumped dry a number of times for inspection of the risers. In addition, the substructure has had to withstand periods of adverse weather and emergency ballasting when severe weather was predicted during times when the columns were dry. It is believed that over-stressing of the reinforcing bars at particular locations in the vicinity of the tri-cells has occurred at these times and that the concrete in these areas is **likely to already be cracked.** These cracks

Figure 5.5 TCP2 During Construction

do not impair the strength of the structure as it stands, but could have an important effect during refloat operations. It is not considered possible to accurately inspect the inside of the tri-cell for cracks.

The integrity of the tri-cell structure during the planned refloat operations has been investigated using non-linear structural analysis to predict the degree of **cracking** in the area. The conclusion drawn from these studies is that cracks more than 1m deep are likely to occur during the deballasting and refloat operations. It is predicted that these cracks will occur at a number of locations in the substructure over a substantial section of wall. The load bearing capacity of the walls and the water-tightness of the structure will only be adversely affected if these cracks propagate into the cells.

However, similar extensive cracking was experienced on at least one other “Condeep” type substructure and in that case the cracks did propagate into a cell. This allowed the ingress of water to a cell. The leak was fortunately small enough to be controlled by the pumps installed on the platform. Structural analysis undertaken following this event was unable to predict why the cracks in the structure deviated from the centre of the wall.

The two-dimension structural analysis used to investigate the cracking in the TCP2 tri-cells is not considered adequate to correctly predict the propagation of the crack, as it does not account for three-dimensional or secondary effects. A three-dimensional structural analysis might provide better results, but such an analysis would also contain uncertainties, which would prevent the exact safety of the tri-cells from being established. The likely extent of the cracking in the tri-cells is therefore uncertain. It has however been established that quite extensive cracking is likely to occur and that there is a significant possibility that such cracks could propagate through the walls of a cell and thereby adversely affect the water-tightness and integrity of the structure.

If the **air pressure** in the cells is lost, or there is a maloperation of the ballast system, then it is extremely probable that cracks will develop through the walls of the cells with subsequent flooding. This will either prevent the substructure being lifted off the seabed or would cause it to fall back onto the seabed after lift off.

Studies have been conducted to consider whether sealing off the tri-cells from the sea could reduce the probability of structural problems. Whilst this could reduce the probability of cracking in the tri-cell walls when the substructure is on the seabed, it would however increase the risks after the substructure breaks free from the seabed and rises in the water. If the tri-cells were closed to the sea, the stresses in the walls and domes of all the base cells would be significantly different from those occuring during installation. Their capacity to resist these new stress distributions is uncertain. In practical terms, sealing the tri-cells would not be easy to achieve and would increase the risk to personnel due to the additional diving work required. For these reasons closing the tri-cells during the refloat operation has not been considered further.

- **Hitting TP1**

The movement of the TCP2 substructure as it breaks free from the seabed is more or less impossible to predict with any degree of accuracy. There is a possibility that the substructure could "skid" across the sea-bed in an uncontrollable manner after breaking loose. The possibility of this phenomenon was considered during installation, and steel dowels installed under the base to try and prevent this movement as the platform approached the seabed. Separating the substructure from the seabed is less controlled than installation and thus it is considered that the chance of uncontrolled horizontal movement would be greater.

In addition to the horizontal movement the substructure is likely to tilt as it breaks free from the seabed due to variation in the soil friction on the skirts, suction under the platform and the possibility of the grout falling off the bottom of the platform. Any initial tilt is likely to be increased by hydrodynamic forces, as the substructure starts moving.

The TCP2 and TP1 substructures are only 35m apart and accordingly there is a possibility of an impact after TCP2 lifts off the seabed. The same problem would exist for TP1 if it were removed before TCP2 (see Section 5.3.3.2).

- **Ballast System Fails**

The ballast system on TCP2 was only designed to be used during the original installation operations and was abandoned after the platform was in location. This system will need to be fully operational for the refloat operation with a high level of reliability. Failure of the system due to either leakage or blockage could give rise to uneven ballasting or flooding of cells. If this occurred during the refloat operation it would be extremely difficult to rectify the situation quickly as the substructure will be unmanned during the critical refloat operations.

Tests on the ballast pipework conducted in the summer of 2000 demonstrated that there were concerns about whether it would be fit to be used for refloating the concrete substructure in eight to ten years time.

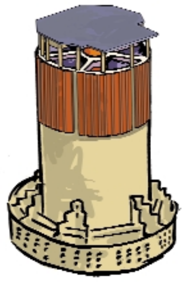
- **Leaks While Floating**

When the substructure is floating there is a possibility that leaks could develop while the platform was being made ready for towing and during the tow to shore. During this period the platform will be unmanned and thus repairs would be difficult to make. Although the pressure on the ballasting system and walls penetrations would be less at towing draft, the pressure has to be sustained for a longer period. The longer-term performance of the ballast system is a particular concern due to uncertainty regarding the wall thickness of the pipework and the possibility of fractures in the pipe due to differential movements of the structure.

5.3.2 Technical Feasibility CDP1

5.3.2.1 Proposed Method

The sequence of operations for refloating the CDP1 substructure would be:



- Remove the required parts of the topside.
- Plug and disconnect the pipelines and risers
- Install water de-ballasting system.
- Remove the solid ballast (sand and gravel) between the central shaft and the outer wall using a suction dredging system working from the concrete deck beams. The top layer of sand and gravel ballast would be removed and deposited on the seabed a short distance from the platform.
- Remove the layer of drill cuttings and any contaminated ballast using a crane with a grab system located on the deck beams. The drill cuttings and contaminated ballast would be transferred to a hopper barge for transportation to shore where they would be treated before onshore disposal.
- Remove the solid ballast below the drill cuttings using the air operated dredging system and also deposit on the seabed.
- Remove debris inside the foundation raft.
- Seal the wave-breaking holes in the outer wall by installing a prefabricated steel cofferdam, made up of six separate sections, around the external face of the wall.
- Plug the penetrations in the base slab.
- Reinstate towing points on the substructure.
- Pump water out of the substructure until structure lifts off the seabed. Studies indicate that only limited “suction” between the substructure and the soil would be likely to occur due to the absence of skirts and the permeability of the sand layer on which the platform is founded.
- Continue pumping water out of substructure until it is floating at its towing draft.
- Tow to inshore location and remove any remaining topside steelwork and the concrete deck beams.
- Remove steel cofferdam and deconstruct concrete substructure.
- Install a temporary cofferdam around the lower section of the substructure and then tow it into a dry dock and complete the deconstruction of the concrete substructure.

Figure 5.6 Present Condition of CDP1

5.3.2.2 Technical Feasibility

During the design of the CDP1 concrete substructure no consideration was given to its removal at a later date. Accordingly the ability of the structure to resist the loads during a refloat operation was not checked and no specific features were incorporated into the design to facilitate removal. Additionally it must be remembered that the platform was originally designed as a booster platform on the Frigg to St Fergus pipelines. After the accident with the DP1 steel substructure in 1974 the platform was converted for use as a drilling platform, but by that time the design had been completed and the construction was well advanced. The substructure was completed in accordance with the original design.

It has been estimated that the chance of a major accident or incident during the refloat, towing and deconstruction operations is three hundred times higher than the acceptance criterion for marine operations. The aspects with the potential to cause the refloat operation to be aborted, are shown diagrammatically in Figure 5.7 and are explained in the following text.

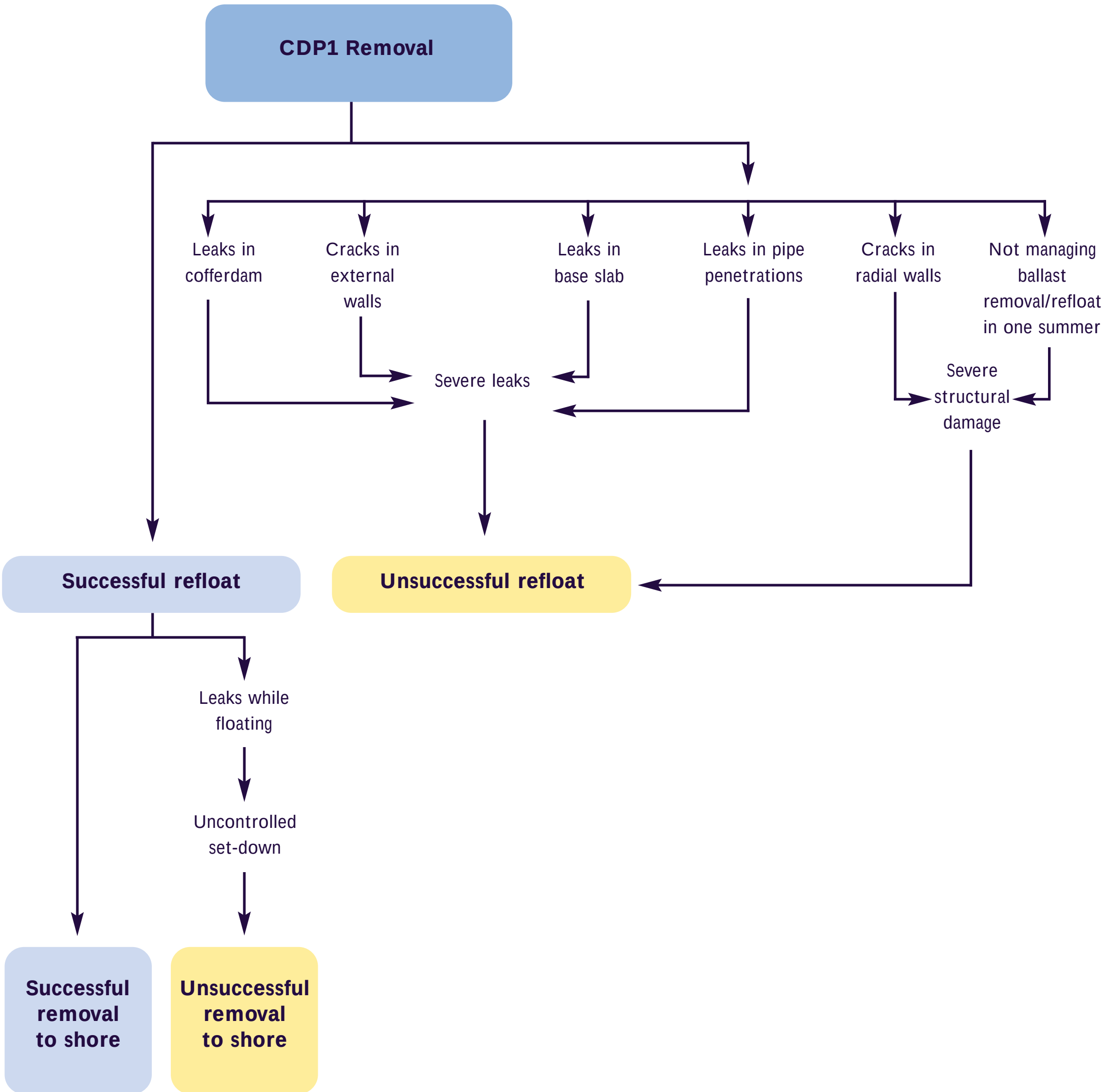


Figure 5.7 Areas of Uncertainty Affecting the Success of the Refloat and Towing of CDP1

- **Leaks in Cofferdam**
- **Cracks in External Walls**
- **Leaks in Base Slab**
- **Leaks in Pipe Penetrations**

The feasibility of refloating the CDP1 concrete substructure has been shown to be highly dependent on the water-tightness of the cofferdam, walls and base slab. The water-tightness of the substructure is the most critical aspect of the refloat operation. Additionally this aspect has a very high uncertainty factor associated with it.

During tow-out and installation of the platform in 1975, an in-flow of seawater of approximately 3,000 m^3/hour was measured (see Figure 5.8). This large leakage was noted and documented at the time by the independent warranty surveyor, Noble Denton & Associates. The leakage is understood to have occurred at many locations in the vicinity of the wave-breaking holes in the outer wall. Leakage was recorded as occurring through construction joints between the pre-cast concrete units in the area and the in-situ concrete between the units. There is also record of **leaks through ineffectively plugged holes** for scaffolding or other temporary equipment. The use of a large external steel cofferdam during an attempted refloat operation would most probably reduce the leakage, but this is by no means certain.

If there are existing leaks below the bottom of the cofferdam these will not be evident until the cofferdam is installed and the water inside the outer wall pumped out. If serious leaks were discovered (principally by being unable to pump out the space inside the outer wall), it would be extremely difficult or perhaps impossible to locate or repair them.

As well as the known leakage there are a number of other places where significant leakage could occur during the water de-ballasting and refloat operation. The holes that were drilled through the base slab for the 24 wells are likely leak points. As the substructure was not initially intended to be a drilling platform, provision for the wells was not included in the design. The holes for the wells were therefore cut after the platform had been installed. This was done using the drilling facilities on the platform to drill through the reinforced and pre-stressed concrete base slab. The wells were plugged and abandoned in 1990 but all the **holes in the base slab will still need to be sealed** before the platform can be refloated.

In addition to the holes for the wells, there are a number of other penetrations in the base slab principally for the instrumentation pipes used to monitor the bearing pressure under the platform. The condition of the pipework penetrating the base slab is unknown, as the system has not been used for many years. Two instrumentation pipes are reported to be broken and lost in the solid ballast. It is not possible at the moment to inspect these items as they are covered with solid ballast and lean mix concrete, the condition of which is unknown. It is unlikely that the lean mix concrete can be relied upon to prevent leakage from the instrumentation pipework. It would be necessary to **find and plug all the penetrations** in the base slab, including the conductor sleeves and instrument connections, before refloat operations could be started.

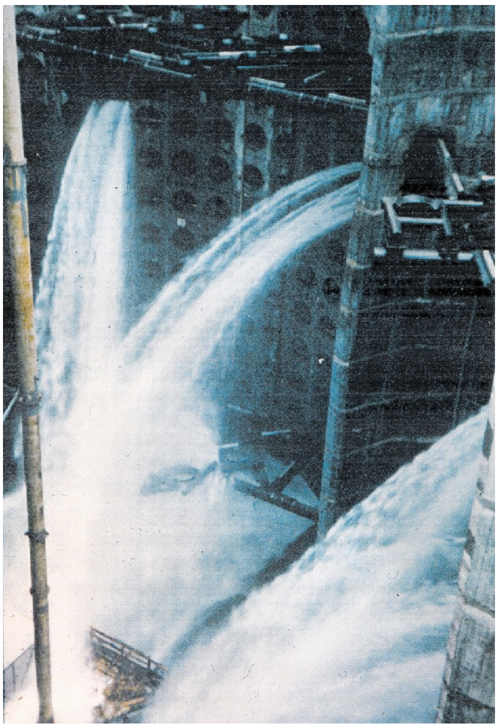


Figure 5.8 Leaks through the External Wall during the Installation of CDP1

During the early life of the platform **severe cracking** occurred in the concrete structure due to wave loading on the platform. Additional solid ballast was added to the substructure to prevent further damage, but large cracks in the radial walls in the direction of the prevailing weather, had already formed. Throughout the operational life of the field the condition of the substructure has been monitored by bi-annual subsea inspection programmes to ensure the safety of the CDP1 platform at all times. It is however known that these cracks are as much as 11m long in some locations. These cracks are in the radial walls of the substructure and it is believed that there is only a low probability that they would propagate into the external walls of the sub-structure during the refloat and towing operations. Significant cracking in the outer wall of the substructure would however result in large leaks that could jeopardise the buoyancy of the concrete substructure whilst floating. Based upon the structural configuration of the walls expert opinion has judged that in its existing condition, such crack propagation, although possible, has a low probability. If however the substructure was left for a significant period of time in an un-ballasted condition with the cofferdam in-place, then the likelihood of cracks propagating into the external walls is much higher.

A further probable source of leakage is the **steel cofferdam** that would need to be installed around the outer wall to seal the 720 wave-breaking holes. This large steel structure, which would need to be approximately 250 m in circumference, would have to be placed against the existing concrete walls of the substructure. It will be extremely difficult to ensure the water-tightness of the cofferdam. Extensive measures can be taken to prevent leakage, however the size of the cofferdam and the fact that it will need to be installed on an old concrete structure, in the open sea, means that there is a **very high probability of significant leakage occurring**.

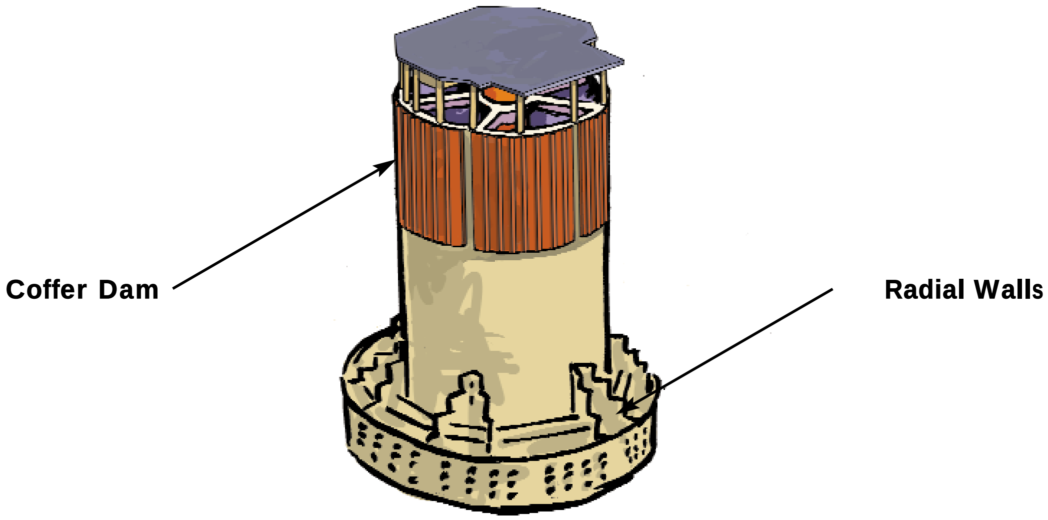


Figure 5.9 Location of the Steel Cofferdam Installed to Seal the Holes in the Outer Wall of CDP1

Due to the design of the substructure, it is not possible to test or demonstrate the water-tightness of the structure until the solid ballast has been removed, the cofferdam has been installed around the outer wall and the water inside the outer wall has been pumped out. In view of all these facts and, in the absence of information to the contrary, it must be assumed that there would be considerable leakage during any refloat operation.

With the cofferdam installed, and the solid ballast removed, the substructure would not be able to withstand a severe winter storm without significant damage, or movement on the seabed. Thus, if there was a delay of a number of months in the refloat operation caused by severe leakage, the platform would have to remain in position over the winter period and there would thus be a serious possibility of total loss of the substructure due to cracking in the walls and base slab.

- **Cracks in Radial Walls**

There is considerable uncertainty and concern regarding the structural integrity of the CDP1 substructure during the de-ballasting, "lift off" and ascent through the water. As noted above, the structure has been damaged during its life and large cracks in the radial walls are known to exist. Whilst the platform retains adequate strength when founded on the seabed, it is not certain to what extent these cracks would impair the strength of the substructure when it is floating.

- **Not Managing Ballast Removal/Refloat In One Summer**

As mentioned previously, when the substructure was adopted as a drilling platform, 24 holes 36" in diameter were cut through the concrete base slab for the wells. The position of these holes was determined by the location of the wellheads and Christmas trees on the topsides. In cutting the holes for the wells in the base slab, it was therefore necessary to cut the reinforcement. The effect that this had on the ultimate strength of the base slab is uncertain at the present time.

During a refloat operation the substructure would experience a totally new series of loads arising from the fact that the cofferdam is installed, and the substructure has been de-ballasted by the removal of approximately 200,000 tonnes of sand and gravel.

If, due to leakage or other operational problems, it were not possible to refloat the platform in the same summer season that the cofferdam was installed and the ballast removed, then there is a high probability that the substructure would be severely damaged by winter storms.

Figure 5.10 CDP1 During a Winter Storm

Difficulty in assessing the weight of items such as marine growth and the ballast remaining in the substructure could give rise to uncertainty in the final refloat weight of the substructure. This in turn would affect the stability and freeboard when floating. In addition, general uncertainty regarding the condition of the solid ballast (compaction, settlement, contamination, debris) could delay the removal of the solid ballast and could require the platform to remain in a lightly ballasted state over a winter period.

5.3.3 Technical Feasibility TP1

5.3.3.1 Proposed Method

The sequence of operations for refloating the TP1 substructure would be:

- Remove parts of the topsides.
- Plug all penetrations of risers and J-tubes and reinstate towing points.
- Install a new water de-ballasting system to allow water to be pumped out of the columns and the cells in the base. This new system would make use of the existing ballasting pipes in the base section of the substructure.
- Pump water out of the cells in the base until a net buoyancy force was achieved. The substructure designers have predicted that hydraulic jacking is not required and that the skirts can be extracted from the soil using buoyancy forces alone.
- TP1 only has two columns and therefore it could be necessary to use different amounts of water in the base cells in order to level the substructure whilst the skirts are being extracted from the seabed and while it is floating.
- Pump additional water out of the cells to reach towing draft.
- Tow substructure to inshore mooring
- Remove the remaining sections of the topsides.
- Deconstruct the columns and upper part of the concrete cells removing the internal steelwork.
- When the floating draft of the substructure has been reduced to approximately 10 m, tow the lower section of the substructure into a dry dock for final deconstruction.

Figure 5.11 Construction of TP1 after Installation of the Deck Structure

5.3.3.2 Technical Feasibility

During the design of the TP1 platform no consideration was given to the removal of the concrete substructure at a later date. Accordingly the ability of the structure to resist the loads during a refloat operation was not checked, and no specific features were incorporated into the design to facilitate removal.

It has been estimated that the chance of a major accident or incident during the refloat, towing and deconstruction operations is twenty to fifty times higher than the acceptance criterion for marine operations. The aspects with the potential to cause the refloat operation to be aborted, are shown diagrammatically in Figure 5.12 and are explained in the following text.

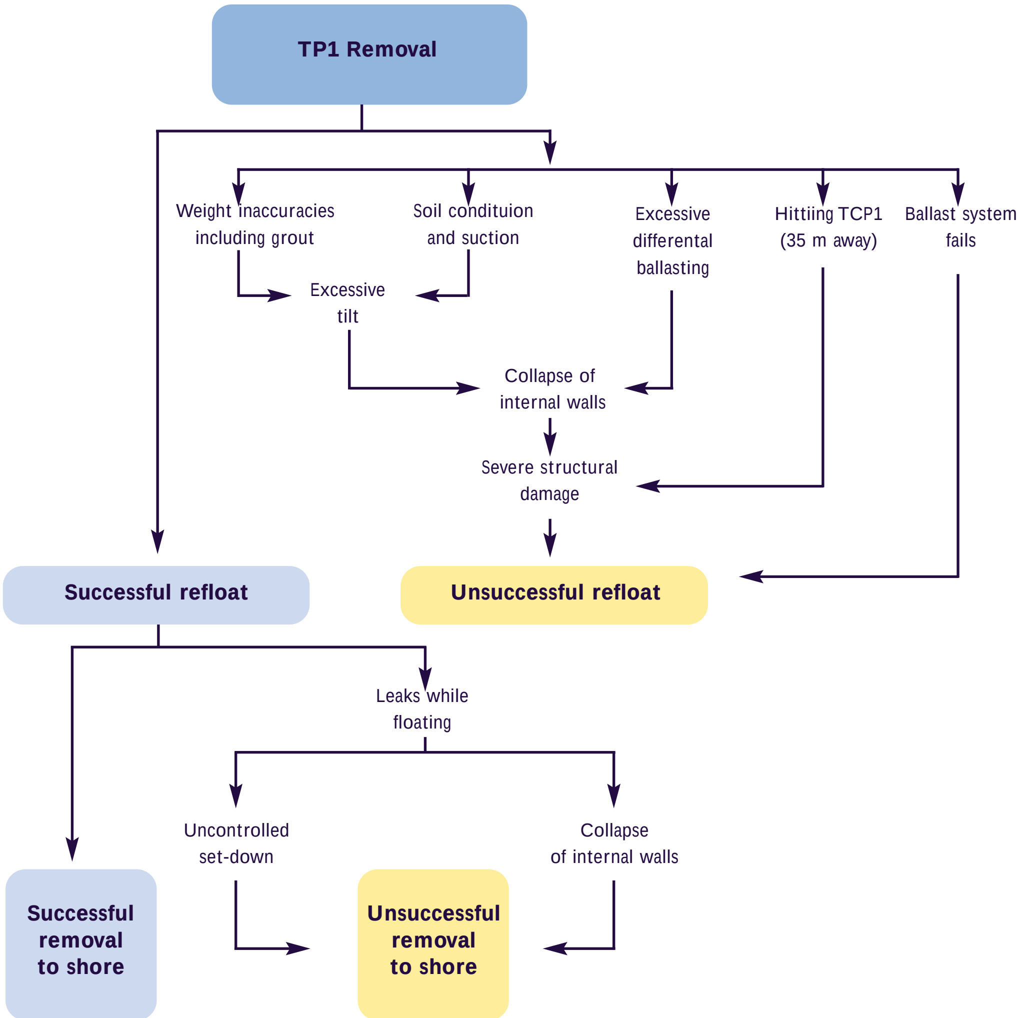


Figure 5.12 Areas of Uncertainty Affecting the Success of the Refloat and Towing of TP1

- **Weight Inaccuracies Including Grout**
- **Soil Conditions and Suction**

Uncertainty relating to the weight of the substructure during the refloat operation is a significant factor when considering the buoyancy force necessary to extract the skirts from the seabed. The main factors that make the weight less certain than at installation are: marine growth, deposits on the top of the cells and the amount of cement grout that might become detached from the base slab. These factors may adversely affect both the tilt (see Figure 5.13) and the maximum ascent of the substructure after breaking loose from the seabed, although for TP1, **tilt** is the critical aspect.

The break-loose resistance of the skirts is a particular uncertainty due to the fact that there is no existing experience of skirts in a similar condition. It is thus very difficult to estimate the lateral soil pressure on the skirts just before the skirt breaks loose and thereby estimate the amount of excess buoyancy that would be required. The opinion of various independent experts has been sought by TFEE Norge in order to arrive at the best estimation of the maximum likely force that will be needed to extract the skirts from the seabed.

The maximum buoyancy force that can be applied to extract the skirts is limited by the effect on the substructure after breaking free from the seabed. If the buoyancy force was too high the platform would rise in an uncontrolled manner. Uncertainties in the weight of the substructure and in measuring the level of water in all the cells contribute towards the uncertainty in estimating the buoyancy force.

- **Excessive Differential Ballasting**

When the TP1 substructure was designed in the early 1970s the concrete design code used was less severe than present codes in respect to the hydraulic loads. Following the failure of a concrete substructure in August 1991 during a deep submersion test, the loads to be used in the design of concrete platforms were increased. Calculations indicate that the original code used for the design of TP1, results in the concrete substructure having a lower factor of safety against collapse than is normal today, although this was considered satisfactory at the time. The effect of this on the overall safety of any refloat operation is not directly obvious, but this factor has been considered in the technical risk analysis described later in this section. The consequences of structural failure are extremely high and thus a conservative approach needs to be adopted when considering the strength of all the structural members.

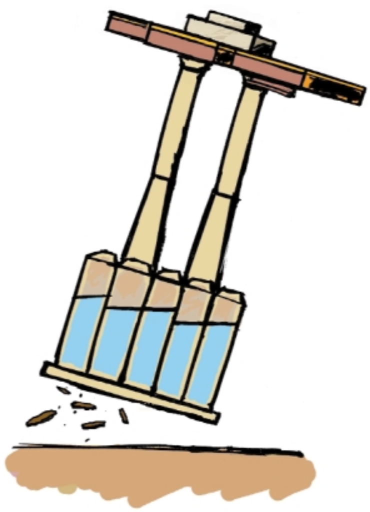


Figure 5.13 Tilt During Lift-off from the Seabed Causing Differential Water Pressure on some Inner Walls

As TP1 only has two columns it could be necessary to have different levels of water in the base cells to keep the substructure level during refloat operations. Studies have shown that the internal walls (see Figure 5.14) have a **rather limited capacity to resist the loads arising from differential ballasting and tilt**. Leakage through the ballast system or the structure, incorrect operation of the ballast system or malfunction of the ballasting or monitoring systems have the potential to produce a differential pressure across an internal wall.

The difference in water level across a wall would also be affected by the "tilt" of the platform after release from the seabed. This would be determined by the weight distribution of the substructure and dynamic effects that could occur when the substructure breaks free from the seabed and rises in the water. Variations in the original level of water in the cells, plus the negative effect arising from leakage between groups of cells will increase the differential pressure on particular walls. The capacity of the internal walls to resist differential water pressure varies with the depth. The walls have their least reserve of strength when the platform is at a depth of approximately 50 to 60 m. It is rather questionable whether the internal walls have sufficient reserves of strength to resist the forces due to the necessary differential ballasting and the possible tilt of the substructure as it rises through the water. The adequacy of the structure to resist the loads during the refloat operation may also be affected by **constructional tolerances or initial defects**. The cells in the base slab are not possible to inspect and therefore conservative assumptions need to be adopted.

Figure 5.14 Construction of the TP1 Substructure showing the Internal Walls and Cells

- **Hitting TCP2**

The movement of the TP1 substructure as it breaks free from the seabed is more or less impossible to predict with any degree of accuracy. There is a possibility that the substructure could "skid" across the seabed in an uncontrollable manner after breaking loose (see Figure 5.15).

In addition to the horizontal movement the substructure is likely to tilt due to variation in the soil friction on the skirts, suction under the platform and the possibility of the grout falling off the bottom of the platform. Any initial tilt is likely to be increased by hydrodynamic forces, as the substructure starts moving.

The TP1 and TCP2 substructures are only 35m apart and accordingly there is a possibility of an impact after TP1 lifts off the seabed. If TCP2 were removed first, the risk of impact would affect the technical feasibility of removing TCP2 (see Section 5.3.1.2).

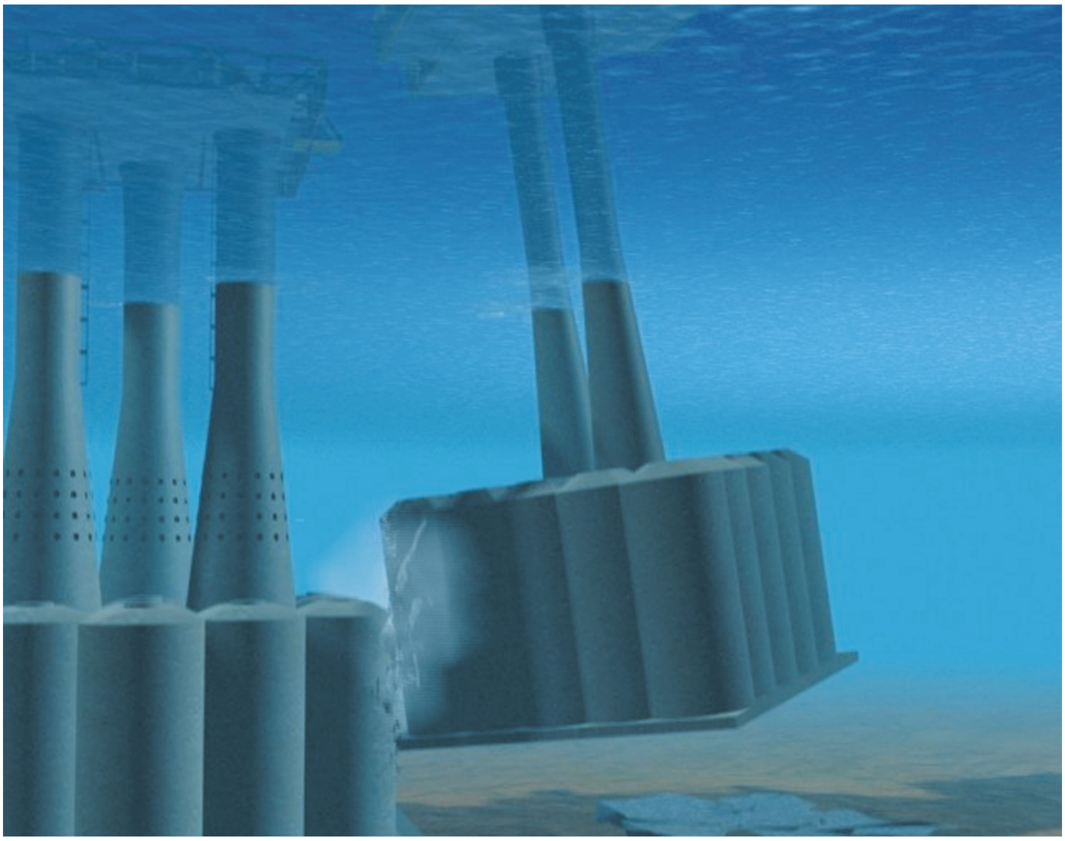


Figure 5.15 Possible Impact between TP1 and TCP2 when Refloating TP1

- **Ballast System Fails**

The reliability of the existing ballasting system pipework and the integrity of the internal concrete walls is of prime importance for this disposal alternative because the substructure would need to remain floating for a considerable length of time whilst it is being deconstructed. The ballast system pipework is approximately 25 years old at the present moment (2002) and would be over 30 years old at the time an attempt might be made to refloat the substructure.

Testing and inspections during the summer of 2000 have shown that the ballast pipework was impaired by some small leaks. It is not possible to deduce what the condition of the pipework may be like in a number of years time when the removal operations would be carried out. It is also not possible to predict the exact behaviour of the ballast piping under operational conditions due to the uncertainties arising from dynamic effects that could occur during the refloat operation. Testing also **identified leakage** between two groups of cells in the base. This leakage is relatively small at the moment and would not have a large effect on floating stability of the substructure. The leaks however are not accessible for repair. Due to the arrangement of the pipework there is particular concern that dynamic forces occurring during the refloat operation could rupture the pipework at a critical time. This situation is particularly critical in locations where there are short sections of exposed pipework inside the cells connecting sections of pipe encased in concrete.

Due to the fact that TP1 only has two columns the **substructure is relatively sensitive to the ballasting arrangements** in the base cells. Serious problems could arise if significant leakage was found to exist between two or three groups of cells when the refloat operation was about to be carried out. The same effect would arise if there were a malfunction of the ballasting system. Failure of an inner wall due to differential water pressure could lead to progressive collapse of the base.

- **Leaks while Floating**

When the substructure is floating there is a possibility that leaks could develop while the platform was being made ready for towing and during the tow to shore. During this period the platform will be unmanned and thus repairs would be difficult to make. Although the pressure on the ballasting system and walls penetrations would be less at towing draft, the pressure has to be sustained for a longer period.

The platform will also be floating at an inshore location for a considerable period of time whilst the columns and base cells are deconstructed. During a significant percentage of this time serious leaks in the ballast system have the potential to cause the loss of the platform. The longer-term performance of the ballast system is therefore of a particular concern.

5.4 AT SEA DISPOSAL

Three different at sea disposal alternatives have been considered for each of the concrete substructures:

- Remove external and internal steelwork, refloat and dispose at a deep water location.
- Remove internal and external steelwork and cut down concrete to provide a clear shipping draft of 55 m.
- Leave in place, removing as much external steelwork as reasonably practicable to avoid hazards to users of the sea.

5.4.1 Refloat and Disposal in Deep Water

This method of disposal would entail refloating the concrete substructures in essentially the same way as described previously for on land disposal. When the concrete substructure was floating at a suitable draft it would be towed to a pre-agreed deep-water location where it would be sunk. The uncertainties and risks associated with refloating the substructures for on land disposal (as described in Section 5.3) also relate to the alternative involving disposal in the deep ocean.

The refloat and disposal in the deep ocean alternative has been fully studied and the technical risk and the risks to personnel are similar to the removal and onshore disposal alternative. Thus, although full assessments of technical, safety, environmental and cost aspects have been made, only limited information about the deep-water disposal alternative is presented in this document. Full details of the studies and assessments made for the disposal in deep water alternative may however be found in the Frigg Field Cessation Plan.

5.4.2 Cutting Down to Provide a Clear Shipping Draft of 55 m

For TCP2 and TP1 this disposal method would entail cutting the columns just above the top of the cells, lifting the sections of column away and placing them on the seabed adjacent to the base. For CDP1 the procedure would be much more complex involving cutting and toppling both the external walls and the radial walls to give the requisite shipping draft.

Several methods of cutting the concrete columns were evaluated, including various combinations of drilling, diamond wire sawing and explosives. The cutting methods were considered feasible in principle but considerable development work would be required to achieve commercial applicability. It is also likely that a large amount of diving work would be necessary to support the cutting operations, much of which would be in particularly hazardous conditions.

The possible methods for cutting down the substructures have been carefully studied and specialist companies retained to assess the practicalities of such operations. The technical risks associated with cutting down the substructures are generally similar to those occurring if the substructures were removed and deconstructed onshore. For TCP2 and CDP1 the risks to personnel involved in cutting down the substructures are higher than the removal and onshore disposal alternative but for TP1 the risks are somewhat lower. The UK and Norwegian fishing industries were particularly opposed to this disposal alternative. Although full assessments of technical, safety, environmental and cost aspects have been made, only limited information about the cutting down disposal alternative is presented in this document. Full details of the studies and assessments made for the cutting down disposal alternative may however be found in the Frigg Field Cessation Plan.

5.4.3 Leave In Place after Removal of External Steelwork

With this method of disposal, the modules and deck forming the topsides would be removed first. Steel items on the outside of the concrete substructures including external risers, external casings, supporting steelwork, ladders, landings etc would then be removed. The J tubes, flowlines and controls umbilicals would be cut at the seabed. Sections of pipe between the substructure and the seabed pipelines would be cut out and removed. A fuller description of the decommissioning works to be undertaken as part of this disposal alternative is given in Section 6.

The majority of the subsea work necessary to remove the external steelwork is planned to be undertaken using remotely operated vehicles controlled from the surface, although some diving work would be required.

The necessary navigation aids would then be installed on the concrete substructures and debris on the seabed around the substructure would be recovered. These activities would be integrated with similar activities for the other Frigg Field platforms and would be planned and undertaken working closely with the various users of the sea and the relevant authorities.

5.5 RISK TO PERSONNEL, ENVIRONMENTAL IMPACT AND COST

This section details the risks to personnel, impact on the environment and cost of disposing the three concrete substructures on land as compared to leaving them in place.

5.5.1 Risk to Personnel

The probability of a fatality or a major injury whilst refloating each of the concrete substructures, towing them to shore and deconstructing them is shown in Table 5.2. The risk to personnel has been estimated based upon a quantitative risk analysis of all the tasks required to refloat the concrete substructures, tow them to shore and deconstruct them. The analysis uses the manhour estimates for the disposal works prepared by the platform designers together with historical data for operations such as offshore and onshore construction, scaffolding, diving, marine operations, helicopter flying etc.

	TCP2	CDP1	TP1
Probability of a Fatality	13%	46%	15%
Probability of a Major Injury	>90%	>90%	>90%
Equivalent **Average** Fatal Accident Rate (FAR)	14	22	15

Table 5.2 Estimated Probability of a Fatality or Major Injury During Refloat, Towing and Deconstruction Operations

Definition of the terms used in Table 5.2 is to be found in Section 5.1.2 under the subheading "Risk to Personnel".

The probability of a fatality when removing all three concrete substructures and disposing of them on land, is estimated to be 60%. (Note that the probability of a fatality is not the sum of the probabilities for each platform, as probabilities cannot simply be added). The probability of a major accident is calculated as more than 90% due to the fact that a number of major injuries are predicted in the risk analysis.

Figure 5.16 shows diagrammatically the probability of a fatality for the removal and onshore disposal alternative as compared to leaving the substructures in place after removal of the external steelwork.

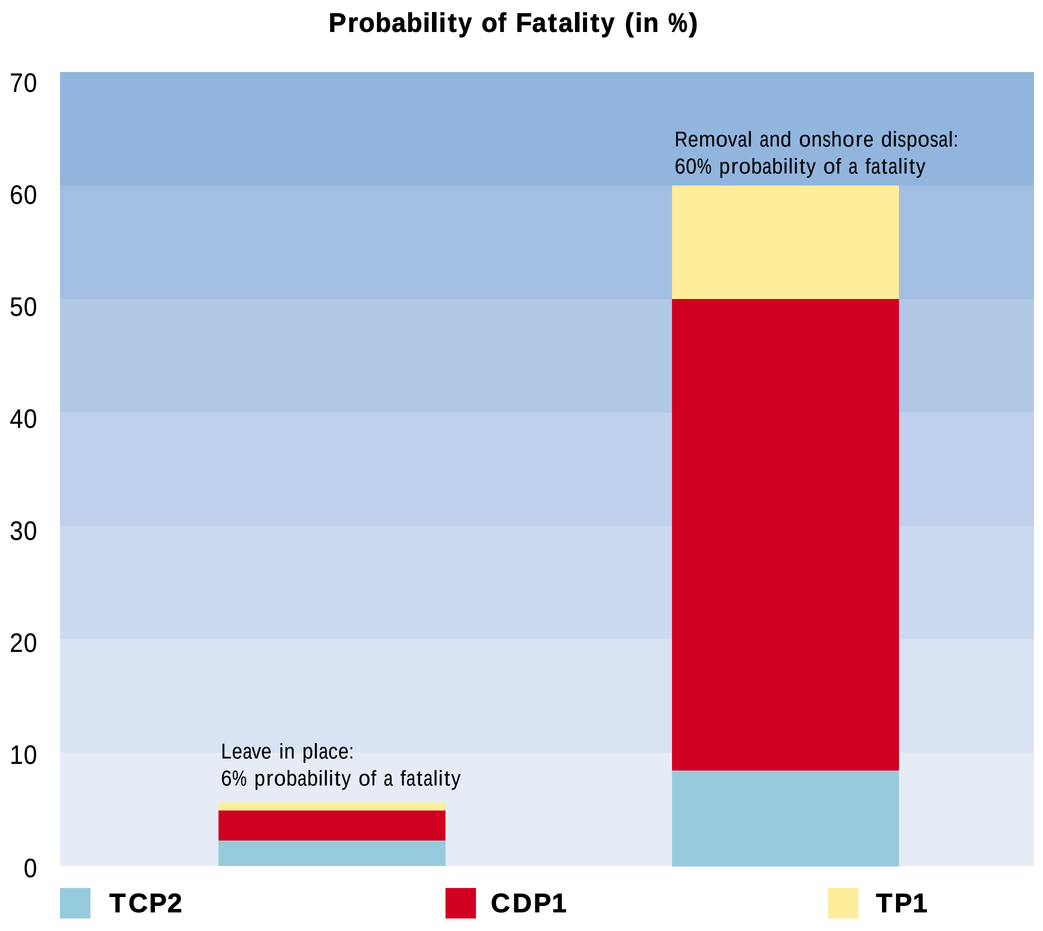


Figure 5.16 Comparison of Probability of a Fatality for Disposal On Land and Leave in Place Alternatives

In Table 5.2, the Fatal Accident Rates (FAR), calculated as an average for all removal and deconstruction activities, are presented to allow comparison with other offshore operations.

The average FAR for personnel on production platforms in the Norwegian sector of the North Sea is

1.3, based upon experience in the last ten years. This rate has changed very little over the last ten years, as the 1990 ten-year average FAR was 1.8.

The average FAR value for personnel on UK production platforms alone is not published. However, based upon figures published by the UK Health and Safety Executive the average FAR value for personnel working on both production platforms and drilling rigs in UK waters has been estimated as approximately 4. As the risk level on drilling rigs is generally higher than on production platforms, the FAR value for UK production platforms alone may be expected to be significantly lower than 4.

For comparison purposes it may therefore be noted that the average FAR values during the refloat, tow and deconstruction of the concrete substructures (as given in Table 5.2) are 10 and 17 times higher than the average rate for Norwegian production platforms and 3 to 5 times higher than the estimated average rate for production platforms and drilling rigs in UK waters.

5.5.2 Environmental Impact

The environmental impacts of refloating the concrete substructures, towing them to shore and deconstructing and disposing of the constituent parts are described in detail in Section 9 of the Environmental Impact Assessment which forms Part 2 of the Frigg Field Cessation Plan.

The energy consumption and the CO_2 emission during the work necessary for removal and on-land disposal of the three concrete substructures is shown in Figures 5.17 and 5.18 compared with equivalent values if they are left in place after removal of the external steelwork.

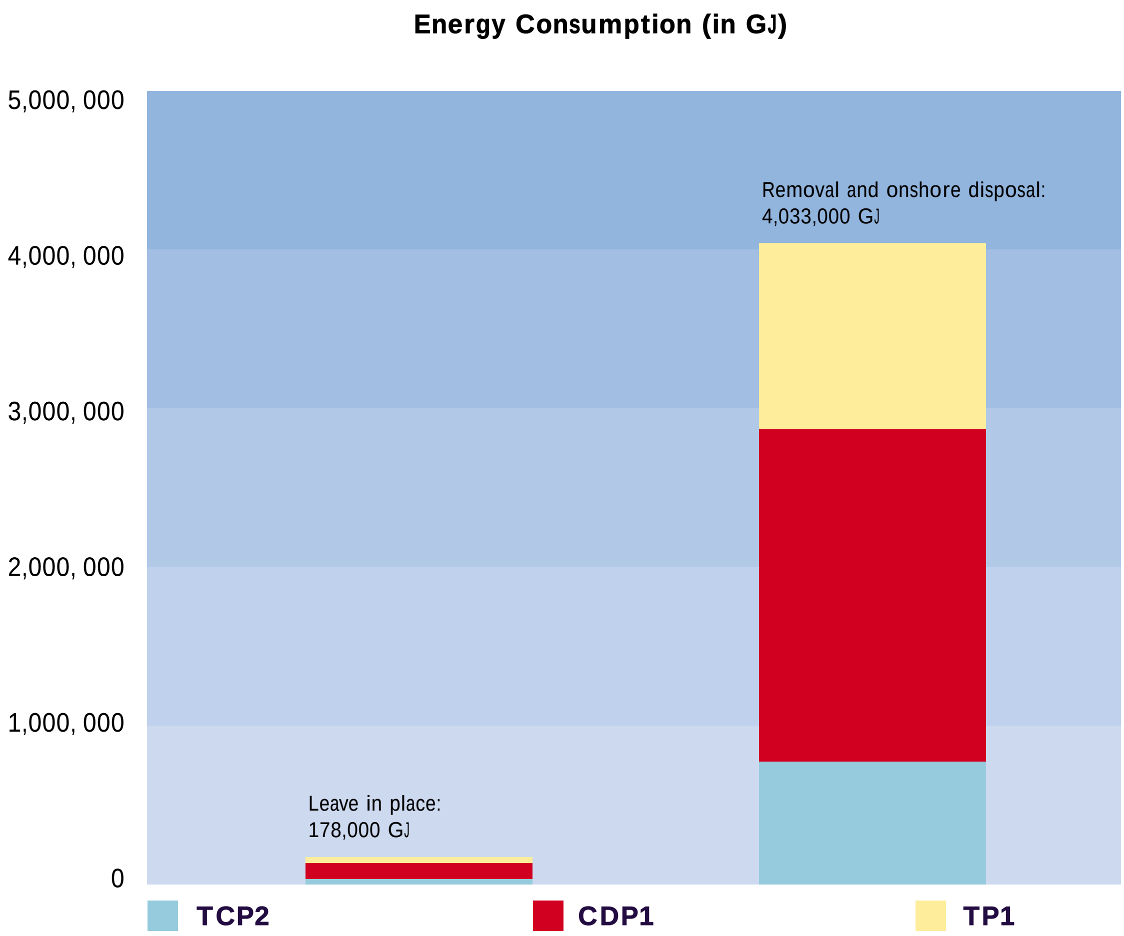


Figure 5.17 Comparison of Energy Consumption for Disposal On land and Leave in Place Alternatives

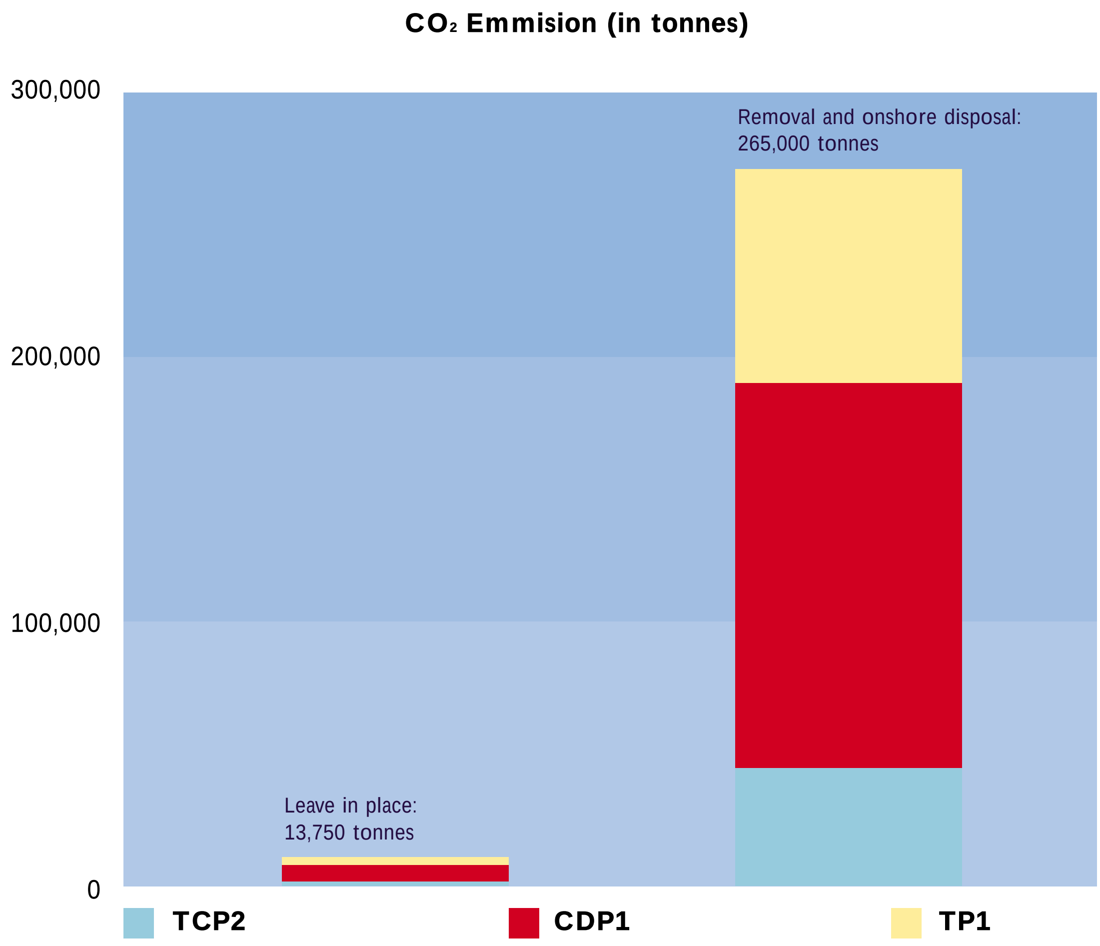


Figure 5.18 Comparison of CO_2 Emissions for Disposal On land and Leave in Place Alternatives

DNV have noted that the energy consumed to remove and deconstruct the three concrete substructures is equivalent to running more than 105,000 family cars for one year. They also note that the release of carbon dioxide into the atmosphere during removal and deconstruction of the three concrete substructures is equivalent to about one quarter of the yearly CO_2 emission from a typical 400 MW gas fired power station.

The qualitative impacts, as assessed by DNV, are given in Table 5.3 for the Disposal on Land and the Leave in Place alternatives.

Parameter	Disposal On land	Leave in Place
Releases (discharges) to sea, water or ground	None/Insignificant	None/Insignificant
Physical Impact on the environment	Moderate Negative	Moderate negative (Very long term)
Aesthetic impact including noise, smell and visual effects	Moderate Negative	None/Insignificant
Waste / Resources Management	Moderate Positive	None/Insignificant - Small Positive
Littering	None/Insignificant	Small Negative
Impacts on fisheries	Moderate Positive	Moderate Negative
Free passage at sea	Moderate Positive	Moderate Negative

Table 5.3 Comparison of Qualitative Impacts for Disposal On land and Leave in Place Alternatives as detailed in the Frigg Environmental Impact Assessment

It is judged that there will be "None/Insignificant" discharges to sea for both disposal alternatives.

During the operations to refloat the concrete substructures DNV have judged that the physical impact on the environment would be "Moderate Negative" due to the need to provide a layer of gravel around TCP2 to assist in the refloating operations. For the leave in place alternative the physical impact of leaving the substructures in place is found to be "None/Insignificant" for the next few hundreds of years and "Moderate Negative" in the very long term.

The onshore deconstruction of the concrete substructures is judged to have a "Moderate Negative" aesthetic impact due to the visual impact, noise, smell and dust associated with breaking up the concrete. The aesthetic impact of leaving the substructures in place is considered to be "None/Insignificant".

The removal of the substructures is judged to have a "Moderate Positive" impact in respect to fisheries and free passage at sea. If the three concrete substructures are left in place the effect is judged to be "Small Negative" to "Moderate Negative" due to the substructures causing a potential obstruction to fishing vessels and passing marine traffic.

The environmental impacts detailed above assume that the operations are carried out essentially as planned and that there is no need to undertake extensive remedial works resulting from a major accident during the disposal operations. If a major unplanned event occurred during the operations, the impact on the environment would be considerably greater. A major leak occurring during the refloat operation would result in the substructure falling back onto the seabed. This would have a significant physical impact on the local environment, as would the extensive marine and diving operations necessary to try and clear up the area.

5.5.3 Costs

The estimated costs of refloating the concrete substructures and disposing of them onshore are given in Table 5.4.

TCP2	CDP1	TP1
2462 MNOK / £188.2m (€ 300m)	4048 MNOK / £309.5m (€ 494m)	1908 MNOK / £145.9m (€ 233m)

Table 5.4 Estimated Cost of On Land Disposal of the Concrete Substructures of TCP2, CDP1 and TP1

The total cost of the work necessary for removal and on-land disposal of the three concrete substructures is estimated to be 8418 MNOK / £643.6m (€ 1027m). A significantly greater cost would be incurred if there were a major accident or incident during the refloating and towing operations. The estimated cost of work to prepare the concrete substructures to be left in place is 125 MNOK / £9.5m (€ 15.2m). In addition the cost of removing the topsides of the three platforms and deconstructing them onshore is estimated to be 1556 MNOK / £119m (€ 190m).

5.6 SUMMARY OF ASSESSMENT

5.6.1 TCP2

The predicted consequences, in terms of safety, environmental impact and cost, of attempting to refloat the concrete substructure of TCP2 as compared to leaving it in place, are summarised in Figure 5.19.

	Removal and Dispose Onshore		Leave in Place	
	As Planned	Major Unplanned Event	As Planned	Major Unplanned Event
Tecnical Feasibility Probability of a major unplanned event		Probability **2 to 4%** i.e. 20 to 40 times greater than acceptance criterion		No potential for major unplanned event
Consequences				
Safety Probability of a Fatality	13%	16 - 60%	2%	–
Impact on Environment Energy Consumed (1000GJ)	738	1000 - 2100	53	–
CO_2 Release (1000 tonnes)	44	80 - 160	4	–
Physical Impact on Environment	"Moderate Negative"	"Moderate Negative" plus "Small Negative"	"Moderate Negative"	–
Cost MNOK £m	2462 188	3200 - 8200 245 - 627	77 5.9	–

Figure 5.19 Predicted Consequences of On land Disposal of the TCP2 Concrete Substructure as Compared to Leaving In Place

There is a significant degree of uncertainty regarding the strength and integrity of the concrete substructure and the ballast pipework during the refloating operations for TCP2. There are also a number of significant uncertainties associated with the method of freeing the substructure from the seabed and its movement as it comes free. The probability of a major accident or incident during the refloating operations has been estimated as between twenty to forty times higher than the acceptance criterion for marine operations.

The technical feasibility of refloating the concrete substructure is therefore uncertain. In addition there are severe safety and financial implications should a major accident occur. After preparing the concrete substructure, as described in Section 6, the impact of discharges to the environment from leaving the substructure in place is assessed to be "None/Insignificant".

5.6.2 CDP1

The predicted consequences, in terms of safety, environmental impact and cost, of attempting to refloat the concrete substructure of CDP1 as compared to leaving it in place are summarised in Figure 5.20.

	Removal and Dispose Onshore: As Planned	Removal and Dispose Onshore: Major Unplanned Event	Leave in Place: As Planned	Leave in Place: Major Unplanned Event
Tecnical Feasibility Probability of a major unplanned event		Probability in the order of **30**% i.e. 300 times greater than acceptance criterion		No potential for major unplanned event
Consequences				
Safety Probability of a Fatality	46%	50 - 70%	3%	–
Impact on Environment Energy Consumed (1000GJ)	2180	2300 - 3700	79	–
CO_2 Release (1000 tonnes)	150	157 - 260	6	–
Physical Impact on Environment	"Moderate Negative"	"Moderate Negative" plus "Small Negative"	"Moderate Negative"	–
Cost MNOk	4048	4700 - 9800	7	–
£m	309	359 -749	0.5	

Figure 5.20 Predicted Consequences of On land Disposal of the CDP1 Concrete Substructure as Compared to Leaving In Place

The main uncertainty relating to the possible refloat and onshore disposal of CDP1 is the water tightness of the structure. There is a significant probability of leakage, either through the cofferdam (that has to be installed to seal the holes in the outer wall), or through ineffectively closed penetrations, broken pipes or cracks in the walls and base slab of the substructure. The probability of a major accident or incident during the refloating operations has been estimated to be three hundred times higher than the acceptance criterion for marine operations.

The consequences of a major accident during the refloat operations have been shown to be particularly severe, especially in respect to the safety of personnel and cost. After preparing the concrete substructure, as described in Section 6, the impact of discharges to the environment from leaving the substructure in place is assessed to be "None/Insignificant".

5.6.3 TP1

The predicted consequences, in terms of safety, environmental impact and cost, of attempting to refloat the concrete substructure of TCP2 as compared to leaving it in place are summarised in Figure 5.21.

	Removal and Dispose Onshore – As Planned	**Removal and Dispose Onshore** – Major Unplanned Event	**Leave in Place** – As Planned	**Leave in Place** – Major Unplanned Event
Tecnical Feasibility Probability of a major unplanned event		Probability **2 to 5**% i.e. 20 to 50 times greater than acceptance criterion		No potential for major unplanned event
Consequences				
Safety Probability of a Fatality	16%	20 - 50%	1%	–
Impact on Environment Energy Consumed (1000GJ)	1115	1200 - 2200	46	–
CO_2 Release (1000 tonnes)	71	80 - 150	4	–
Physical Impact on Environment	"Moderate Negative"	"Moderate Negative" plus "Small Negative"	"Moderate Negative"	–
Cost MNOK £m	1908 146	2700 - 7000 206 - 535	41 3.1	–

Figure 5.21 Predicted Consequences of On land Disposal of the TP1 Concrete Substructure as compared to Leaving in Place

The main areas of concern relating to the possible refloat of the TP1 concrete substructure are the strength of the inner walls in the base, and the stability and strength of the structure during the separation and ascent from the seabed. The integrity of the ballast pipework is also uncertain. The probability of a major accident or incident during the refloating operations has been estimated as between twenty to fifty times higher than the acceptance criterion for marine operations.

The technical feasibility of refloating the concrete substructure is therefore uncertain. In addition there are severe safety and financial implications should a major accident occur. After preparing the concrete substructure, as described in Section 6, the impact of discharges to the environment from leaving the substructure in place is assessed to be "None/Insignificant".

5.6.4 Proposed Disposal Arrangements for TCP2, CDP1 and TP1

Due to the significant reasons set out in Sections 5.6.1, 5.6.2 and 5.6.3, it is considered preferable to leave the concrete substructures of Frigg Field platforms TCP2, CDP1 and TP1 in place, rather than dispose of them on land, or at another location at sea.

The activities to be undertaken as part of the decommissioning process for the concrete substructures are detailed in Section 6 and the impacts of leaving them in place are described in Section 7.

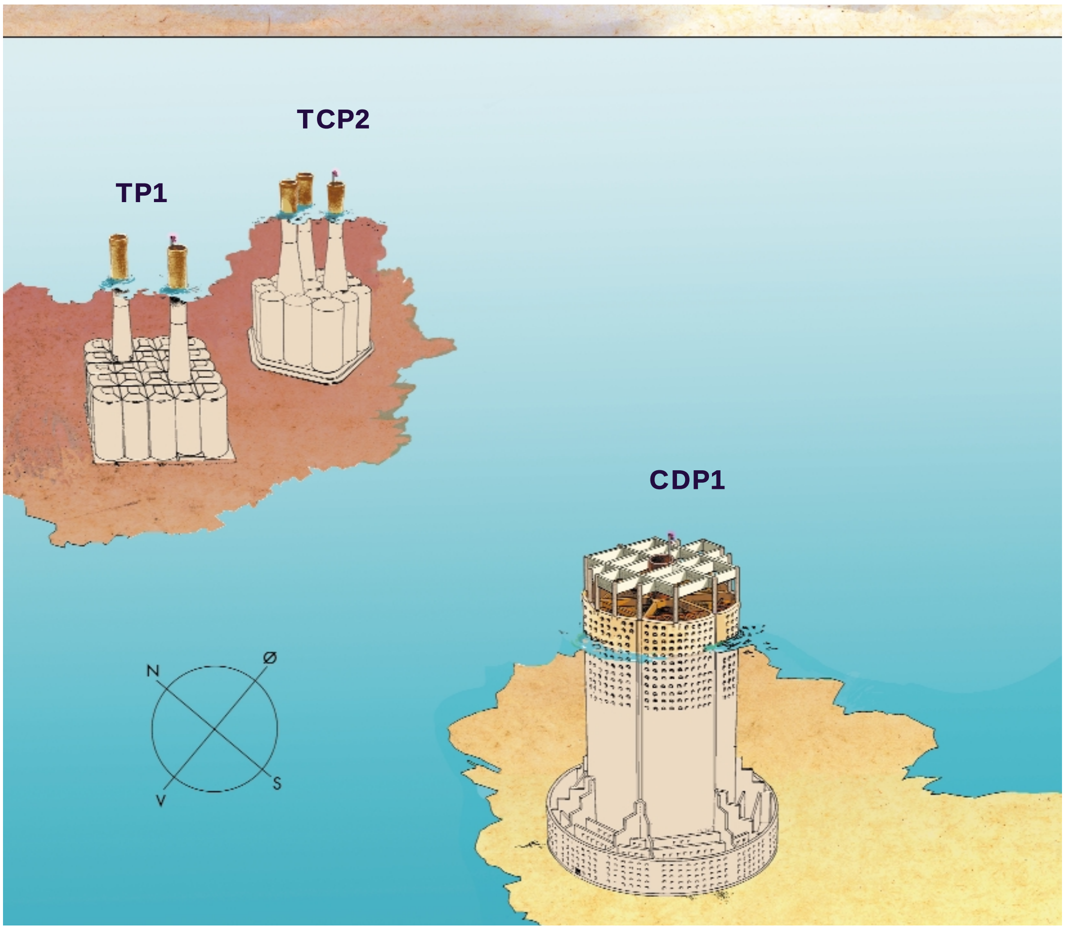


Figure 5.22 Proposed Decommissioned Condition of the Frigg Field Concrete Substructures

6. Planned Activities for TCP2, CDP1 and TP1 Concrete Substructures

6.1 APPROACH

Preparing the concrete substructures to be left in place is part of the overall process of decommissioning of the Frigg Field facilities. The work will be undertaken as a single integrated project involving both Norwegian and UK facilities.

The requirements of the 1992 OSPAR Convention and OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations have been fully complied with during the assessment of disposal alternatives and will continue to receive the highest priority throughout the implementation phase.

No facilities will be removed, transported, or disposed of without the necessary approvals being obtained from the relevant national regulatory authorities.

6.2 OVERALL SCHEDULE

The overall schedule for the Frigg Field decommissioning is shown in Figure 6.1. The end of the gas production is assumed to take place in 2004 depending on the reservoir behaviour.

After production ceases the equipment on the platforms will be cleaned and taken out of service. Work will go on continuously up until the end of the first quarter of 2007. After that time, offshore works are planned to take place mainly during the summer seasons. The amount of offshore work planned for any one year has been estimated on the basis of what can reasonably be undertaken during the summer season. Onshore disposal activities are scheduled to be carried out continuously from 2007 onwards. The proposed programme of disposal activities will be completed by the end of 2012, providing production from the field ceases in 2004 and other elements do not affect the schedule.

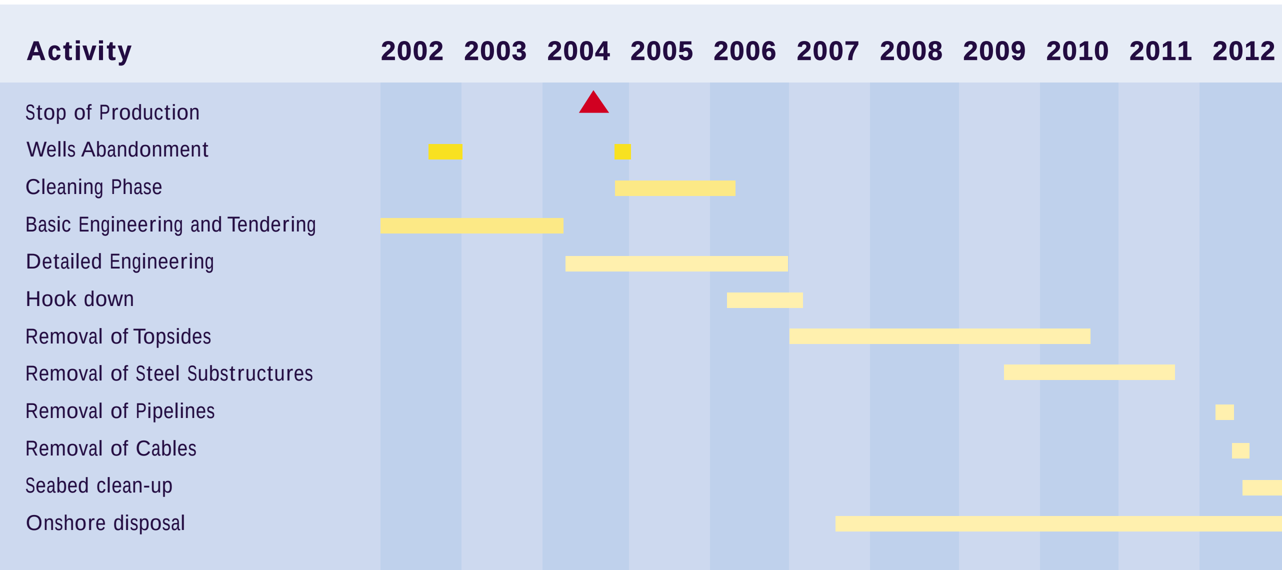


Figure 6.1 Proposed Schedule for the Disposal Activities

Most of the preparation work for the concrete substructures will be undertaken before the topsides are removed in the period 2007 to 2010. The navigation aids will be installed after the topsides have been removed.

6.3 REMOVAL OF STEELWORK ON OUTSIDE OF CONCRETE SUBSTRUCTURES

There are a number of steel items such as risers, riser clamps, stairways, landings etc attached to the outside of the concrete substructures of TCP2 and TP1 (See Figure 6.2). If these steel items were left in place, over time they would corrode and fall on to the seabed around the substructure where they would become a hazard to fishing operations. It is therefore proposed to remove these steel items from the outside of the concrete substructures as part of the decommissioning process for the platforms. In addition the steel walk-ways and stairs below the deck level of CDP1 will also be removed (see Figure 6.3).

Figure 6.2 Risers and External Steelwork on the Outside of TP1 Column

Figure 6.3 Stairways and Walkways Below Deck Level on CDP1

6.4 REMOVAL OF ITEMS INSIDE CONCRETE SUBSTRUCTURES

Tanks and pipes containing diesel oil, hydraulic oil and methanol used for operational purposes within the columns will be drained and cleaned in accordance with accepted practice. The glass reinforced epoxy pipework used for filling and emptying the TP1 columns of water will be removed. The flexible pipes inside the J Tubes in the TCP2 columns will also be removed. Fluorescent lights in the columns will be removed.

The steelwork within the columns of TCP2 and TP1, and the central shaft of CDP1, will be left in place together with the protective aluminium and zinc anodes. These items are not considered to adversely affect the natural environment but will degrade gradually over time. Measures will be taken to allow the free flow of seawater water through the columns to ensure equal internal and external pressures and to prevent stagnation of the water in the columns.

All materials and substances removed from the substructures will be transported and disposed of on shore in accordance with relevant national and international regulations. None of the concrete substructures has ever been used for the storage of crude oil. Cleaning operations to remove hydrocarbon deposits within the cells or columns are therefore not required.

6.5 INSTALLATION OF NAVIGATION AIDS

Navigation aids will be installed on the concrete substructures and regularly maintained. They will be designed to ensure a high level of reliability. Back-up systems will be incorporated and parts of the navigational aids system will be changed at regular intervals. The navigational aids themselves, and their maintenance programme, will satisfy the requirements of both national regulations and international conventions. TFEE Norge has made contact with the responsible authorities in both Norway and UK and a dialogue has been started to ensure that the navigation aids will comply fully with relevant national requirements.

In addition measures will be taken to ensure that the Frigg Field substructures remain marked on navigation charts and relevant information about the Frigg Field decommissioning project will be circulated to mariners. Although it is rather difficult to quantitatively assess the effect of these measures, it has been conservatively estimated by specialists that the likelihood of collision could be reduced by as much as 50%.

To assist fishermen, it is planned to introduce the position of the concrete substructures into the UK "FishSAFE" programme which is a computerised system providing fishermen with information about obstructions or hazards in the fishing grounds. Fishing vessels fitted with the "FishSAFE" equipment receive a visual and audible alarm when they come within 6 nautical miles of an identified obstacle.

Regular surveillance will be carried out to check that the navigation aids are operational. The surveillance schedule will initially be determined based upon the predicted performance of the navigation aid system. Operational experience will then be used to assess the surveillance interval. It is envisaged that the navigation aids will be designed in such a way as to allow them to be changed from a helicopter, thus obviating the need to man the platforms for this purpose. The responsibility for the maintenance of the navigation aids remains with the Frigg Field Licensees, unless otherwise agreed with the authorities.

6.6 DEBRIS REMOVAL

All debris on the seabed forming a hazard to other users of the sea will be removed within the Frigg Field.

A pre-debris removal survey will be carried out first to identify the location of the debris. It is planned to recover the majority of the debris using remotely operated vehicles, although diver assistance may be required in certain instances. If larger items are encountered it may be necessary to use divers to sling the load for recovery to the surface. Debris recovered from the seabed will be transported to shore for recycling or disposal.

At the end of the debris clearance operation, a post clean up survey will be undertaken by sonar sweep, to confirm and document that the seabed is free of debris. The results from the survey will be submitted to the appropriate Norwegian and UK authorities.

Independent trawling tests carried out by the fishermen's organisations will then be performed as part of the effort to open up the Frigg Field area for fishing activity. Such tests will verify that no obstructions remain in the area that would impede fishing operations. The test programme will be established in co-operation with the fishermen's federations in Norway and UK to ensure that representative equipment is used in the test. The results from the trawling test will be submitted to the appropriate Norwegian and UK authorities.

7. Impacts of Leaving Concrete Substructures in Place

The impacts of leaving the Frigg TCP2, CDP1 and TP1 concrete substructures in place after decommissioning are described in this section. The impact categories used are in accordance with the categories listed in Table 5.1. The impacts described for each category are taken from the comprehensive Environmental Impact Assessment (EIA) prepared by independent consultants DNV, the full text of which is included in the Frigg Field Cessation Plan.

Energy

After the substructures have been decommissioned very little further energy will be consumed. The energy used will consist of small amounts of electricity to power the navigation aids and the helicopter fuel used to visit the platform for periodic inspection and maintenance of the navigation aids.

The power for the navigation aids will most probably be provided by arrays of solar cells suitably mounted on the substructures.

Emissions to Atmosphere

Following the decommissioning process there will be no emissions to the atmosphere apart from the emissions from helicopters used to inspect and maintain the navigation aids on the substructures.

Releases to Sea, Water or Ground

An inventory of the materials that will be left in place is given in Table 7.1.

Material (tonnes)	TCP2	CDP1	TP1
Materials forming Substructure			
Reinforced/prestressed concrete	159,173	146,976	126,919
Stone, sand or concrete ballast	69,920	268,703	35,010
Cement grout under substructure	18,254		750
Marine growth (estimate)	865	1,900	781
Drill cuttings (5,600 m3)	-	11,300	-
Materials inside Columns/Shaft			
Carbon steel	1,603	317	880
Stainless steel	22.2	-	1.1
Anodes (zinc and aluminium)	44.2	3.2	5.1
Paint	4.6	0.9	2.6
Electric cabling in the colums/shaft	34.1	6.7	18.8

Table 7.1 Inventory of Materials Left in Place

The impact of discharges to sea from the materials left in place have been assessed by DNV to be "None/Insignificant". Further information about the materials that will be left in place is given in the subsections below.

Reinforced and Prestressed Concrete

Samples of concrete have been taken from the substructures of TCP2 and TP1 to assess whether possible leaching of chemicals additives used in the fresh concrete would have any long-term environmental impacts. As a result of the tests, SINTEF, the independent Norwegian research institute, concluded that "the quantity of leachable admixtures is small and it has to be expected that it will not cause any long term contamination problem". This finding confirms that the concrete substructures are basically inert and will have no long term polluting effect on the environment.

After some considerable time the surface of the concrete will spall and then the steel reinforcement will rust.

Stone, Sand and Concrete Ballast

The stone, sand and concrete ballast will be retained with the concrete substructures and it is unlikely that this will be released into the marine environment for hundreds of years. The stone is a naturally occurring inert material that will not pollute the marine environment.

Cement Grout Under Substructure

This material is located within the base of the structures and is not considered to contaminate the marine environment.

Marine Growth

Samples of biota have been taken from the outside of the three concrete substructures and tested. Sea squirts were found in all the samples collected however at a couple of locations blue mussels were the dominant specie. Low levels of PCBs were found in the material collected from TCP2 and TP1. The level of PCBs found (< 8.0 µg/kg wet weight), classify the blue mussels in SFT Class 2 (moderately polluted) regarding PCBs. No PCBs were detected in the samples collected from CDP1.

PAH components were detected in only two samples taken and in both cases the levels were low (< 7.4 µg/kg wet weight), classifying the blue mussel in SFT Class 1 (slightly polluted) for PAH.

The levels of metals measured in sea squirts, (the dominating growth), was found to be low with classification in SFT Class 1 (slightly polluted). Higher levels of metals, particularly cadmium, were found in some of the blue mussel samples and in a sponge taken from TP1. The exact source of this contamination is uncertain although the specialists analysing the samples have noted that higher levels of cadmium seems to be a general pattern when mussels are found on oil installations.

It is concluded that the biota on the outside surface of the concrete substructures is only slightly contaminated.

Drill Cuttings Inside CDP1 Concrete Substructure

When the wells were drilled on CDP1, approximately 5,600 m^3 of drill cuttings were deposited within the concrete substructure. All the wells were drilled with water based mud. After the cuttings had been discharged, a layer of gravel was placed on top of them within the substructure. Taking samples of the drill cuttings has been judged unacceptably hazardous as none of the safety or utility systems are now operational on CDP1. There are however good reasons to believe that the drill cuttings within CDP1 are comparable to the drill cuttings discharged to sea when the wells on DP2 were drilled. On this basis, It is proposed that the cuttings within CDP1 shall be left in place undisturbed. This recommendation is in line with the recently published UKOOA Drill Cuttings Initiative which states that, in cases where the quantity and composition of the drill cuttings are similar to those believed to be in CDP1, the likely best environmental strategy is to leave the drill cuttings in place to degrade naturally. It is noted that information about the findings of the UKOOA Initiative has been presented to the OSPAR Offshore Industry Committee and it is recognised that drill cuttings will be an issue to be discussed at the OSPAR 2003 Ministerial Meeting.

Leaving the drill cuttings in place is considered to have an insignificant effect on the environment around CDP1. Studies have been undertaken to evaluate the long-term effect of release of the drill cuttings as the concrete structure degrades. Based upon the likely volume and contamination level of the CDP1 drill cuttings it has been estimated that the impact on the surrounding environment is expected to be "Small Negative" or "Insignificant".

The environmental impact is likely to be largest if the cuttings were to be released through a sudden collapse of the concrete substructure. In such an event the discharge of the sand and gravel contained within the substructure onto the seabed would have a greater environmental impact than the discharge of a relatively small volume of drill cuttings.

Samples taken from the seabed around CDP1 in the summer of 2000 showed none of the typical contaminants found in drill cuttings proving that no drill cuttings were discharged onto the seabed outside the substructure.

Carbon Steel and Stainless Steel in the Columns

The steel within the columns will naturally decay over time but the rate of release will be slow and there will be no impact on the environment.

Anodes (Zinc and Aluminium)

The zinc and aluminium anodes inside the columns were provided to prevent corrosion of the internal steel-work. Over time the anodes will be degraded and the aluminium and zinc will be slowly released. This will have no impact on the environment.

Paint

The paint included in the inventory is associated with the steelwork inside the columns and shaft. This will degrade very slowly over time but the rate of release will be so slow that there will be no impact on the environment.

Cabling

The electrical and instrument cables within the columns will degrade very slowly over time but the rate of release will be so slow that there will be no impact on the environment.

Physical Impact on the Environment

In the next 100 years, very little physical damage to the three Frigg Field concrete substructures is predicted. There are known to be cracks in some of the substructures but these do not affect their integrity when resting on the seabed and will not have any significant effect on the durability of the substructures in the first 100 years. In the next few hundred years the physical impact of leaving the substructure in place is judged by DNV to be "None/Insignificant".

After that time corrosion of the horizontal reinforcement in the splash zone is likely to give rise, initially to spalling of the concrete, and later to local damage, which may be expected in roughly 100 to 150 years. The overall integrity of the structures will however not be affected.

The columns of TCP2 and TP1, and the walls of CDP1, are predicted to remain in place for 500 to 800 years before collapsing. For TCP2 and TP1, local damage in the splash zone will reduce the protection to the vertical pre-stressing steel in the columns, which will eventually become corroded. The top section of the column may then be unable to sustain extreme wave loads and become more severely damaged. For CDP1 local damage to the structure will become more extensive over time. The above-water deterioration of all three structures will however take place relatively slowly and the navigation aids, with suitable maintenance, may be expected to remain in place for several hundred years.

In the very long term, concrete fragments, reinforcing steel and solid ballast will be deposited on the seabed. This will be similar in effect to discharging gravel ballast on the seabed and is judged by DNV to be a "Moderate Negative" impact.

Aesthetic Impacts including Noise, Smell and Visual Effects

There are considered to be no aesthetic impacts such as noise, smell or dust as a result of leaving the concrete substructures in place.

Waste / Resources Management

After decommissioning the concrete substructures will not generate any waste.

Littering

The seabed around the concrete substructures will be cleaned as described in Section 6 and the external steelwork removed so that it cannot fall onto the seabed around the substructures. The potential for littering in the next few hundred years is therefore considered to be insignificant. It is recognised that leaving the substructures in place may be regarded as littering. The littering impact is judged by DNV to be "Small Negative".

Impacts on Fisheries

The long-term consequences for the fisheries in the Frigg area are difficult to predict, because it is dependent on how the fisheries in this area will develop in the future. Based on fisheries statistics, the Frigg area is today regarded to be of medium importance to the fisheries in this part of the North Sea. This may change in the future, but no predictions are possible on this issue. However, assuming that in future, the fishery will be present to a comparable extent as it is today, the consequence of leaving the substructures in place may be characterised as "Small Negative" to "Medium Negative".

This assessment has been based solely on the fact that the substructures left in place form a potential obstruction to fishing activity in the area and does not imply any negative effect on fish stocks. The Norwegian Institute of Marine Research has noted that after 30 years of operation the Frigg Field installations have become part of the ecosystem. It is therefore their opinion that leaving the three concrete substructures in place will not harm the fishery resources or other marine fauna.

Free Passage at Sea

Independent experts, using the best available shipping data, have assessed the impact on users of the sea of leaving the concrete substructures in place. The statistical probability of a collision by fishing vessels or passing vessels has been estimated and the results are shown in Table 7.2.

Platform	Yearly Probability of Collision by Fishing Vessels	Yearly Probability of Collision by Passing Vessels
TCP2	1 in 100,000	1 in 20,000
CDP1	1 in 40,000	1 in 10,000
TP1	1 in 130,000	1 in 27,000
All Three Concrete Substructures	1 in 24,000	1 in 5,500

Table 7.2 Yearly Probabilities of Vessel Collisions with the Frigg Field Concrete Substructures if Left in Place

The figures given above are based upon current marine operations and are regarded as a best indication of the risk level after decommissioning of the Frigg Field. The risk of collisions will be minimised by the use of suitable navigation aids. The introduction of more sophisticated navigational equipment such as ECDIS (Electronics Charts Display and Information System) and higher levels of training for mariners in accordance with international conventions is predicted to reduce the probability of collision further.

The 500 m safety zones around the three concrete substructures will remain in place during the approved decommissioning work. After decommissioning has been completed consideration will be given to the removal of the safety zone.

8. Monitoring

8.1 MONITORING

Environmental surveys involving seabed sampling have been undertaken in both the Norwegian and UK sectors of the Frigg Field four times since 1986. The environment in the Frigg area is thus well known. It is planned to undertake two further environmental surveys of the whole area (both Norwegian and UK sectors) after production from Frigg Field ceases in 2004.

At the end of the decommissioning work programme, a further environmental survey, including seabed sampling, will be undertaken to document the environmental conditions at that time. A survey of the condition of the concrete substructures and the adjacent seabed will also be undertaken at the end of the decommissioning programme. The results from the environmental and condition surveys will be submitted to the appropriate Norwegian and UK authorities.

The need for further monitoring activities will then be determined based upon the findings of the surveys and discussions with the relevant parties. There is a possibility that leaving the concrete substructures in place will have a beneficial effect on fish stocks in the area, although it is not possible to be certain at this time.

The navigation aids installed on the concrete substructures will be designed to ensure a high level of reliability. They will incorporate back-up systems and parts of the system will be changed at regular intervals, determined by the predicted system performance. TFEE Norge is working together with relevant authorities and specialist companies to evaluate the use of relevant emerging technologies. The navigational aids themselves, and their maintenance programme, will satisfy the requirements of both national regulations and international conventions.

Regular surveillance will be carried out to check that the navigation aids are operational. It is envisaged that the navigation aids will be designed in such a way as to allow them to be changed from a helicopter, thus obviating the need to man the platform for this purpose. The responsibility for the maintenance of the navigation aids remains with the Frigg Field Licensees, unless otherwise agreed with the authorities.

A visual check on the above-water condition of the concrete substructures will be undertaken and recorded when the navigation aids are being checked by helicopter. The anticipated condition of the substructures in the coming years is discussed in Section 7 subsection “Physical Impact on the Environment”. The implications of any observed deterioration of the substructures, in relation to the safety of users of the sea, will be assessed and any required action determined in consultation with the Norwegian and UK authorities.

8.2 FUTURE LIABILITY

The Frigg Field concrete substructures, which it is proposed to leave in place, remain the property and responsibility of the Frigg Field Licensees, unless other arrangements are agreed with the Governments of Norway (TCP2 concrete substructure) and UK (CDP1 and TP1 concrete substructures).

9. Supporting Studies and Peer Reviews

General and Environmental

- TFEE: "Frigg Field Cessation Plan" (Containing the Disposal Plan and the Environmental Impact Assessment)
- London Offshore Consultant: "Frigg Cessation Study", Vol. 1 and 2 – Final Report & Technical Notes – CD ROM, dated 01.01.2000, DocsOpen 104335 (103922 & 103925)
- Kværner Oil & Gas: "Inventory Accounting TP1", Kværner Oil and Gas Report, Ref. 005-TR-V-B-001, Rev A, Dated 17.02.2000 DocsOpen 108189.
- Kværner Oil & Gas: "Inventory Accounting TCP2", Kværner Oil and Gas Report, Ref. 005-TR-V-C-001, Rev A, Dated 19.06.2000 DocsOpen 108190.
- Kværner Oil & Gas: "Inventory Accounting Module M52/P48 – Lille Frigg Tie-in", Kværner Oil and Gas Report, Ref. 005-TR-V-G-001, Rev A, Dated 21.02.2000 DocsOpen 105411.
- Kværner Oil & Gas: "Inventory Accounting Module M35 – Frøy Tie-in (TCP2)", Kværner Oil and Gas Report, Ref. 005-TR-V-F-001, Rev A, Dated 11.02.2000 DocsOpen 108191.
- Kværner Oil & Gas: "Inventory Accounting Module M51 – East Tie-in (TCP2)", Kværner Oil and Gas Report, Ref. 005-TR-V-H-001, Rev A, Dated 15.02.2000 DocsOpen 108192.
- DNV: "Asbestos Mapping on Frigg QP, TP1, TCP2 and DP2", DNV Report Ref. 2000-3396, Rev.1, dated 18.10.2000 DocsOpen 106058.
- SINTEF: "Frigg Platforms TP1 and TCP2 – Leaching of Chemical Admixtures from Hardened Concrete", SINTEF Report, Ref. 10096, dated 30.11.2000 DocsOpen 101231.
- Rogaland Research: "Trace Metals and Organic Contaminants in Biota from the TCP2 and TP1 Installations in the Frigg Field", Rogaland Research Report RF 2002/029, dated 14.02.2002.
- Rogaland Research: "Trace Metals and Organic Contaminants in Biota from the DP1 and CDP1 Installations in the Frigg Field", Rogaland Research Report RF 2001/198, dated 12.09.2001.
- Rogaland Research: "Environmental Impacts of Cuttings and Mud Discharged into the CDP1 Concrete Structure", Rogaland Research Report RF 2001/197, dated 12.09.2001.

Studies Relating to Reuse

- Dames and More and Rogaland Research: "Frigg Reef - Feasibility Study for an Artificial Reef on the Frigg Field", Revision 0, dated 07.11.1999, DocsOpen 99662.
- Kjeller Vindteknikk: "Wind Power Study for the Frigg Field", Report dated 30.06.2000, DocsOpen 105738.
- TFEE Norge: "Cost Estimate – Wind Power at Frigg", Report dated 21.08.2000, DocsOpen 104902.
- Aker Maritime: "Emission-Free Power Generation at Frigg", Report Ref. 58766-AE-A-001, dated 30.06.2000, DocsOpen 104348.
- Valiant: "The Reuse of Frøy Facilities and Equipment from Frigg", Report Ref. VI-99-ER-0064, dated 19.11.1999, DocsOpen 99541.

Studies Related to Safety

- Safetec: "Frigg Field - Concrete Structures Disposal Options Safety Evaluation", Safetec Report, Ref. ST-8708-RA-1, Rev. 04, dated October 2000 DocsOpen 107122.
- Safetec: "Frigg Field Collision Frequency Prediction – Fishing Vessels", Safetec Document, Ref. 8708/Fish-TN.doc, dated 30.10.2000, DocsOpen No. 107121.
- Anatec "Frigg Field Cessation Project – Assessment of Collision Risk from Passing Vessels", Anatec Report, Ref. A1031-TFE-CR-00, Rev.00, dated October 2001, DocsOpen No. 125131

Studies Related to Concrete Substructures

- Aker Engineering: "Disposal of Concrete Structure – GBS Disposal TCP2, Frigg", Aker Engineering Report, Ref. RE 58367 – 001, Rev. 2E, dated 16.12.1999 DocsOpen 101231.
- Aker Engineering: "TCP2 Disposal Study Phase II: Procedure for In-situ Inspection of Ballast System", Aker Engineering Report, Ref. RE 58367 – 003, Rev. 04, dated 01.09.2000 DocsOpen 109505.
- Aker Engineering: "TCP2 Disposal Study Phase II: Non-linear Analysis of Tricells walls, Analysis and Structural Consequences", Aker Engineering Report, Ref. RE 58367 – 004, Rev. 04, dated 01.09.2000 DocsOpen 109506.
- Aker Engineering: "TCP2 Disposal Study Phase II: Capacity Check Top of Domes", Aker Engineering Report, Ref. RE 58367 – 006, Rev. 02, dated 26.09.2000 DocsOpen 109509.
- Aker Engineering: "TCP2 Disposal Study Phase II: Feasibility of Hydraulic Jacking Method", Aker Engineering Report, Ref. RE 58367 – 007, Rev. 02, dated 21.09.2000 DocsOpen 109511.
- Aker Engineering: "TCP2 Disposal Study Phase II: Alternative Systems for Refloating", Aker Engineering Report, Ref. RE 58367 – 008, Rev. 02, dated 22.09.2000 DocsOpen 109512.
- Aker Engineering: "TCP2 Disposal Study Phase II: Evaluation of the Condition of the Cell Ballast System", Aker Engineering Report, Ref. RE 58367 – 011, Rev. 02, dated 15.01.2001 DocsOpen 109515.
- Aker Engineering: "TCP2 Disposal Study Phase II: Worst Case Scenario – Maximum Ascent During the Refloat, and Ship Impact Capacity", Aker Engineering Report, Ref. RE 58367 – 010, Rev. 003 dated 01.11.2000 DocsOpen 109469.
- Doris Engineering: "CDP1 Disposal Study", Doris Engineering Report, Ref. RE-FF-91-28-0001, Rev.1C, dated 01.12.2000 DocsOpen 96052.
- Doris Engineering: "TP1 Disposal Study – Disposal Options Final Report", Doris Engineering Report, Ref. RE-FF-95-28-0001, Rev.1C, dated 15.11.1999 DocsOpen 96053.
- Doris Engineering: "TP1 & CDP1 Disposal study – CDP1 Option 4 - On-bottom Stability During Removal Steps", Doris Engineering Report, Ref. 65-1570-CDP1-WT-D-004, Rev.02, dated 01.11.2000 DocsOpen 107000.
- Doris Engineering: "TP1 & CDP1 Disposal study – CDP1 Option 4 - Structural Assessment During the Removal Steps", Doris Engineering Report, Ref. 65-1570-CDP1-SC-D-0002, Rev.04, dated 01.11.2000 DocsOpen 106999.
- Doris Engineering: "TP1 & CDP1 Disposal study – TP1 Option 3 - Alternative Method using SSCV ", Doris Engineering Report, Ref. 65-1570-TP1-GL-E-0006, Rev.01, dated 01.11.2000 DocsOpen 107002.
- Doris Engineering: "TP1 & CDP1 Disposal study – TP1 Option 3 - Structural Assessment of Column Strength capacity after Partial Cutting", Doris Engineering Report, Ref. 65-1570-TP1-SC-D-0002, Rev.01, dated 01.11.2000 DocsOpen 107001.
- Doris Engineering: "TP1 & CDP1 Disposal study – TP1 Option 4 - Alternative Deballasting Systems for Refloat", Doris Engineering Report, Ref. 65-1570-TP1-PI-E-0002, Rev.02, dated 01.11.2000 DocsOpen 106944.
- Doris Engineering: "TP1 & CDP1 Disposal study – TP1 Disposal Options - Scheduling", dated 12.04.2000 DocsOpen 106996.
- Doris Engineering: "TP1 & CDP1 Disposal study – CDP1 Disposal Options - Scheduling", dated 12.04.2000 DocsOpen 106998.
- COWI: "Disposal of Frigg Concrete Structures Technical Risk Assessment", COWI Report, Ref. P51690-001, Rev. G, 2 July 2001, DocsOpen 104680.

Peer Review Verification Studies

Structural Aspects – Norwegian Institute of Technology (SINTEF)

- SINTEF:: "Frigg Field Concrete Platform TP1: Structural Engineering Review of Draft Disposal Study Report by Doris", SINTEF report STF22F9956, Rev 4, dated 09.12.1999 DocsOpen 102555.
- SINTEF: "Frigg Field Concrete Platform TCP2: Structural Engineering Review of Draft Disposal Study Report by Aker Maritime", SINTEF report STF22F99757, Rev 4, dated 09.12.1999 DocsOpen 102554.
- SINTEF: "Frigg Field Concrete Platform CDP1: Structural Engineering Review of Draft Disposal Study Report by Doris", SINTEF report STF22F99755, Rev 4, dated 09.12.1999 DocsOpen 102553.
- SINTEF: "TCP2 Disposal Study, Phase II, Engineering studies by Aker Engineering AS, Expert review", SINTEF, dated 15.05.2000 DocsOpen 109480.
- SINTEF: "Disposal Study Phase II Expert Review", Engineering Studies by Doris and Aker Maritime, SINTEF Memo, dated 31.06.2000 DocsOpen 122646.
- SINTEF: "Evaluation of Residual Lifetime for Oil Platforms in The North Sea Made of Reinforced Concrete - The Frigg Field", Sintef Report, STF22F01601, January 2001, DocsOpen No. 108776.
- SINTEF: "Deteorioration of Reinforced Concrete Platforms In the North Sea – The Frigg Field", SINTEFintef Report, STF22F01604, February 2001, DocsOpen No. 108671.

Geotechnical Aspects – Norwegian Geotechnical Institute

- NGI: "TCP2 Platform Disposal: Comments to Akers Maximum Ascent Calculations", Norwegian Geotechnical Institute Report, dated 07.11.2000 DocsOpen 122665.
- NGI: "Platform TP1 - Review of Disposal Study Reports by Doris Engineering - Geotechnical Engineering Aspects", Norwegian Geotechnical Institute, dated 08.10.1999 DocsOpen 102549.
- NGI: "Platform TCP2 - Review of Disposal Study Reports by Aker Maritime - Geotechnical Engineering Aspects", Norwegian Geotechnical Institute, dated 13.10.1999 DocsOpen 102550.
- NGI: "Platform CDP1 - Review of Disposal Study Reports by Doris Engineering - Geotechnical Engineering Aspects", Norwegian Geotechnical Institute, dated 03.09.1999 DocsOpen 102552.
- NGI: "TCP2 Platform Disposal ", Technical Note, Norwegian Geotechnical Institute, dated 07.06.2000 DocsOpen 122644.
- NGI: "CDP1 Platform Disposal, Revised Comments", Technical Note, Norwegian Geotechnical Institute, dated 07.06.2000 DocsOpen 122643.

Marine Operations Aspects – Noble Denton

- Noble Denton: "Elf Frigg Field Disposal of Concrete Structures – Independent Marine assessment of the Options for Disposal of Platform TCP2", Noble Denton Report, Ref. NDEL/L 18843/AW, Rev. 2, ated 19.01.2000 DocsOpen 102574.
- Noble Denton: "Elf Frigg Field Disposal of Concrete Structures – Independent Marine assessment of the Options for Disposal of Platform CDP1", Noble Denton Report, Ref. NDEL/L 18845/AW, Rev. 2, dated 19.01.2000 DocsOpen 102572.
- Noble Denton: "Elf Frigg Field Disposal of Concrete Structures – Independent Marine assessment of the Options for Disposal of Platform TP1", Noble Denton Report, Ref. NDEL/L 18844/AW, Rev. 2, dated 19.01.2000 DocsOpen 102571.

Structural Assessment - DNV

- DNV: "Verification of Disposal of Concrete Structures TP1", DNV Report, Ref. 2000-3287, Rev. 0A, dated 21.12.2000 DocsOpen 108022.
- DNV: "Verification of Disposal of Concrete Structures TCP2", DNV Report, Ref. 2000-3051, Rev. 0A, dated 21.12.2000 DocsOpen 108021.
- DNV: "Verification of Disposal of Concrete Structures CDP1", DNV Report, Ref. 2000-3286, Rev. 0A, dated 21.12.2000 DocsOpen 108023.

Structural Assessment - University of Munich - Ingenieurburo Professor Schiessl

- Ingenieurburo Professor Schiessl: "Technical Note 1 Frigg Field Disposal", Ingenieurburo Professor Schiessl Report, Ref I-2/5/059/00-1, Rev. 0, dated 20.06.2000 DocsOpen 107070.
- Ingenieurburo Professor Schiessl: "Technical Note 2 Frigg Field Disposal", Ingenieurburo Professor Schiessl Report, Ref I-2/5/059/00-2, Rev. 0, dated 02.08.2000 DocsOpen 107070.
- Ingenieurburo Professor Schiessl: "Technical Note Frigg Field Disposal, Review of the Conclusions of the Workshop of 30.08.2000", Report No. I-25108/00-1, Professor Dr.-ing. Peter Schiessl, dated 29.11.2000.

Structural Assessment – COWI Consulting Engineers - Denmark

- COWI: "Capacity of internal walls of TP1" COWI Consulting Engineers Report, Ref. P-51690-, Ref. ST-8708-RA-2, Rev.0, dated 18.06.2001 DocsOpen 123486.

TFEE Reports and Minutes

- TFEE: "Structural Aspects of the Disposal of the Frigg Concrete Platforms", TFEE Norge Report, DocsOpen No.106437, dated 03.01.2001.
- TFEE: "Minutes of Meeting, Workshop, Disposal of the Concrete Structures, Frigg Field", TFEE Norge Document, dated 04.09.2000, Ref. DocsOpen Report No. 105822.
- TFEE: "MOM, Workshop, Technical Risk Assessment Disposal of the Concrete Structures, Frigg", TFEE Norge Document, dated 26.01.2001, Ref. DocsOpen Report No. 108089.
- TFEE: "Frigg Concrete Platform Disposal Structural Aspects of Cutting Down and Removal", TFEE Norge Report, dated 28.04.2001, DocsOpen No. 123575.

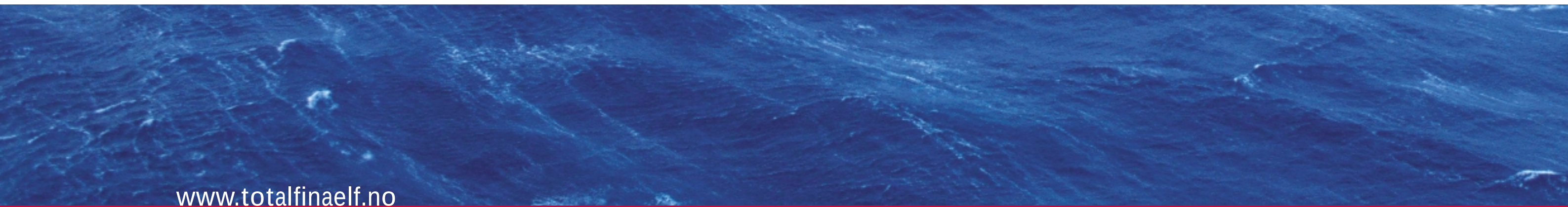
Studies Related to Onshore Disposal

- Dr. techn. Olav Olsen a.s: "Removal – Offshore Concrete Structures", Summary Report for Phases I and II, dated January 2002.

Appendix A – Abbreviations and Glossary

anode	A metallic element which prevents the corrosion of steelwork by electrolytic reaction with seawater
benthic	Relating to the ocean depths
CDP1	Frigg Field Concrete Drilling Platform 1
CO_2	Carbon dioxide
CPA	Closest Point of Approach
DNV	Det Norske Veritas
dowel	A vertical steel member projecting downwards from the base of a gravity platform, used to restrict horizontal movement of the substructure during installation
DP	Dynamic Positioning
DP1	Frigg Field Drilling Platform 1 (Wreck)
DP2	Frigg Field Drilling Platform 2
DTI	UK Department of Trade and Industry
EIA	Environmental Impact Assessment
FAR	Fatal Accident Rate (fatalities per 100 million manhours of exposure)
FCC	Frigg Field Complex (the three bridge linked platforms TCP2, TP1 and QP)
Energy Consumption	The sum of the energy used to undertake the work plus the energy used for recycling materials
flowline	A pipeline between a well and the processing facilities
GJ	Giga Joules (1000 million joules)
GSm^3	Giga cubic meters of gas at standard conditions (1000 million m3)
guide frame	A steel frame fixed to the platform substructure which provides support to the steel well casing between the seabed and the topsides.
hydrostatic	Used as in “hydrostatic pressure” to indicate the pressure at a particular depth in the sea ignoring any effects of currents or waves
IMO	International Maritime Organisation
IMO Guidelines	International Maritime Organisation document “Guidelines and Standards for the Removal of Offshore Installations and Structures on the Continental Shelf and in the Exclusive Economic Zone” adopted by the IMO Assembly in 1989 (Resolution A.672 (16))
J-tube	A J shaped steel tube fixed to a platform that provides a conduit for small diameter pipelines and cables from the seabed to the topsides
kg	Kilogram
km	Kilometre
kWh	Kilo watt hour
l	litre
lean mix	Used in the context of “lean mix concrete” to describe concrete made using smaller than usual amounts of cement and thus having a relatively low strength
LSA	Low Specific Activity
m	metre
m^3	cubic metre
manifold	Process equipment for joining a number of pipes into one pipe
mg	milligram
µg	microgram
MNOK	Million Norwegian Kroner

MPE	Norwegian Ministry of Petroleum and Energy
NGO	Non-Governmental Organisation
nm	Nautical miles
olivine	A type of rock used as ballast in the TCP2 concrete substructure
OSPAR	The Convention for the Protection of the Marine Environment of the North East Atlantic 1992.
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Poly Chlorinated bi-phenyls
PLL	Potential Loss of Life (predicted number of fatalities)
QP	Frigg Field Quarters Platform
QRA	Quantitative Risk Assessment
RF	Rogaland Research
riser	The part of a subsea pipeline running from the seabed up to the topside
ROV	Remotely Operated Vehicle
SFT	Norwegian Pollution Control Authority
SINTEF	The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology
SSCV	Semi Submersible Crane Vessel
TCP2	Frigg Field Compression and Treatment Platform 2
TFEE Norge	TotalFinaElf Exploration Norge AS
THC	Total Hydrocarbon Concentration
TP1	Frigg Field Treatment Platform 1
UK	The United Kingdom of Great Britain and Northern Ireland
UKOOA	United Kingdom Offshore Operators Association
“	inch
£m	Million Pounds



TotalFinaElf Exploration Norge AS, Post Office Box 168, 4001 Stavanger, Norway