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Decommissioning of offshore concrete gravity based structures (CGBS) in the OSPAR maritime area/other global regions

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1 Executive summary

This revision of the original 2003 report reflects the increased knowledge base around decommissioning options for concrete gravity based structures (CGBS). In the intervening period there have been extensive studies into decommissioning options by industry and government authorities. Both the Frigg and Ekofisk CGBSs have been decommissioned in this period and were granted derogations allowing the concrete base to be left wholly in place.

While CGBS designs fall into three main categories, each one is unique with its design modified to suit the particular function and environmental conditions. The structures can measure up to 50 metres in diameter, weigh up to 1.2 million tonnes and be standing in open water up to 300 metres deep. The work required to refloat or deconstruct a redundant CGBS would pose significant challenges, requiring due consideration of the risks to worker safety, the environment and project execution.

Decommissioning was not considered in the original design of many of the early platforms and factors such as loss of buoyancy, corrosion to ballast system piping and sediment build-up introduce technical uncertainties to refloating a CGBS. The detachment of a CGBS from the seabed would take many months of preparation work and the exact moment of release is unpredictable, posing safety hazards and making it difficult to time a refloat to coincide with a favourable weather window for towing. Any unintended loss of buoyancy is likely to have significant safety, environmental and cost implications.

To date only two small (15,000 tonnes) platforms in shallow and sheltered estuary waters have been successfully refloated. Studies into the decommissioning options for the 300,000+ tonnes Statfjord, Brent and Dunlin CGBSs are currently under way.

If considered technically feasible, the additional cost of removing a large CGBS compared with removing the topside and leaving the base wholly in place, is likely to be around €1bn per platform if the operation is successful at first attempt and considerably more if it fails. Up to 80% of the decommissioning cost will be borne by the relevant national government through established tax offsets. National government will have to consider the value to the wider society of relinquishing that tax revenue especially if a more complex decommissioning option is pursued.

Independent studies have shown that a CGBS left wholly in place with its topside removed for onshore recycling has the lowest environmental impact of the decommissioning options. Demolition in place is likely to have the highest environmental impact.

The decommissioning experience to date and studies of the decommissioning options for other CGBSs has tended to confirm the original report’s concerns: that the removal or partial removal of a CGBS poses significant technical challenges, carries high safety and environmental risks and would incur disproportionately high costs compared with the benefits to society. For large CGBS structures such risks are likely to be beyond an acceptable level of good industry practice.

Decommissioning options for the remaining 22 CGBSs in the OSPAR area will need to be individually considered, as regulatory bodies require. Current knowledge and extensive studies reinforce the need for CGBSs to remain a derogation category under OSPAR’s Decision 98/3.

The CGBS concept remains crucial to the exploitation of oil and gas deposits in ever more hostile environments. New designs now incorporate end-of-life considerations which may reduce the difficulties associated with their future decommissioning.
Definition of terms used in the report

Caisson: a watertight concrete structure that sits on the seabed to act as a base for the CGBS and which contains compartments that can be used for the processing or storage of oil and act as buoyancy tanks during the tow-out and installation.

CGBS: Concrete Gravity Based Structure

Cofferdam: a temporary watertight structure that is pumped dry to allow construction work

Columns: another name for shafts

Decommissioning: permanent removal from service

Deconstruction: controlled destruction of a structure

Derogation: an exemption from the OSPAR’s decommissioning regulations

Freeboard: the proportion of a floating structure above the waterline

Operator: the company which owns and manages the CGBS installation


Reuse: subsequent use of a structure for a similar or different purpose to that for which it was originally designed

Shafts: tubular reinforced concrete structures extending upwards from the caisson to protrude above the waterline and support the topside equipment

Topside: the steel structure which sits on top of a CGBS and houses drilling equipment, processing plant and/or accommodation

While every effort has been made to ensure the accuracy of the information in this publication, it does not constitute a legal interpretation of the rules and regulations surrounding the decommissioning of Concrete Gravity Based Structures. Neither the International Association of Oil and Gas Producers, nor any of its members, will assume liability for any use made thereof.
2 Offshore Concrete Gravity Based Structures (CGBS) – overview

Introduction

The oil and gas industry first developed and deployed concrete offshore structures in the North Sea during the early 1970s. They provided development solutions to the large scale of oil fields discovered at a time when the pipeline infrastructure to transport the products to land was immature. The main factors which led to the development of the CGBS were as follows:

- Many of the early North Sea fields had high production rates which required very large processing facilities
- CGBSs were ideal to support the very high topside weight of the processing facilities—the largest exceeds 50,000 tonnes
- CGBSs could withstand the extreme environmental forces in the North Sea and could be constructed in the region using local resources
- Since the North Sea lacked an extensive pipeline infrastructure to transport the crude oil to shore, in some cases the only solution was to store the oil offshore and transport it using tankers loaded through loading buoys. The CGBS design allowed the base to be used for the safe and reliable storage of large volumes of processed crude oil. The largest storage capacity of any CGBS is 2 million barrels (approx. 300 million litres)

Throughout their evolution, CGBSs have proved to be a very successful design option for the production of oil and gas. The first CGBS installed in the OSPAR Maritime region (see Fig 3.1) was the Ekofisk Tank on the Norwegian Continental Shelf in 1973. The South Arne platform in the Danish sector of the North Sea was the last CGBS installed in the OSPAR region. It was installed in 1999.

Appendix 1 provides a full summary of offshore CGBSs deployed by the oil and gas industry.

2.1 Design

A CGBS is generally a very large and extremely heavy reinforced concrete structure which is placed on the seabed. It withstands the extreme environmental forces by virtue of its own weight and inherent strength.

CGBS platforms are among the largest and most impressive structures ever built and moved by man. To date the Troll platform is installed in the deepest water (303m) and the Hibernia platform is the heaviest weighing 1.2 million tonnes on land. The designs of CGBSs vary considerably and their weights range from 3,000 to 1.2 million tonnes with corresponding topsides weighing between 650 and 52,000 tonnes.

A typical CGBS has a concrete base (often called a caisson) with one or more shafts to support the topside platform. When empty, voids within the base known as cells (along with the hollow shafts) provide buoyancy during the latter stages of construction, tow-out and installation. When a CGBS is in operation, the cells are flooded with seawater or act as storage and in some cases separation facilities for crude oil.

CGBSs divide into three main types depending on the design of the concrete base or caisson:

- concrete base with a single caisson extending above sea level (surface piercing)
- concrete base with one or more concrete shafts extending above sea level
- concrete base supporting steel legs and topside facilities

The CGBSs of these designs are used for a combination of drilling, production activities and accommodation. The different arrangements were engineering solutions tailored by various contractors to meet clients’ requirements and site conditions.
Base caisson extending above sea level (surface piercing caisson)

Effectively the surface piercing caissons design has a single large diameter caisson supporting the topside structure. This caisson can be up to 50m in diameter and can be surrounded by a larger diameter outer wall to dissipate wave energy. This wall is typically 16 metres above the surface of the water.

Base caisson with multiple with concrete shafts

This is the most common form of CGBS in the OSPAR region and features a base caisson with up to four slender surface piercing shafts supporting the topside. The slender shafts reduce the forces on the structure in the wave zone.

Base caisson supporting steel legs and topside

The concrete base caisson supporting jack up leg design can be constructed with or without oil storage facility and has been used in shallower water to ease installation.

The deployment of each CGBS type can be seen in Appendix 2.

With all CGBS designs the stability on the seabed is ensured by the weight of the structure while the strength of the seabed soil determines the size of base required. To secure horizontal stability the design often includes edging (commonly referred to as the skirt) which protrudes from the periphery of the base and penetrates the seabed to resist the sliding and overturning forces. The type of seabed soil and related design of the CGBS base dictate the length of the skirts required and become major factors when contemplating removal of the structure (see section 5).
2.2 Construction

Two construction methods are employed in CGBS designs:

- **Dry/wet build** – the lower section of the concrete base is constructed in a dry dock and towed into sheltered water for completion while the structure is floating.
- **Dry build** – the entire concrete sub-structure (base and shafts) is constructed in the dry dock. This method is applicable to CGBS designs for water depths up to around 100m.

Both methods require the availability of a dry dock or casting basin which can be a permanent facility used for ship and rig repair or a temporary dry dock with deep water access. The availability of such docks and facilities is an important factor when selecting the preferred decommissioning option (see section 5).

2.3 Installation of CGBS

Normally a CGBS is towed to its designated offshore location using ocean-going tugs. The topside is generally fitted prior to tow out or can be added after the CGBS is installed at its final location.

During installation the cells within the CGBS base are flooded with sea water to sink it to the seabed. To successfully refloat a CGBS the cells within the base would need to be completely watertight at pressures sufficient to displace the seawater content of the entire base. However, the original ballast systems were not designed to be used after installation so the mechanical pipework and fittings were commonly made of carbon steel. This pipework will have subsequently corroded. This corrosion, along with other penetrations into the buoyancy cells such as well conductors which were driven after installation, will compromise the potential to refloat a CGBS once production ceases (see section 5).
In some installations the seabed conditions made it necessary to increase the on-bottom weight by placing additional ballast into or onto the base to ensure full penetration of the skirts. In sandy seabed locations it was necessary to install scour protection (usually in the form of rock) around the perimeter of the base.

Twenty of the 27 CGBSs in the OSPAR Maritime area have under-base grouting to avoid high hot-spot contact pressure and ensure even contact pressure between the concrete base and the seabed. The variations in the installation technique of the CGBS have a significant bearing on the options available for its eventual removal (see sections 5 and 6).

2.4 Performance in operation

CGBSs have performed well in the North Sea and some will have been in operation for more than 40 years by the time they cease production. There have been instances of loss of pipework integrity within the dry shafts but there are no examples of serious corrosion of the reinforcing or pre-stressed steel tendons. The concrete component of these structures has required low maintenance and regular inspections have confirmed their continued integrity and allowed the original design life to be extended. During their operating period many CGBSs have undergone facility modifications with the addition of new process modules (adding weight) without any adverse impact on their structural integrity.

Cuttings produced during the well drilling operations can surround portions of the CGBS base and lie on the top of the storage cells and in some cases within the drilling shafts. Some of these cuttings may be contaminated with oil-based drilling fluids (see section 7) and their presence has both weight and environmental implications for the decommissioning options.

In some CGBS installations the cells within the bases are used for the separation of produced water (water that has been extracted from the reservoir along with the oil) and to store crude oil. Sand produced with the crude oil will accumulate in the base of these storage cells adding weight to the structure. The buoyancy, removal and disposal implications of these sand and residual hydrocarbons deposits will require careful evaluation if a refloat operation is considered (see sections 5 and 6).
3 Regulatory requirements for decommissioning

The decommissioning of redundant offshore oil and gas drilling and production facilities is regulated by host State licence requirements or local regulations. International law may also be applicable if the host State is party to relevant global or regional conventions such as the International Maritime Organization (IMO).

OSPAR sets out the requirements for decommissioning CGBSs within its Maritime Area (see below). Individual governments of sovereign states may impose more stringent requirements for decommissioning CGBSs within their jurisdiction.

3.1 The OSPAR Convention

The OSPAR Convention is the current legal instrument guiding international co-operation on the protection of the marine environment in the North-East Atlantic.

OSPAR Decision 98/3 covers the disposal of disused offshore installations and came into force in February 1999 (Ref 1). It states that: ‘Reuse, recycling or final disposal on land will generally be the preferred option for the decommissioning of offshore installations in the maritime area.’

It continues: ‘The dumping at sea, and the leaving wholly or partly in place of disused offshore installations is prohibited.’

However, Decision 98/3 also recognises that the decommissioning of such large installations situated in exposed marine environments is likely to present particular problems. Therefore an exemption or derogation may be sought for a concrete installation to be ‘dumped or left wholly or partly in place’ where it can be shown that ‘there are significant reasons why an alternative disposal method is preferable to re-use or recycling or final disposal on land’. In these circumstances the ‘competent authority’ (usually the national government) has the power to grant a derogation from the general requirements.
Where a CGBS falls within the categories allowing derogation to be considered, the operator is required to identify a comprehensive range of decommissioning options. The operator must also undertake a comparative assessment of these options as required by Clause 7 Annex 2 of Decision 98/3: ‘The information collated for the assessment shall be sufficiently comprehensive to enable a reasoned judgement on the practicability of each disposal option, and to allow for an authoritative comparative evaluation.’

Section 5 of this report discusses generic decommissioning options that may be developed for each CGBS for the purposes of comparative assessment.

It is noted that where the general rules of OSPAR Decision 98/3 apply, a decommissioning programme must provide for full removal for reuse, recycling or final disposal of the installation on land.

### 3.2 IMO guidelines

The International Maritime Organization (IMO), headquartered in London, is primarily concerned with safety at sea and safe maritime navigation and sets worldwide standards and guidelines, including guidelines for the removal of offshore installations. The 1989 IMO Guidelines recommend the complete removal of all structures weighing less than 4,000 tonnes in water less than 100m deep. Under the guidelines, structures in deeper waters can be partially removed with a suggested minimum 55m of clear water left above the structure to permit safe navigation. Key considerations in the IMO guidelines include:

- An unobstructed water column of at least 55m should be provided above the remains of any partially removed installation to ensure safety of navigation.
- The position, surveyed depth and dimensions of any installation not entirely removed should be indicated on nautical charts and any remains, where necessary, properly marked with navigational aids.
- The person responsible for maintaining the navigational aids and for monitoring the condition of any remaining material should be identified.
- It should be clear where liability lies for meeting any future claims for damages.

It should be recognised that not all nations throughout the world are members of IMO and therefore the 55m criteria may vary in different parts of the world.

### 3.3 National guidance

**United Kingdom** – The Department of Energy and Climate Change (DECC) provides the UK industry with guidance (Ref 2) to help operators comply with the requirements of the *Decommissioning of Offshore Installations and Pipelines* regulations within the *Petroleum Act 1998*. This guidance addresses the process for derogation application under OSPAR 98/3. It should be noted that the UK Government does not accept that concrete installations can be dumped at sea, either at their original location or elsewhere.

In its guidance the DECC states: ‘*As with other installations, the topsides of concrete installations must be returned to shore for re-use, recycling or disposal*.'
The DECC also requires that the documentation prepared to inform the comparative assessment must be subjected to an independent ‘Expert Verification’ process to ‘confirm that the assessments are reliable’.

**Norway** – The requirements for decommissioning plans are stated in the *Petroleum Act* and its supporting regulation. While this Act does not contain specific paragraphs referring to CGBS decommissioning, in March 2012 the Norwegian Petroleum Directorate issued a report dealing with disposal of concrete facilities. The report (Ref 3) is a positioning paper which obliges operators to evaluate all disposal options according to Norwegian law and regulations.

**Other North Sea countries** – In general the guidance for dealing with CGBS decommissioning is less defined in other countries although both The Netherlands and Denmark are Contracting Parties to the OSPAR Convention. In The Netherlands the *2002 Mining Act (Mijnbouwbestluit)* provides for the Government to require Decommissioning Plans to be submitted to the authorities for approval.

### 3.4 Comparative assessment

To bring consistency and transparency to the issues involved with CGBS decommissioning, OSPAR Decision 98/3 requires a comparative assessment of each decommissioning option for derogation candidates. This assessment ‘shall be sufficient to enable the competent authority of the relevant Contracting Party to draw reasoned conclusions on whether or not to issue a permit under paragraph 3 (derogation) of this Decision and, if such a permit is thought justified, on what conditions to attach to it’.

The process balances the wider societal issues against technical practicality, health and safety risks, short and long term environmental impacts and overall project costs borne by the operator and State. This system has proved successful in addressing conflicting aspects for the benefit of industry, stakeholders and the Regulatory Authorities.
4 CGBS population

A total of 41 CGBSs have been installed worldwide with another 3 under design or construction. Appendix 1 contains a complete list of all CGBSs deployed for oil and gas production together with their operational status. Figure 4 shows their location by country.

![Population of CGBSs](image)

**Figure 4**
Population of CGBSs denoting those in OSPAR area.
Note. Germany is an OSPAR signatory but its platforms were in the Baltic and thus outside the OSPAR area.

4.1 CGBSs located outside the OSPAR Maritime Area

CGBSs continue to be constructed and deployed around the world from Australia to Russia and Canada to the Philippines (see Appendix 1 for a full list). The CGBS approach is especially useful in remote areas or where there are extreme weather, wave or ice conditions, in areas where pipeline infrastructure is limited and for applications where storage of large quantities of crude oil or LNG is required.
There is a total of 27 CGBSs installed in the OSPAR Maritime Area, including 5 of the 7 structures decommissioned to date.

There are twelve CGBSs installed in the Norwegian sector in water depths ranging from 70 to 303m. The earliest, the Ekofisk Tank, was installed in 1973 and the Troll gas production platform (installed in 1995) stands in the deepest water at 303m.

The UK sector has another 12 CGBSs in water depths ranging from 43m to 151m. Most date back to the 1970s although the most recent, the Harding platform, was installed in 1995.

A further two CGBSs are installed in the Dutch sector of the North Sea. The final and youngest CGBS in the OSPAR Maritime Area is the South Arne platform which was installed in the Danish Sector of the North Sea in 1999.

Of the 27 CGBSs located in the OSPAR region, 17 have facilities for oil storage.
5 Decommissioning options

Although every CGBS has unique features which need to be considered on an individual basis, there is a range of generic CGBS decommissioning options which should be considered for the purposes of comparative assessment.

Where a CGBS falls within a category where derogation may be considered (defined in Annex 1 OSPAR Decision 98/3), the operator is required to identify a comprehensive range of decommissioning options and undertake a comparative assessment of those alternatives to fulfil Clause 7 Annex 2 of Decision 98/3. OSPAR’s Decision 98/3 recognises the technical challenges and cost associated with the removal of such large structures and states: ‘If an operator is able to demonstrate there are significant reasons why an alternative disposal method is preferable to re-use or recycling or final disposal on land the operator may consider applying for a derogation to leave the structure wholly in place.’

5.1 Potential decommissioning options

Operators may consider following generic decommissioning options having regard to the design and working conditions of specific CGBS structure.

Reuse at existing location
- Energy related – e.g. carbon capture/storage
- Other commercial or research activities

Full removal
- Reuse at another location
- Inshore deconstruction with onshore recycling and disposal
- Offshore disposal
- Offshore demolition, transport to shore with onshore recycling and disposal

Partial removal
- Removal of any structure to an intermediate level for navigational purposes.

Leave wholly in place
- With topside removed and with suitable navigational aids installed

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<td>other environmental compartments (including emissions to the atmosphere)</td>
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<td>energy/resource consumption</td>
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<td>other environmental consequences (including cumulative effects)</td>
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<tr>
<td><strong>Technical</strong></td>
<td>risk of major project failure</td>
<td>High</td>
<td>Medium</td>
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<td><strong>Societal</strong></td>
<td>fisheries impacts</td>
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Operators should investigate the viability of each of the above decommissioning options on a case-by-case basis. This investigation must be sufficiently comprehensive to enable a reasoned judgment on the practicability of each disposal option, and to allow for an authoritative comparative evaluation (see section 3.4). The table below is designed to facilitate the comparative evaluation as required by OSPAR decision 98/3 although it should be noted that the UK’s DECC does not allow disposal at sea.

Over the last 10-15 years a great deal of engineering study work has been undertaken by operators in an effort to understand, and where possible reduce to manageable and acceptable levels, the safety, environmental, technical and financial risks associated with decommissioning.

### 5.2 Reuse at existing location

The end of the economic life for an oil/gas field will be defined by the exhaustion of economically recoverable hydrocarbon reserves in the catchment area and therefore any future reuse of a CGBS would be for a non-hydrocarbon venture. This option assumes the design life of the CGBS could be extended and topside adapted to alternate use.

Regardless of the type of reuse the structure would inevitably require decommissioning at some stage in the future and therefore the reuse option must be regarded as a deferral of decommissioning rather than a final solution.

Many possibilities have been suggested for the reuse of decommissioned CGBSs and include:

- Energy related: carbon dioxide sequestration hubs, centres for wind or wave power generation and electrical power distribution hubs
- Research related: scientific research centres (notably for marine research) and meteorology stations
- Other uses: communication and navigation centres, diver training centres, fish farms, prisons and casinos

Other possibilities could also be proposed.

All reuse options must take into account the cost and financial sustainability of maintaining an offshore installation - particularly where permanent or periodic manning is required. The operators’ experience demonstrates that maintenance costs running to tens of millions of Euros per year should be anticipated.

Primary technical risks and consequences associated with changes of use include:

- Resolving complex legal and commercial issues to enable the transfer of liabilities to a new user
- The requirement for structures to operate far beyond the original design life
- Structural integrity, maintenance costs and, if manned, the need for suitable accommodation and emergency/life support systems
- A reused CGBS will require decommissioning at some time in the future

### 5.3 Complete removal by refloat

Full removal options using a refloat are predicated on the ability to reverse the installation procedures to raise the CGBS sufficiently to tow it to a new location for reuse, to an inshore deconstruction facility or to an offshore disposal site. The technical, safety and environmental aspects of a refloat have to be analysed and if a refloat is feasible, the costs estimated for the purposes of OSPAR’s comparative assessment.
Refloating a CGBS is dependent on seven critical and interdependent parameters:

- Continued structural integrity
- Accurate determination of structural weight
- Restoration of water-tightness and buoyancy control during refloat, towing and deconstruction
- Creation of a ‘jacking force’ to release the CGBS from the seabed
- Time and weather considerations
- The ability to tow the CGBS for offshore disposal or inshore deconstruction
- Onshore dry docks or other facilities capable of accommodating and safely and efficiently dismantling and disposing of the structure

Sufficient confidence must be established in the integrity of these parameters before refloating a CGBS could be attempted.

**Primary Technical Risks and Consequences**

**Structural Integrity**

- ‘As is’ structural and watertight integrity cannot be guaranteed for refloat purposes although the CGBS will remain fit for purpose as a topside support
- Some refloat operations could impose load conditions not considered in the original design

**Weight**

- The weight of a CGBS may have been altered during installation and throughout its working life and this creates uncertainty
- A small underestimate of the CGBS weight (including an influx of water) will prevent the structure lifting off the seabed
- A small overestimate of the CGBS weight will result in a premature and potentially uncontrolled lift off from the seabed and a shallower than predicted draught

**Buoyancy**

- Watertight integrity will need to be restored and maintained
- Buoyancy will need to be managed and controlled over many months
- Once floating, any loss of watertight integrity could result in increased draught and the possibility of grounding or even total loss of the CGBS
- Any loss of internal segregation or ballast control could result in the structure listing at an angle, making further work unsafe, or floating too low in the water increasing the risk of grounding

**Jacking**

- The need to generate significant jacking forces at seabed level to release the CGBS
- Any inability to achieve sufficient jacking forces (due to small horizontal cracks leaking the pressure) may prevent separation of the structure from the seabed

**Time and weather**

- The time taken to separate the structure from the seabed is unpredictable and may take months. Therefore the operation is likely to be interrupted by periods of adverse weather

**Towing**

- Towing a refloated CGBS to a deep water location for disposal or inshore water for deconstruction with little ability to select the weather window
**Structural integrity**

At the time of installation, the ballast piping and control system was of known integrity and could control any inclination of the structure (or the trim) and the draught of the floating CGBS. As the systems were not required during the working life of the structures the pipework was made of carbon steel and the level of integrity is uncertain due to the potential for corrosion and the inability to inspect the system. In many cases these facilities may not have the necessary level of integrity to be relied upon during decommissioning.

The process of refloating could subject the structure itself to forces not considered in the original design. While these factors do not prevent the continued safe use of the structure to support topside facilities, they have a significant impact on the ability to safely refloat a CGBS.

**Weight**

The weight of a CGBS has to be accurately calculated in order to refloat the structure safely. However, solid ballast may have been added after installation to achieve the required on-bottom stability. Uncertainties about the exact weight of a CGBS increase throughout its operating life with changes to the topside, drill cuttings on or within the structure, a potential build-up of sediment within the cells, and marine growth. Work done during the decommissioning of the Ekofisk Tank estimated the total weight of the sediment at 2,300 tonnes. The volume of sediment will vary from cell to cell depending on the production arrangement and may influence the trim of the structure in the event of a refloat.

Even with the topside removed, all other avenues for increases in the weight of a CGBS must be assessed to establish the ‘as is’ conditions. Access may prove difficult when assessing the amount of sediment deposits in the cells and drill cuttings contained within the structure for both weight calculations and removal purposes.

The behaviour of soil or grouting adhering to the base of a CGBS separated from the seabed is unpredictable. A volume of grout or soil may adhere to the base and some or all of this material may become progressively detached during the tow-in operation. This could cause unpredictable changes in buoyancy, draught and trim.

**Buoyancy**

In order to achieve a controlled refloat, the structure has to be neutrally buoyant on separation from the seabed. Neutral buoyancy occurs when the lift forces generated by buoyancy equal the gravitational force of the platform’s weight – so the structure would neither impose weight on the seabed nor float upwards. At this stage the cells within the base would be partially water-filled and by introducing more air to increase buoyancy, the CGBS would start rising in a controlled manner.

To prevent a released CGBS rising up through the water in an uncontrolled manner, the difference between buoyancy and weight will need to be carefully controlled. However, quantifying the weight of a CGBS carries uncertainties due to the combination of factors discussed above, and any errors could cause it to rise or rotate uncontrollably.

The use of external buoyancy systems (tanks or cofferdams) to reduce reliance on the inherent buoyancy of a CGBS may be possible. This process was used during the refloating of the two small Schwedeneck-See platforms each weighing around 15,000 tonnes. However, to refloat a bigger (300,000+ tonnes) CGBS the tanks and structures would need to be extremely large making them difficult to manoeuvre and attach to the main structure. Once attached, significant horizontal loading may be experienced due to wind and wave impingement.
**Jacking**

Increasing buoyancy may not free the structure from the seabed. In order to separate the CGBS from the seabed in a controlled manner, high pressure seawater will need to be injected beneath the foundations (if feasible) in a process known as jacking. This is a predictable process and can be undertaken during periods of favorable weather conditions although small cracks or local water channels may prevent the achievement of the very high pressures required for separation. The high jacking forces may also create stresses in the structure not accounted for in the original design.

**Time and weather**

The behavior of a CGBS held with a level of positive buoyancy and uniform under-base jacking forces remains difficult to predict with confidence. Depending on the nature of the seabed material it could take weeks or months for a CGBS to break free. The required buoyancy and jacking forces would need to be established and maintained by engineers working from attendant vessels. Such operations would be subject to weather thresholds.

**Towing, offshore disposal/insbore dismantling and onshore disposal**

Where refloating a CGBS is considered feasible, consideration must be given to either towing the structure to a suitable deep water location for disposal or to a location with the infrastructure to support deconstruction, recycling and waste management. As with the original tow-out, any tow-in will be weather sensitive. However, as there is little control of the timing of the CGBS’s release from the seabed, the tow-in cannot be timed to avoid poor weather conditions.

To achieve a safe refloat the ballast control system would need to be sophisticated enough to assist the refloat and to continuously monitor and control the structure’s trim during the tow-in and throughout the deconstruction phase. Inshore deconstruction would take many months, throughout which the structure’s reducing weight would have to counteracted by buoyancy control in order to maintain a safe and practical freeboard.

The final deconstruction stage would require a dry dock, however some of the original construction sites are no longer available. Inshore dry dock facilities with deep water access may need to be built or recommissioned to accommodate these large structures before deconstruction work could be completed.
5.4 Complete removal by offshore demolition

Where refloating a CGBS is not possible or practical the option exists to deconstruct it in its original position by progressively removing a number of sections for recovery to the surface or depositing on the seabed.

**Primary technical risks and consequences**

**Mechanical cutting**
- Availability of safe and reliable cutting methods
- Failure to complete critical cut (e.g. diamond wire breakage/trapped blade) within weather window leaving unstable CGBS sections exposed to storm conditions and raising safety issues on revisiting worksite
- Cutting in the splash zone and near surface depths – maximum exposure to environmental loads and carrying the greatest risk of cut failure
- Effect of the release of pre-stress energy

**Explosive charges**
- Failure to remove sections completely – unstable CGBS sections left exposed to storm conditions raising safety issues on revisiting worksite
- Recovery of debris

**Lifting**
- Lifting large sections of CGBS through the splash zone (unless depositing material on seabed was acceptable)

**Time and weather**
- The time taken to demolish a CGBS progressively and to recover the spoil is likely to be measured in months and years as operations would be limited to acceptable weather and sea state operating thresholds

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**Figure 5.3**
Gullfaks A under construction in a dry dock.
*Photo: Leif Berge / Statoil*
Mechanical cutting

This option would require the development of methods for cutting through large sections of concrete underwater and for the recovery (where necessary) of those irregular sections by offshore crane to be processed onshore.

Where depositing material on the seabed is acceptable to regulatory authorities, the structure could be cut into significantly larger sections either mechanically or by explosives, with those pieces allowed to fall to the seabed.

These decommissioning options would require cutting through large cross sections/diameters of reinforced concrete underwater. Large diameters would range from 20m for designs with shafts to 45 to 50m for surface piercing caissons (see section 2) with concrete section thickness typically ranging from 0.7m to 2m. Some structures have an outer protective wall which can extend to up to 140m in diameter.

It should be noted that to date no experience exists in cutting large cross sections of heavily reinforced prestressed concrete structural members underwater in offshore environments. To develop safe and reliable cutting methods will require the current generation of cutting tools to be increased in size by an order of magnitude. Cutting operations will also be complicated by any equipment left installed within the shafts such as pipework, manifolds, stairways, platforms and the like as it may not be practical to remove all these items due to access/egress constraints and safety issues.

Studies have concluded that extensive development and testing of equipment will be required to prove the scaling of cutting technologies. While such developments may be possible the resulting tooling is likely to pose significant challenges in manoeuvring, positioning and securing both underwater and in the splash zone.

Such development may eventually allow diverless technology to be considered for these decommissioning options.

Existing technologies for cutting thick sections of reinforced concrete onshore include:-

- Abrasive water jets
- Track saw/chain saw/diamond stitch drilling
- Reciprocal wire/chain sawing
- Diamond wire cutting
- Shaped explosive charges

The limitations of these methods will be compounded in offshore deep water applications. CGBS operators should assess each of the methods to determine suitability for the specific project and requirement. Factors that would be typically addressed may include:-

Safety

- The need to avoid uncompleted cuts as it may be unsafe to return to a part-cut section therefore weather windows and tool breakages, wear rates and blade trapping all have to be considered
Technology

- The impact of cutting different materials and structures as internal pipework and other equipment may have to be left in place
- Size of a suitable cutting tool from a deployment perspective - launching through the splash zone, control and manoeuvrability in the water column, space availability at the cutting face and containment of reactive forces
- Some CGBSs have pre-stressed tendons to maintain the concrete in compression, thus the likely reaction to any energy released if the tendons were cut needs to be fully understood

Explosives

Where explosive charges are considered the recovery of debris from the seabed has to be taken into account. Current experience shows that a clean ‘cut’ is difficult to achieve as the steel reinforcing bars and tendons are not shattered by the explosion in the same way as rigid concrete.

Lifting

Where the demolition spoils have to be recovered, consideration of the following will be required:-

Capacity of available craneage
- Use of buoyancy
- The potential for steel reinforcement to remain intact
- Method of attaching irregular shape CGBS pieces for lifting by a heavy lift vessel
- Transfer of very heavy loads through the splash zone
- Transportation arrangements and sea fastenings
- The availability of onshore recycling facilities capable of handling the large sections and volumes of material
5.5 Partial removal

Decision 98/3 prohibits leaving disused offshore installations wholly or partly in place. However, if the operator can show through the comparative assessment that there are ‘significant reasons’ why these alternatives are ‘preferable to reuse or recycling or final disposal on land’ a permit may be issued allowing the structures to be left wholly or partly in place.

Partial deconstruction of CGBS refers to removing the shafts and enables operators to meet the IMO’s request for 55m of clear water above the structure. The removed material may be either deposited on the seabed (not currently permitted by the UK Government) or recovered to the surface for processing onshore. This option has a lower environmental impact than full removal (see section 7) although it will result in an underwater obstacle creating third party liabilities which will be mitigated by measures such as marking the site on marine maps. Any additional hazard from depositing the shafts in the vicinity of the CGBS base would be negligible.

While this option would be safer and technically less challenging than full deconstruction offshore, challenges still remain and are as set out above for full deconstruction. While the scale is smaller, a large proportion of the work would be close to the surface where the sea state and weather conditions have the maximum impact.

The environmental impact of any cell contents must be assessed and considered (see section 7 for more detail).

5.6 Wholly left in place

As outlined above where the individual assessment highlights significant obstacles to employing other decommissioning options, the operator can apply for a derogation to leave the structure wholly in place.

*Primary technical risks and consequences*

**Safety**
- The lowest worker exposure of all options

**Risks to other sea users**
- Shipping collision risk
Ongoing liabilities
- Monitoring and maintenance of navigational aids
- General third party liabilities

Cell Contents
- For those CGBS with oil storage, satisfactory solution for the long term management of cell contents (refer section 7)

Worker exposure
Limiting operations to removing the topside minimises worker exposure. The procedures for topside removal are more established and the risks and costs are understood and manageable.

Risks to other sea users
A CGBS will have been marked on nautical charts throughout its working life and be well known to local shipping. Where the structure is wholly left in place its presence must continue to be indicated on nautical charts. Consideration should be given to the provision and ongoing maintenance of the navigational aids in accordance with international standards.

Ongoing liabilities
In addition to the maintenance of the navigational aids, the long term the structural integrity, likely degradation mechanisms and eventual failure modes (along with their environmental impact) will need to be assessed. These aspects are examined in sections 7 and 10.

Cell contents
All decommissioning options should consider the impact of any cell contents during the comparative assessment evaluation to determine how these may influence the different outcomes and in particular the environmental impact (see section 7 for more detail).
6 Safety

The offshore oil and gas industry in the OSPAR Maritime Area has a strong safety culture. Although working in harsh and uncontrollable environments, CGBS operators implement safe working practices which result in accident rates that compare well with many land-based industries (Ref 4). To achieve this level of safety operators accurately identify risks and manage or eliminate those risks by design, the use of technology and/or work practices. The industry and governments require, and the public would expect, the same standards and safety levels during the decommissioning phase.

Each decommissioning option poses safety challenges especially the early CGBSs which did not include any end-of-life considerations. All such safety issues need to be identified at the planning stage. This requires individual assessment of each decommissioning option (see section 5) to identify both the risks and methods of mitigating those risks to ensure safety is not compromised.

In 2006 Total concluded there was a 47% probability of a fatality if its CGBS known as MCP01 was decommissioned by full removal and onshore disposal (see Ref 8). This operation carried a 60% probability of a major unplanned event which would increase the probability of a fatality to between 50% and 70%. The probability of a fatality during partial removal was put at at 53% (Ref 12) but if the structure was left wholly in place with its topside removed, the chance of a fatality was less that 1%.

Figure 6 MCP01 having its topsides removed by SCANMET’S “piece Small” method (photo: Total)
6.1 Summary of safety risks associated with CGBS reuse

Any reuse of a CGBS will involve modification and/or reworking of the topside. The oil and gas producers have already identified and control the risks involved in such work and this information would be available to the structure’s new operator. It would be the responsibility of any new operator to consider the safety of the ongoing operation and the eventual decommissioning of the structure.

6.2 Summary of safety risks associated with full removal

The main safety risks to people posed by the refloating and removal of CGBS come during:
- Preparation
- Release from seabed
- Towing to deepwater inshore location
- Inshore dismantling operations

In assessing the feasibility of each decommissioning option the operator must consider each of these problems in turn.

**Preparation**

The removal of a CGBS is likely to involve a large fleet of vessels and extensive preparatory works. Workers will be required to re-establish a controllable buoyancy system, install a jacking system and remove accumulated silts and drill cuttings (see section 7) along with any additional ballast and scour protection placed during installation. These processes will involve additional man-hour exposure to hazardous activities such as working underwater, lifting operations and working at height.

If diverless technology could not be developed and diving in enclosed spaces was unavoidable, the operation would be subject to very close scrutiny and the risks may be intolerable.

**Release from seabed**

Timing of the CGBS’s release from the seabed is unpredictable and an unexpected release could create acute hazards to both people and equipment. Once released, any miscalculation in the weight of the CGBS could lead to the structure rising uncontrollably and settling at a higher than intended clearance from the seabed. This will make the floating structure less stable than expected.

**Towing**

The unpredictable timing of the release from the seabed leaves the towing operation exposed to unsuitable weather conditions. The behaviour of the under-base grout is difficult to predict; it may adhere to the structure on separation from the seabed and fall away during the refloat or later while under the tow. Any unexpected changes to the re-established buoyancy could create additional dangers for personnel on the towing vessels.

**Inshore deconstruction**

During deconstruction the buoyancy of the remaining structure will have to be carefully controlled and adjusted (reflecting the structure’s diminishing weight) if safe working conditions are to be maintained.
6.3 Summary of safety risks associated with partial removal

While this option reduces the duration of the work and does not require working on the seabed, in its evaluation of the options for decommissioning MCP01 Total concluded the risk of a fatality were higher when partly removing a CGBS than it was during a full removal. There are risks associated with cutting heavy CGBS sections and the lifting (if required) of those sections on board a vessel or barge for transportation to shore.

Some potential risk will remain for other users of the sea.

**Cutting** – the challenges of cutting such large sections of reinforced concrete under water would have to be overcome for this option to be realised. Explosives may offer a safer option.

**Lifting** – if the detached sections cannot be left on the seabed they will have to be removed for onshore processing. This requires attaching the submerged, heavy and irregular sections to a crane and lifting them through the splash zone. Sea fastening of irregular sections for transportation and land based processing also involve hazards to personnel.

While the risk to merchant shipping would be removed by reducing the height of the structure to below the surface (the IMO recommends 55m), the risk of snagging fishing nets would remain.

6.4 Summary of safety risks associated with CGBS left wholly in place

While there are known and manageable safety risks associated with a topside removal, the main risks to people from a CGBS left wholly in place are primarily those related to ship collision and snagging of fishing nets.

For CGBSs that remain in place with the topsides removed (such as Frigg and Ekofisk), the risk of ship collision has been assessed and mitigated by marking their locations on navigation charts and installing high integrity navigational aids on the protruding shafts to warn vessels. The use of equipment with long maintenance intervals and which can be replaced by helicopter removes the need to get personnel aboard a decommissioned CGBS. The operator will continue to monitor the navigational aids to ensure they are functioning correctly.

The short to medium term risk to fishermen through net snagging would be minimal as the protruding structure itself presents a visible obstruction and a warning to fishing boats sailing close by. However over the very long term (possibly hundreds of years) the shafts of the CGBS will start to break down and could create a hazard to ship traffic and fisheries in the future and may require alternative methods of marking.
7 Environmental impact

The environmental impacts of the decommissioning options discussed in section 5 (reuse, complete removal, partial removal or wholly left place) will differ markedly for each CGBS and each structure will require an individual environmental impact assessment (EIA). In general the removal options will impose significant short term environmental impacts (including the disturbance of drill cuttings) while structures left in place may have less severe but longer term effects on the offshore ecosystem. The small proportion of non-water contents (see Ref 5) in the cells of CGBSs (especially those used for oil production or storage) must be assessed with all decommissioning options.

Concrete and steel are inert and marine life and growth quickly adapts to any installation as can be seen in the photograph below of a steel jacket structure removed from the North Sea (no deep water CGBSs have been removed in the OSPAR area).

![Figure 7 The ability of the marine environment to adapt to installations is evident from this cross brace removed during decommissioning of the small steel jacket rig.](Photo: Heerema)

With the exception of the effects of any residual hydrocarbons within those structures used for oil storage, the impacts of the various decommissioning options for a CGBS either at the site or inshore at dismantling locations will largely relate to physical disturbance and the interference with amenities and other users of the sea. All of these aspects should be evaluated in the comparative assessment.

From an environmental perspective OSPAR 98/3 requires the following matters to be taken into account when assessing disposal options:

- impacts on the marine environment including exposure of biota to contaminants associated with the installation, biological impacts arising from physical effects, conflicts with mariculture and the conservation of species (protection of their habitats) and interference with other legitimate uses of the sea
- impacts on other environmental compartments including: emissions to the atmosphere, leaching to groundwater, discharges to surface fresh water and effects on the soil
- consumption of natural resources and energy associated with re-use or recycling
- other consequences to the physical environment which may be expected to result from each option
- impacts on amenities, the activities of communities and on future uses of the environment
7.1 Reuse

Any reuse of a CGBS will only delay its ultimate decommissioning so this option is not considered in this section.

7.2 Refloat for onshore disposal

Refloat and onshore disposal is the preferred option according to OSPAR 98/3 but this does not offer the optimal solution with respect to the environment.

In November 2011 the Norwegian company Multiconsult published the findings of a study commissioned by the Norwegian Climate and Pollution Agency (Klif) on the environmental impact of dismantling concrete structures. The report, entitled ‘Study of the environmental impact of disposing of concrete installations’ (Ref 6), concluded that the environmental impact from onshore disposal may be substantial in respect of:

- noise, dust and dispersing polluted water during dismantling
- space required for the demolition site
- energy consumption during dismantling
- limited opportunities to reuse very large quantities of recycled salt-contaminated material and waste deposits of crushed concrete

All removal options will result in the disturbance of the ecosystem which will have become established around the structures in the decades following their installation. The impacts on the marine environment include exposure of biota to contaminants associated with the installation, biological impacts arising from physical effects, conflicts with mariculture and the conservation of species (protection of their habitats), and interference with other legitimate uses of the sea.

Over the longer term this option may offer the best solution in terms of returning the seabed to its original state although it would involve high levels of energy consumption/CO$_2$ emissions and have the highest environmental impact onshore.

7.3 Refloat for deepwater disposal

If the refloat of a CGBS is considered feasible, towing it to a deepwater site for disposal by sinking would be a more environmentally friendly option than taking it to shore for dismantling as this would require a large amount of energy and the resulting release of CO$_2$. If the concrete structure is crushed during sinking it would expose the cell contents to seawater giving rise to potential pollution. However, the wax content of the residue in the cells is high and is assumed to be relatively immobile. For that reason only a very slow leaching of hydrocarbons to the seawater is anticipated.

This option would move the environmental impact on the seabed from the original location to the disposal site and would involve high energy consumption/CO$_2$ emissions.

Although OSPAR 98/3 allows the option of seeking derogation for deepwater disposal, it should be noted that the UK government prohibits the deep water disposal of UK installations. The reaction from the wider society of this disposal method would need to be considered.
7.4 Offshore deconstruction and removal

Offshore deconstruction would create the largest adverse environmental impact at the original site and will involve extensive open water subsea work, considerable marine transport activities and high volumes of onshore material handling. This process is most likely to expose the cell contents and drill cuttings (as above) in high concentrations to the open water and will also require the biggest offshore operation if the dismantled debris is to be recovered from the seabed after toppling or explosives are used.

In addition to causing extensive disturbance on the seabed, it is likely that this option will also consume the most fuel and therefore result in the highest level of CO$_2$ emissions.

7.5 Partial removal/partly leave in place

Where IMO guidelines are followed, a CGBS partly left in place would have its shafts removed below the surface to provide a free navigation depth of 55m. The upper shaft sections may be placed on the seabed near the installation or may have to be taken to shore for disposal to fulfil local regulations. With the shaft(s) removed, the exposure of the lower part of the CGBS to wave action would be minimised and the structure may stay intact almost indefinitely.

In comparison with those outlined above, the option to leave partially in place minimises onshore and inshore environmental impact while limiting seabed disturbance and energy consumption/CO$_2$ emissions. In the longer term the existing seabed and water column ecosystems would remain undisturbed.

7.6 Leave wholly in place

Multiconsult’s report for the Norwegian Climate and Pollution Agency concludes that the option of leaving a CGBS wholly in place has the lowest environmental impact compared with the other decommissioning options.

An unofficial translation of the summary states: ‘The environmental impact of abandoning concrete installations in the North Sea is limited. The biological production which currently occurs on these installations would disappear if they were removed, and the structures do not affect fish populations or fishing. If they are fitted with lights and navigation equipment, the threat of any conflict with shipping is small.’

It goes on to say: ‘At the same time, the potential environmental impact of removal to land is substantial. A danger of accidents naturally exists when refloating installations and moving them to land, but the conflicts primarily relate to environmentally acceptable cleaning and removal of hydrocarbons, demolition and intermediate waste storage. These operations are expected to involve a high risk of dispersing polluted water as well as generating dust and noise. A large amount of space would be required, both on land and in the sea, and the level of potential conflicts with neighbours is expected to be high.

In terms of energy consumption and emissions to the air, abandonment of a concrete structure at sea would be far more favourable than disposing of it on land.

‘From an overall perspective, therefore, offshore abandonment would clearly have the lowest environmental impact.’

Over the much longer term the structure of a CGBS left wholly or partly in place will eventually fail, causing limited exposure of the cell contents to open water.
7.7 Drill cuttings

Drill cuttings are crushed sediment from the rock formations extracted when drilling a well.

Some drill cuttings may be contaminated with hydrocarbons because of the type of drilling fluid (known as ‘mud’) applied when the well was drilled. The muds are pumped into the wellbore to stabilise the hole and flush the cuttings out of the well. Before 1990 oil-based and synthetic-based muds were used while now more environmentally friendly water based muds predominate. The cuttings were normally washed to recover the fluids and then discharged over the side forming accumulations on the seabed. In 1999, this practice was stopped for all but those cuttings lubricated with water-based muds. Oil and synthetic lubricated cuttings were either re-injected into the well or brought onshore for secure disposal.

The legacy management of contaminated cuttings on the seabed was investigated by industry in the early 2000s with the findings subjected to extensive independent scientific review and stakeholder engagement. The recommendations were broadly adopted by OSPAR (OSPAR Recommendation 2006/5 on a Management Regime for Offshore Cuttings Piles – see Ref 7) and are based on evaluating the volume and extent of the cuttings, the persistence of any contaminated area and any potential oil leakage into the water column. Options to consider are: recovery for onshore disposal or reinjection in the well, covering, or leaving undisturbed in place. In cases considered by this process to date, the most environmental friendly solution has been to leave the cuttings undisturbed.

The drill cuttings on or around a CGBS will create a challenge if the structure is to be removed as they can increase weight, obstruct external access to the base and will be disturbed during the refloat operation. Where removal of the CGBS is considered the controlled relocation of some cuttings will be required.

7.8 Content of storage cells

Figure 7.8
A cutaway section illustration of the layout of storage cells within a CGBS base
**Oil storage within CGBS cells**

The contents of the cells within the CGBS base depend on its operational phase and will be relevant to all disposal options. The number of cells within each CGBS ranges from 1 to more than 80. They vary in size and shape from 11m square by 30m high to 18m in diameter by 60m in height, and provide total oil storage capacities ranging from 500,000 to 2 million barrels.

The cells within a CGBS used for gas production are normally flooded with water while those within platforms used for oil production are utilised for oil storage. These cells will be partially oil and partially water filled and contain an accumulation of sediment from the well stream. It is anticipated that some oil will be deposited as wax on the surface of the cells and may also have permeated into the concrete surface.

Access to the cells was not normally included in early CGBS designs, thus gaining access for decommissioning purposes presents significant technical and safety challenge. As far as is possible on technical and safety grounds, the content of storage cells should be understood. During the decommissioning process consideration should be given to assessing and analysing the cell contents.

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Figure 7.8.1  Comparative illustration of the size of storage cells within a CGBS.
**Quantity and composition of sediments/residual fluids in CGBS cells**

To undertake an EIA and meet the OSPAR 98/3 requirements it will be necessary to develop a description of the cell contents which may employ both analysis and physical measurement.

**Fluids**

Trapped or ‘attic’ oil may be present above the inlet/outlet piping. Residual wax may have adhered to the cold surface of the structure and an oil water emulsion layer (the interphase layer in Fig 7.8.2) may be present between the attic oil and water layer.

Residual water within the CGBS will represent more than 90% of the volume and is likely to be similar in composition to that discharged during the production period.

**Sediments**

Throughout a CGBS’s 30-40 year working life even the smallest proportions of sediment within the produced fluids would lead to some accumulation within the storage cells. This sediment may include oil-wet sand, scale particles, wax deposits, rust particles, residual drilling fluids, production chemicals and small quantities of waste or debris from the platform’s drainage systems. The quantities and composition of sediments can be determined based on the chemical composition of the produced fluids and samples obtained from accessible parts of the production system.
Analysis of Dunlin Alpha shows that 99% of the cell content is water (see Ref 4). Physical measurement and sampling of cell sediment during the decommissioning of the Ekofisk Tank (see section 8) revealed soft deposits between 1m and 3m deep comprising approximately 39% oil, 28% water and 33% solids. In other installations the proportion of sediments may be around 10% by volume and the estimated weight can run to thousands of tonnes.

7.9 Cell content treatment strategies

Hydrocarbons

In installations used for oil processing and storage, as much of the attic oil should be removed from the cells as is practically possible. Intervention utilising existing platform systems prior to decommissioning may provide the most efficient and effective evacuation option.

Sediments

Operators must consider the environmental impacts of both leaving the sediment in the cells and removing it. This necessitates assessing the quantity and composition of the sediment, and the most likely way in which it will eventually be exposed.

Based on the experience of structures decommissioned to date it has not been possible to recover sediments from the cells within the base of a CGBS.

If the sediment can be removed the disposal options may include recovery to shore for treatment and disposal or re-injection into redundant production wells or specially drilled disposal wells. Both options are likely to present further issues because of the volumes of sediment involved and regulatory (OSPAR) concerns over ‘disposal’ of material.

Leaving the cell contents in place may be permitted if the sediment is unlikely to result in unacceptable risk to the environment. Sediments left within a CGBS would be subjected to a combination of long term containment and eventually very slow leaching into the marine environment at a rate which is not predicted to cause harm.

Studies indicate that the reinforced concrete structure is likely to take hundreds of years to degrade to the extent that the sediment escapes into the environment. The rate and volume of the eventual release will be low.
8 Decommissioning experience to date

The design of some of the first CGBSs did not specifically address decommissioning although more recent practice has been to include refloat analyses as part of the front end design in an effort to facilitate an eventual removal. However, there remain considerable challenges to refloating any CGBS. An extensive case-by-case analysis of those structures approaching the end of their productive life shows that while reversal of installation may be theoretically possible, the process may be technically impractical, pose unacceptable risks to personnel and the environment (see sections 5, 6 and 7) and involve disproportional costs with little or no societal benefit.

This case by case analysis is underpinned by the comparative assessment process set out in OSPAR’s guidance which is designed to bring transparency to both the arguments addressing the consideration of conflicting aspects and the Governmental decision making process (see section 4.2).

To date the OSPAR process has been followed with respect to the 7 concrete structures that have been decommissioned in the North and Baltic Seas over the last 12 years. Details of the specific decommissioning projects and a brief description of the project outcomes are provided below:

<table>
<thead>
<tr>
<th>Name of CGBS</th>
<th>Water depth (m)</th>
<th>Sub-structure weight (tonnes)</th>
<th>Decommissioning Project Execution Year</th>
<th>Decommissioning option selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schwedeneck-See –A</td>
<td>25</td>
<td>15,000</td>
<td>2002</td>
<td>Complete removal</td>
</tr>
<tr>
<td>Schwedeneck-See –B</td>
<td>16</td>
<td>14,000</td>
<td>2002</td>
<td>Complete removal</td>
</tr>
<tr>
<td>Frigg TCP2</td>
<td>103</td>
<td>229,200</td>
<td>2005 to 2008</td>
<td>Leave wholly in place</td>
</tr>
<tr>
<td>Frigg TP1</td>
<td>103</td>
<td>162,000</td>
<td>2005 to 2008</td>
<td>Leave wholly in place</td>
</tr>
<tr>
<td>Frigg CDP1</td>
<td>98</td>
<td>415,700</td>
<td>2005 to 2008</td>
<td>Leave wholly in place</td>
</tr>
<tr>
<td>MCP01</td>
<td>117</td>
<td>376,000</td>
<td>2005 to 2008</td>
<td>Leave wholly in place</td>
</tr>
<tr>
<td>Ekofisk Tank</td>
<td>70</td>
<td>273,700</td>
<td>2005 to 2008</td>
<td>Leave wholly in place</td>
</tr>
</tbody>
</table>

Figure 8 Decommissioned CGBSs in the North Sea and Baltic Sea

8.1 Schwedeneck-See – German Baltic Sea (outside OSPAR)

Both Schwedeneck-See decommissioning projects involved small and light structures (weighing 15,000 and 14,000 tonnes) installed in sheltered shallow-water estuaries. These structures were successfully removed by increasing buoyancy with the use of additional steel buoyancy chambers.
8.2 Frigg and MCP01 – UK/Norwegian North Sea

This decommissioning project involved 4 significant CGBSs in the northern North Sea (3 located on the UK/Norway median line and 1 in UK waters) which had been used to deliver gas to the UK for 25 years. Over several years the operator, Total, commissioned more than 50 extensive studies by industry experts evaluating the options for decommissioning the structures. Total also engaged with interested stakeholders (including fishing groups) and had the studies independently assessed by technical experts as it investigated the feasibility of the different decommissioning options. Ultimately the recommendation was that, in view of the limited environmental benefit and the severe safety and financial implications of a major accident, the inherent uncertainties involved in removing the structure were unacceptable. The option to leave the structures wholly in place was proposed and after scrutiny by OSPAR members, this was approved by the UK and Norwegian Governments in 2003.

8.3 Ekofisk Tank – Norwegian North Sea

The Ekofisk Tank was installed in 1973 in 70m of water in the Norwegian Sector of the North Sea, and was the first CGBS with oil processing and storage to be decommissioned. Following extensive analytical work, public consultation and an independent review, it was concluded that the project risk of an unsuccessful refloat, including risk to neighboring installations was unacceptably high, that the at-shore demolition would entail significant safety risks to personnel, and that the whole operation would consume a disproportional amount of resources resulting in a negative energy and emission balance compared with in place disposal.

In 2002 the Norwegian Government approved the proposed decommissioning programme allowing the CGBS substructure to be left in place, with aids to navigation installed and maintained. Dunlin A, Statfjord A and three CGBSs at Brent are currently the subjects of extensive studies into the various decommissioning options (see section 5) by their respective operators.
9 Monitoring and legacy management

It is likely that a derogated CGBS partly or wholly left in place will not experience gross failure for some considerable time. However, reinforced concrete in the splash zone will be less resilient and may survive in the range 70 to 300 years.

Monitoring programmes for derogated CGBSs should therefore be designed with regard to the very long periods of time involved and the slow rate of the structure’s deterioration.

9.1 Monitoring

Concrete substructures wholly left in place will be equipped with high integrity navigational aids to fulfil both sovereign state and IMO requirements. Remote monitoring of the navigational aids would be carried out to ensure continuous operation of the equipment while reducing or removing the need for physical visits to a hazardous and deteriorating structure.

It is envisaged that the navigational aids will be designed for deployment and retrieval by helicopter to avoid the need to man the structures to maintain this equipment.

Some national jurisdictions may require the establishment and maintenance of a 500m exclusion or safety zone around derogated structures that are visible above sea level.

Figure 9.1
Long service interval navigational aids on the decommissioned Ekofisk Tank
(Photo: ComPower/ConocoPhillips)

Circles highlight navigational aides
9.2 Legacy management

Where required by the legislative regime, operators accept responsibility for decommissioned facilities in perpetuity. However, the continued existence of corporate entities cannot be assured for such extended timescales. Therefore other arrangements will need to be made where these obligations can be transferred, with appropriate financial considerations.

Operators active on the UK’s Continental Shelf (UKCS) who leave items on the seabed as part of an approved decommissioning programme make a payment into the Fisheries Legacy Trust Company (FLTC). The trust was established in 2007 to manage interactions between the offshore oil and gas industry and the fishing industry and, in particular, to manage an endowment fund set up to address any legacy issues concerning offshore structures.

Over the very long term the structural degradation and collapse of a CGBS left wholly or partly in place may create the potential to snag fishing nets. Advances in protocols and fishing-related technologies are expected to reduce this risk. The FLTC has made significant progress in several key areas including the updated FishSAFE device (installed on fishing vessels to warn of the location of oil and gas-related infrastructure) and long term access to the data about seabed hazards. Information on the structure and work of the FLTC is available at http://www.ukfltc.com/.
Costs are an essential part of the comparative assessment of decommissioning options and the issue is often raised in open stakeholder engagement sessions (see section 11). As each CGBS installation is different, their decommissioning costs will vary and will have to be estimated on an individual basis. While noting these differences, the limited published costs for decommissioning experience to date and that some options are still untried, for the purposes of this report an attempt has been made to provide indicative costs for decommissioning the remaining CGBSs in the OSPAR area. Some of the figures have been obtained by extrapolation (both numerically and by tonnage) of published data and are provided to give order of magnitude estimates only.

As Governments typically allow legitimate expenses incurred during development, operation and decommissioning of oil and gas infrastructure to be offset against tax, the cost of decommissioning has an impact on the relevant exchequer. The Norwegian regulator’s *Disposal of Concrete Facilities* report (Ref 10) concluded that tax offset will cover about 80% of the cost of decommissioning installations in its area. Those in public office will have to consider the public perception of forfeiting in the region of €500 million per structure in tax revenue to remove disused CGBSs in the North Sea compared with the benefits/amenities that revenue could buy onshore (see Section 11).

The only large CGBSs to be decommissioned to date are Frigg, MCP01 and Ekofisk, all of which were left wholly in place. As no large CGBSs have been removed, either partially or completely, any assessment of the likely costs of doing so are only estimates incorporating a high degree of uncertainty. The biggest area of risk and uncertainty concerns the technical feasibility of the decommissioning options and the associated costs (see section 5).

Beyond the costs described below, additional expense will be incurred in plugging the wells, ending production and removing debris from the seabed. These costs can exceed €100 million per platform.

### 10. Leave wholly in place

There are wide variations in the cost of decommissioning a CGBS as this depends on the individual design, location and use of each installation. The cost of decommissioning MCP01 (Ref 8) by leaving it wholly in place with the topside removed was €119 million (2004 prices) which equates to €150 million in 2012.

The cost of decommissioning Frigg TCP2 by removing the topside and leaving the structure wholly in place exceeded €200m (2010 prices). Decommissioning of TP1 and CDP1 in the Frigg Field by removing the topsides and leaving the CGBS structures wholly in place cost in excess of €120 million and €86 million (2012 prices) respectively (see Ref 9). Exact decommissioning figures for CGBSs in the Frigg Field are difficult to establish as the cost of removing pipework and seabed clean-up is shared between several installations.

The combined topside weight of the four CGBSs decommissioned to date was 49,000 tonnes and the cost of decommissioning these installations with the CGBSs left wholly in place was in the region of €556 million (2012 prices). The remaining 22 CGBSs in the OSPAR area have a combined topside weight approaching 513,000 tonnes. On that basis, the cost of decommissioning those installations by removing the topsides and leaving the structures wholly in place could be estimated to be in the region of €5.8 billion (2012 prices).

A more recent study (Ref 10) published in 2012 by the Norwegian Petroleum Safety Authority Norway and the Climate and Pollution Agency (Klif) estimated the cost of decommissioning fields containing CGBSs within the Norwegian sector at €6.1 billion. This figure includes the decommissioning of smaller steel jacket installations and the report notes that several fields reported
weighted cost estimates and other cost allocations are uncertain. When considering the data covers 10 CGBSs in the Norwegian sector, it suggests a similar order of magnitude cost to that outlined above for the remaining 22 CGBSs in the OSPAR area.

### 10.2 Partial removal

Partial removal of CGBSs where the shafts are cut at 55m below sea level may be possible for structures such as Frigg and MCP01. However, in its report examining the decommissioning options for MCP01, Total concluded the costs of removing the internal and external steelwork and cutting the shafts to 55m below sea level would be higher than the full removal of the CGBS structure (Ref 11). Partial removal costs could be lowered by advances in cutting technologies (see section 5.4) although the cost would still run to several hundred million Euros and carry significant risk of failure and cost escalation during execution.

### 10.3 Full removal

While removal of a CGBS in deep water has not been undertaken, the estimated cost of the full removal of MCP01 with onshore disposal was €753 million (2004 prices) rising to a potential €1.3 billion if a major unplanned event occurred (see Ref 8). The actual cost of decommissioning MCP01 by removing the topside and leaving the CGBS wholly in place was €119 million (2004 prices). At 2012 prices these would represent roughly €150 million for topside removal only and €1 billion for full removal, therefore the estimated cost difference between the two options can be put at €850 million.

While these figures are unique to MCP01, if they are extrapolated to the 22 remaining CGBSs in the OSPAR area, the cost of removing the topsides and leaving the bases wholly in place would be in the region of €3.3 billion. If those installations were required to be fully removed with onshore disposal the cost would increase by a further €18.7 billion to €22 billion.

MCP01’s operator estimated there was a 60% probability of a major unplanned event occurring during full removal and onshore disposal of the CGBS (see Ref 8). If an accident occurred during the removal process it was estimated that the total cost of removing MCP01 would rise to €1.3 billion (2004 prices) which equates to €1.7 billion in 2012 prices. If such events happened during full removal of 12 (55%) of the remaining CGBSs in the OSPAR area, the cost of removing all 22 of the remaining CGBS installations would increase to an estimated €30 billion.

It should be noted that the MCP01 report put the probability of a major unplanned incident occurring during topside removal at less than 1%.
II Engaging with stakeholders

National governments impose additional regulatory requirements on CGBS decommissioning including that for public consultations.

The UK requires statutory consultation with various parties, including fishing and cable laying interests, as part of its approval programme in order that their views on the recommended disposal option are gathered. In Norway the Decommissioning Plan requires a separate Impact Assessment Programme to be prepared to ensure the public are properly informed and to provide various stakeholders with the opportunity to express opinions and inputs into the scope and execution of the project.

Within the North Sea area it has become industry practice to go beyond the regulatory requirements where there is likely to be legitimate public interest in the outcome—such as CGBS decommissioning where alternative options have to be investigated. Engagement can take a variety of forms including meetings, interactive websites, newsletters and video-linked meetings (‘webinars’), with audiences ranging from fishing industry representatives to environmental groups and academics.

The objective is to have an open and transparent process by proactively gathering a broad selection of concerns and opinions of all interested parties to inform the detailed comparative assessment. Such consultation also enables the decision process to be understood and the technical and safety aspects to be shared before a formal decommissioning plan is submitted for Government approval.

Early engagement was adopted while developing the Ekofisk Tank and Frigg Field decommissioning programmes and resulted in support for (and eventual approval of) leaving the concrete structures wholly in place. Currently the Brent, Statfjord and Dunlin decommissioning projects are following the ‘open and early dialogue’ route.

During the MCP01 consultation process (Ref 12), some stakeholder groups expressed a preference for the full removal to shore option. However, if full removal was technically unfeasible or inherently unsafe, then the leave in place option was preferred to deep water disposal and cut down to -55 meters. Deepwater disposal was viewed as environmentally unacceptable while cutting the shafts to -55m resulted in a hazard to fishing operations.

The issue of cost is often raised during stakeholder consultations. Having been made aware that the majority of cost would be covered by the taxpayer, stakeholders said the societal choice needs to be considered. Some called for a cost/benefit analysis and an assessment of financial acceptability (Ref 13).

Such dialogue does not mean that all stakeholders will agree with recommended outcome. However, it is more likely that a broad spectrum of interested parties will understand the reasons behind the recommendations and the process used to develop them, before those recommendations are submitted to the regulator.

Details of activities and feedback can be found at individual project websites.
Decommissioning of CGBS in the OSPAR maritime area/ other global regions

The information contained in these appendices has been sourced from Arup resources and publicly available information. The information is intended to be indicative only, and should not be relied upon without consulting the relevant operator.

Appendix I: Table of CGBSs installed in the OSPAR area and outside the OSPAR area

### CGBSs in OSPAR region

Existing CGBSs in Norwegian Sector

<table>
<thead>
<tr>
<th>Platform</th>
<th>Number of shafts</th>
<th>Function</th>
<th>Operator</th>
<th>Water Depth m</th>
<th>Installation Date</th>
<th>Topside weight at installation thousand te</th>
<th>Sub-structure weight incl. ballast thousand te</th>
<th>Oil storage million bbl</th>
<th>Length of skirts m</th>
<th>Under-base grouting</th>
<th>Solid ballast</th>
<th>Decommissioning Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ekofisk Tank</td>
<td>1</td>
<td>D/Q</td>
<td>Phillips Petroleum Norway</td>
<td>72</td>
<td>1973 - 1989</td>
<td>8 - 215</td>
<td>897</td>
<td>1.0</td>
<td>0.4</td>
<td>No</td>
<td>Sand; 20k te in closed cells</td>
<td>Derogation granted 2001</td>
</tr>
<tr>
<td>Protective Barrier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gravel; 621k te in closed cells</td>
<td></td>
</tr>
<tr>
<td>Frigg TCP2</td>
<td>3</td>
<td>D/C</td>
<td>Elf Petroleum Norge</td>
<td>103</td>
<td>1977</td>
<td>14 - 230</td>
<td>No storage</td>
<td>3</td>
<td>Yes</td>
<td>Olivine; 70k te in closed cells</td>
<td>Derogation granted 2003</td>
<td></td>
</tr>
<tr>
<td>Statfjord A</td>
<td>4</td>
<td>DPQ</td>
<td>Statoil</td>
<td>145</td>
<td>1977</td>
<td>20 - 316</td>
<td>1.2</td>
<td>3</td>
<td>Yes</td>
<td>Sand; 85k te in closed cells</td>
<td>Study stage</td>
<td></td>
</tr>
<tr>
<td>Statfjord B</td>
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<td>DPQ</td>
<td>Statoil</td>
<td>145</td>
<td>1981</td>
<td>40 - 532</td>
<td>1.9</td>
<td>4</td>
<td>Yes</td>
<td>Olivine; 150k te in open cells</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statfjord C</td>
<td>4</td>
<td>DPQ</td>
<td>Statoil</td>
<td>145</td>
<td>1984</td>
<td>40 - 588</td>
<td>1.9</td>
<td>3.8</td>
<td>Yes</td>
<td>Iron ore; 231k te in closed cells</td>
<td></td>
<td></td>
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<tr>
<td>Gullfaks A</td>
<td>4</td>
<td>DPQ</td>
<td>Statoil</td>
<td>135</td>
<td>1986</td>
<td>42 - 561</td>
<td>1.95</td>
<td>3.4</td>
<td>Yes</td>
<td>Iron ore; 216k te in closed cells</td>
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<td></td>
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<tr>
<td>Gullfaks B</td>
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<td>DPQ</td>
<td>Statoil</td>
<td>142</td>
<td>1987</td>
<td>28 - 447</td>
<td>No storage</td>
<td>1.3</td>
<td>Yes</td>
<td>Gravel; 187k te in closed cells</td>
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<td>Oseberg A</td>
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<td>PQ</td>
<td>Norske Hydro</td>
<td>109</td>
<td>1988</td>
<td>38 - 575</td>
<td>No storage</td>
<td>1.4</td>
<td>Yes</td>
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<td>4</td>
<td>DPQ</td>
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<td>217</td>
<td>1989</td>
<td>50 - 830</td>
<td>2.0</td>
<td>22</td>
<td>Yes</td>
<td>Iron ore; 185k te in closed cells</td>
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<td>Sleipner A</td>
<td>4</td>
<td>DPQ</td>
<td>Statoil</td>
<td>82</td>
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<td>37 - 463</td>
<td>No storage</td>
<td>1</td>
<td>Yes</td>
<td>Olivine; 240k te in closed cells</td>
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<td></td>
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<td>Draugen</td>
<td>1</td>
<td>DPQ</td>
<td>Norsk Shell</td>
<td>251</td>
<td>1993</td>
<td>21 - 232</td>
<td>1.4</td>
<td>9</td>
<td>Yes</td>
<td>Olivine; 3k te in closed cells</td>
<td></td>
<td></td>
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<td>Troll A</td>
<td>4</td>
<td>DPQ</td>
<td>Statoil</td>
<td>303</td>
<td>1995</td>
<td>23 - 683</td>
<td>No storage</td>
<td>36</td>
<td>Yes</td>
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## Existing CGBSs in UK Sector

<table>
<thead>
<tr>
<th>Number</th>
<th>Platform</th>
<th>Number of shafts</th>
<th>Function</th>
<th>Operator</th>
<th>Water Depth (m)</th>
<th>Installation Date</th>
<th>Topsides Weight at installation thousand ton</th>
<th>Sub-structure weight incl. ballast thousand ton</th>
<th>Oil storage million bbl</th>
<th>Length of skirts (m)</th>
<th>Under-base grouting</th>
<th>Solid ballast</th>
<th>Decommissioning Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Brent B</td>
<td>3</td>
<td>DPQ</td>
<td>Shell UK Exploration and Production</td>
<td>139</td>
<td>1975</td>
<td>10</td>
<td>331</td>
<td>1.1 (no longer in use)</td>
<td>4</td>
<td>Yes</td>
<td>Sand; 142k te in closed cells</td>
<td>Study stage</td>
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<tr>
<td>15</td>
<td>Beryl A</td>
<td>3</td>
<td>DPQ</td>
<td>Apache North Sea</td>
<td>117</td>
<td>1975</td>
<td>14</td>
<td>251</td>
<td>0.9</td>
<td>3.5</td>
<td>Yes</td>
<td>Sand; 123k te in closed cells</td>
<td></td>
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<tr>
<td>16</td>
<td>Frigg TPI</td>
<td>2</td>
<td>P</td>
<td>Elf Petroleum Norge</td>
<td>103</td>
<td>1976</td>
<td>8</td>
<td>162</td>
<td>no storage</td>
<td>2</td>
<td>Yes</td>
<td>Concrete; 35k te in closed cells</td>
<td>Derogation granted in 2003</td>
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<td>17</td>
<td>Brent D</td>
<td>3</td>
<td>DPQ</td>
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<td>142</td>
<td>1976</td>
<td>14</td>
<td>301</td>
<td>1.1 (no longer in use)</td>
<td>5</td>
<td>Yes</td>
<td>Sand, 110k te in closed cells</td>
<td>Production ceased Dec 2011. Decommissioning preparation ongoing</td>
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<tr>
<td>18</td>
<td>MCP01</td>
<td>M/C</td>
<td>Total</td>
<td></td>
<td>94</td>
<td>1976</td>
<td>16</td>
<td>374</td>
<td>No storage</td>
<td>n/a</td>
<td>No</td>
<td>Sand; 220k te</td>
<td>Derogation Granted in 2008</td>
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<tr>
<td>19</td>
<td>Dunlin A</td>
<td>4</td>
<td>DPQ</td>
<td>Fairfield Energy</td>
<td>151</td>
<td>1977</td>
<td>23</td>
<td>320</td>
<td>0.84</td>
<td>4</td>
<td>Yes</td>
<td>Granular; 91k te in closed cells</td>
<td>Study stage</td>
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<tr>
<td>20</td>
<td>Ninian Central</td>
<td>4</td>
<td>DPQ</td>
<td>Canadian Natural Resources</td>
<td>135</td>
<td>1978</td>
<td>28</td>
<td>345</td>
<td>1.0</td>
<td>3.5</td>
<td>Yes</td>
<td>-</td>
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<td>21</td>
<td>Cormorant A</td>
<td>4</td>
<td>DPQ</td>
<td>TAQA</td>
<td>150</td>
<td>1978</td>
<td>21</td>
<td>341</td>
<td>1.0</td>
<td>3</td>
<td>Yes</td>
<td>-</td>
<td></td>
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<tr>
<td>22</td>
<td>Brent C</td>
<td>4</td>
<td>DPQ</td>
<td>Shell UK Exploration and Production</td>
<td>141</td>
<td>1978</td>
<td>18</td>
<td>288</td>
<td>0.6 (no longer in use)</td>
<td>3</td>
<td>Yes</td>
<td>-</td>
<td>Study stage</td>
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<tr>
<td>23</td>
<td>Ravenspurn North</td>
<td>3</td>
<td>PQ</td>
<td>BP</td>
<td>43</td>
<td>1989</td>
<td>9</td>
<td>46</td>
<td>No storage</td>
<td>2</td>
<td>No</td>
<td>Olivine; 5k te in open cells</td>
<td></td>
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<tr>
<td>24</td>
<td>Harding</td>
<td>Submerged caisson</td>
<td>DPQ</td>
<td>109</td>
<td>1995</td>
<td>23</td>
<td>120</td>
<td>0.57</td>
<td>2.3</td>
<td>No</td>
<td>No</td>
<td>Granite; 15k te in open cells</td>
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Existing CGBSs in Denmark and Netherlands

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<th></th>
<th>Platform</th>
<th>Number of shafts</th>
<th>Function</th>
<th>Operator</th>
<th>Water Depth</th>
<th>Installation Date</th>
<th>Topsides Weight at installation thousand te</th>
<th>Sub-structure weight incl. ballast thousand te</th>
<th>Oil storage million bbl</th>
<th>Length of skirts m</th>
<th>Under-base grouting</th>
<th>Solid ballast</th>
<th>Decommissioning Status</th>
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<tbody>
<tr>
<td>25</td>
<td>South Arne</td>
<td>2</td>
<td>DP</td>
<td>Amerada Hess Denmark</td>
<td>60</td>
<td>1999</td>
<td>7</td>
<td>153</td>
<td>0.55</td>
<td>3</td>
<td>No</td>
<td>Iron ore; 51k te in open cells</td>
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<tr>
<td>26</td>
<td>F/3</td>
<td>3 (one steel leg)</td>
<td>DPQ</td>
<td>NAM Netherlands</td>
<td>43</td>
<td>1992</td>
<td>6</td>
<td>91</td>
<td>0.19</td>
<td>0.3</td>
<td>No</td>
<td>Iron ore; 35k te</td>
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<tr>
<td>27</td>
<td>Halfweg</td>
<td>Submerged caisson</td>
<td>W</td>
<td>Unocal Netherlands</td>
<td>25</td>
<td>1995</td>
<td>Jack-up 0.75</td>
<td>3.0</td>
<td>No storage</td>
<td>1</td>
<td>Yes</td>
<td>-</td>
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</tr>
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</table>

Type of Platform

D Drilling
LNG LNG receiving terminal
P Production/processing
Q Quarters

Main references used

(note: some references provide contradictory information, therefore information presented should be considered indicative only)
3. Operators websites and publications
4. Offshore Technology Conference papers
### CGBs outside OSPAR region

Existing CGBs outside the OSPAR area

<table>
<thead>
<tr>
<th>Platform, Country</th>
<th>Number of shafts</th>
<th>Function</th>
<th>Operator</th>
<th>Water Depth m</th>
<th>Installation Date</th>
<th>Toppsheds Weight at installation thousand te</th>
<th>Sub-structure weight incl. ballast thousand te</th>
<th>Oil storage million bbl</th>
<th>Length of skirts m</th>
<th>Under-base grouting</th>
<th>Solid ballast</th>
<th>Decommissioning Status</th>
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<tbody>
<tr>
<td>Ubarana Pub 3 Brazil</td>
<td>28</td>
<td>Caisson</td>
<td>DPQ</td>
<td>Petrobras</td>
<td>15</td>
<td>1977</td>
<td>Not known</td>
<td>36</td>
<td>0.145</td>
<td>Not known</td>
<td>No</td>
<td>Sand</td>
</tr>
<tr>
<td>Ubarana Pub 2, Brazil</td>
<td>29</td>
<td>Caisson</td>
<td>DPQ</td>
<td>Petrobras</td>
<td>15</td>
<td>1978</td>
<td>Not known</td>
<td>36</td>
<td>0.145</td>
<td>Not known</td>
<td>No</td>
<td>Sand</td>
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<td>Ubarana Pag 2, Brazil</td>
<td>30</td>
<td>Caisson</td>
<td>DPQ</td>
<td>Petrobras</td>
<td>15</td>
<td>1978</td>
<td>Not known</td>
<td>36</td>
<td>0.145</td>
<td>Not known</td>
<td>No</td>
<td>Sand</td>
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<td>Schwedeneck See A Germany</td>
<td>31</td>
<td>DP</td>
<td>RWE-DEA Germany</td>
<td>25</td>
<td>1984</td>
<td>1</td>
<td>15</td>
<td>2</td>
<td>No storage</td>
<td>Yes</td>
<td>Concrete; 5k te in closed cells</td>
<td>Structure removed 2002</td>
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<td>Schwedeneck-See B Germany</td>
<td>32</td>
<td>DP</td>
<td>RWE-DEA Germany</td>
<td>16</td>
<td>1984</td>
<td>1</td>
<td>12</td>
<td>2</td>
<td>No storage</td>
<td>Yes</td>
<td>Concrete; 4k te in closed cells</td>
<td>Structure removed 2002</td>
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<td>Boom B, Gippsland Basin. SE Australia</td>
<td>33</td>
<td>DPQ</td>
<td>ExxonMobil Australia</td>
<td>61</td>
<td>1996</td>
<td>2</td>
<td>42</td>
<td>n/a</td>
<td>1</td>
<td>Yes</td>
<td>Concrete; 10k te in closed cells</td>
<td></td>
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<tr>
<td>West Tuna, Gippsland Basin. SE Australia</td>
<td>34</td>
<td>DPQ</td>
<td>ExxonMobil Australia</td>
<td>61</td>
<td>1996</td>
<td>7</td>
<td>88</td>
<td>n/a</td>
<td>1</td>
<td>Yes</td>
<td>Concrete; 17k te in closed cells</td>
<td></td>
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<tr>
<td>Wandoor, Australia</td>
<td>35</td>
<td>PQ</td>
<td>ExxonMobil Australia</td>
<td>54</td>
<td>1997</td>
<td>7</td>
<td>112</td>
<td>0.4</td>
<td>0.3</td>
<td>No</td>
<td>Iron ore; 39k te in open cells</td>
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<tr>
<td>Hibernia, Offshore Newfoundland</td>
<td>36</td>
<td>DPQ</td>
<td>ExxonMobil Canada</td>
<td>80</td>
<td>1997</td>
<td>39</td>
<td>1210</td>
<td>1.3</td>
<td>1.8</td>
<td>Yes</td>
<td>Grecrete; 720k te in closed cells</td>
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<tr>
<td>Malampaya, Philippines</td>
<td>37</td>
<td>PQ</td>
<td>Shell Philippines Exploration BV</td>
<td>43</td>
<td>2000</td>
<td>10</td>
<td>172</td>
<td>0.39</td>
<td>0.3</td>
<td>No</td>
<td>Iron ore; 76k te in open cells</td>
<td></td>
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<tr>
<td>Orlan Platform, Sakhalin I, Russia</td>
<td>38</td>
<td>Caisson</td>
<td>DPQ</td>
<td>Exxon Neftegas</td>
<td>14</td>
<td>2005</td>
<td>12</td>
<td>59</td>
<td>1</td>
<td>Not known</td>
<td>Not known</td>
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<tr>
<td>Lunskoye A, Sakhalin II, Russia</td>
<td>39</td>
<td>DPQ</td>
<td>Sakhalin Energy Investment Company</td>
<td>48</td>
<td>2005</td>
<td>22</td>
<td>103</td>
<td>2</td>
<td>No</td>
<td>None</td>
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<tr>
<td>Piltun Astokhskoye PA-B, Sakhalin II, Russia</td>
<td>40</td>
<td>DPQ</td>
<td>Sakhalin Energy Investment Company</td>
<td>32</td>
<td>2005</td>
<td>28</td>
<td>90</td>
<td>n/a</td>
<td>No</td>
<td>Iron ore; 69k te in closed cells</td>
<td></td>
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<tr>
<td>Adriatic LNG, offshore of Porto Levante, Italy</td>
<td>41</td>
<td>Caisson</td>
<td>LNG</td>
<td>Termini GNL Adriatico, Srl</td>
<td>29</td>
<td>2008</td>
<td>15</td>
<td>550</td>
<td>250,000 m3 LNG</td>
<td>1</td>
<td>No</td>
<td>Sand; 250k te under tank compartment and in perimeter cells</td>
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</table>
Planned CGBSs outside the OSPAR maritime area

<table>
<thead>
<tr>
<th>Field</th>
<th>Number of shafts</th>
<th>Function</th>
<th>Operator</th>
<th>Water Depth m</th>
<th>Installation Date</th>
<th>Topside Weight at installation thousand t</th>
<th>Sub-structure weight incl. ballast thousand t</th>
<th>Oil storage million bbl</th>
<th>Length of skirts m</th>
<th>Under-base grouting</th>
<th>Solid ballast</th>
<th>Decommissioning Status</th>
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<tr>
<td>42</td>
<td>1</td>
<td>DPQ</td>
<td>Exxon Mobil Canada</td>
<td>95</td>
<td>Construction phase</td>
<td>42</td>
<td>782</td>
<td>1.45</td>
<td>0.7</td>
<td>No</td>
<td>Oregrout; 105,300m³</td>
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<tr>
<td>43</td>
<td>4</td>
<td>DPQ</td>
<td>Exxon Nefgas</td>
<td>34</td>
<td>Construction phase</td>
<td>28</td>
<td>156</td>
<td>No storage</td>
<td>1.5</td>
<td>No</td>
<td>Not known</td>
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<td>44</td>
<td>Not known</td>
<td>DPQ</td>
<td>Husky Energy</td>
<td>Not known</td>
<td>FEED phase</td>
<td>Not known</td>
<td>Not known</td>
<td>Not known</td>
<td>Not known</td>
<td>Not known</td>
<td>Not known</td>
<td></td>
</tr>
</tbody>
</table>

Type of Platform
D  Drilling
LNG  LNG receiving terminal
P  Production/processing
Q  Quarters

Main references used
(note: some references provide contradictory information, therefore information presented should be considered indicative only)
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4. Offshore Technology Conference papers
Appendix 2: Table of base types

Concrete Sub-Structures

Type 1: Surface-Piercing Base Caisson
1 Ekofisk Tank
13 Frigg CDP1
18 MCP01
20 Ninian Central
28 Ubarana Pub 3
29 Ubarana Pub 2
30 Ubrana Pag 2
33 Bream B
34 West Tuna
36 Hibernia
38 Chayvo Orlan
41 Adriatic LNG

Type 2: Base Caisson supporting concrete columns
2 Frigg TCP2
3 Stratfjord A
4 Stratfjord B
5 Stratfjord C
6 Gullfaks A
7 Gullfaks B
8 Osberg A
9 Gullfaks C
10 Sleipner A
11 Draugen
12 Troll
14 Brent B
15 Beryl A
16 FriggTP1
17 Brent D
19 Dunlin A
21 Coromorant A
22 Brent C
23 North Ravenspurn
25 South Arne
26 F/3
31 Schwedeneck-See
32 Schwedeneck-See
35 Wandoo
37 Malampaya
39 Lonskoye-A
40 Piltun Astokhske PA-B
42 Hebron
43 Arkutun-Dagi
44 White Rose

Type 3: Base Caisson supporting jack-up deck
24 Harding
27 Halfweg
13 References and other relevant sources of information

References

Ref 1 http://www.ospar.org/documents/dbase/decrecs/decisions/od98-03e.doc
Ref 4 http://www.hse.gov.uk/statistics/fatals.htm
Ref 6 http://www.olf.no/en/Publica/Environmental-reports/Study-of-the-environmental-impact/
Ref 7 http://www.ospar.org/documents/dbase/publications/p00451_overview%20implementation%20cutting%20piles%20rec%202006-5.pdf
Ref 8 http://www.uk.total.com/pdf/our_activities/ExplorationProduction/SF/OSPAR_report.pdf
Ref 12 http://www.uk.total.com/pdf/our_activities/ExplorationProduction/SF/mcp01_statutory_consultation_060329.pdf

Other relevant sources of information

14 Relevant Studies

Another important source of knowledge has been obtained through a number of generic studies. The Olsen study looks at re-floatation and onshore deconstruction of specific concrete installations. The Atkins study looks at different disposal options such as leave wholly in place, partial removal and other options and includes safety, environmental and technical issues related to the different options.

For further information and publications, please visit our website at

www.ogp.org.uk