International Association of Oil & Gas Producers

REPORT 484

FEBRUARY 2018

Decommissioning of Offshore Concrete Gravity Based Structures (CGBS) in the OSPAR Maritime Area / Other Global Regions

Acknowledgements

Decommissioning Committee

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Revision history

VERSION	DATE	AMENDMENTS
2.0	February 2018	Minor amends throughout
1.0	November 2012	First release

Contents

1. Summary

This update of the 2012 report reflects the increased knowledge base on decommissioning options for concrete gravity-based structures (CGBS) up to the end of 2017. Since the previous publication, there have been further studies into CGBS decommissioning options, primarily undertaken by the Brent Decommissioning project. In 2017, public consultation took place within the UK concerning a proposal from the owners of the Brent field to leave three CGBS's in place. The UK government is anticipated to further consult with OSPAR Contracting Parties regarding this proposal in 2018. Before 2012, the owners of the Frigg and Ekofisk CGBSs had been granted derogation from the full removal requirement within OSPAR 98/3 and these structures have been left wholly in place.

While CGBS designs fall into three main categories, each is unique with its design modified to suit the particular function and environmental conditions. The structures can weigh up to 1.2 million tonnes, stand in open water up to 300 metres deep and span 50 metres wide at sea surface level. The work required to re-float 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 a primary consideration in the original design of many of the early platforms and factors such as loss of buoyancy, corrosion of ballast system piping and sediment build-up introduce technical uncertainties to re-floating 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 re-float to coincide with a favourable weather window for stabilization and towing. Any unintended loss of buoyancy is likely to present significant safety, environmental and cost implications.

To date, only two small (15,000 tonnes) concrete base platforms in shallow and sheltered estuary waters have been successfully re-floated. Studies into the decommissioning options for the 300,000+-tonne Statfjord, Brent and Dunlin CGBSs have been progressed significantly since the last revision of this report.

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 exceed €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 wider society of relinquishing that tax revenue especially if a more complex decommissioning option is pursued.

Independent studies have consistently 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 be considered individually, 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.

Definition of terms used in the report

Caisson: a watertight concrete structure that rests 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 Decision 98/3 decommissioning requirement for full removal

Freeboard: the proportion of a floating structure above the waterline

Operator: the company which owns and manages the CGBS installation

OSPAR: The 1992 (Oslo-Paris) Convention for the Protection of the Marine Environment in the North-East Atlantic (www.ospar.org)

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

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. The main factors which led to the development of the CGBS were as follows:

- Many of the early North Sea fields were capable of high production rates which required very large processing facilities
- CGBSs were capable of supporting the very high topside weight that large processing facilities entailed - the largest topsides 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, the CGBS structures could store large volumes of oil offshore until it could be transferred to tankers using loading buoys for transport to shore. The largest storage capacity of any CGBS is 2 million barrels (approx. 300 million litres)

Throughout their life cycle, CGBSs have proved to be a very successful design option for 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 and many CGBSs installed in the 1970s remain in operation. The South Arne platform was installed in the Danish sector of the North Sea in 1999; this was the last CGBS installed in the OSPAR region.

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 heavy reinforced concrete structure which is placed on the seabed. It can withstand extreme environmental forces by virtue of its own weight and inherent strength.

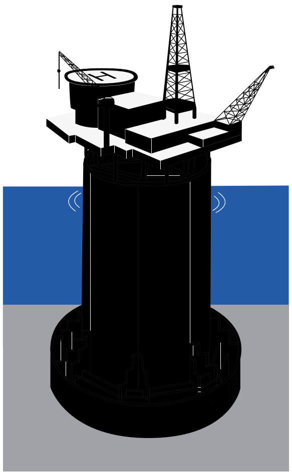
CGBS platforms are among the largest and most impressive man-made structures. The Troll platform is installed in the deepest water (303 m) and the Hibernia platform is the heaviest weighing 1.2 million tonnes on land. The designs of CGBSs vary considerably and their weights range from 3,000 to 1.2 million 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:

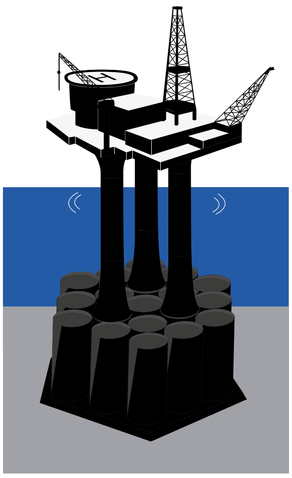
- concrete base with a single caisson extending above sea level (surface piercing)
- concrete base with one or more concrete shafts extending above sea level
- concrete base supporting steel legs and topside facilities

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.



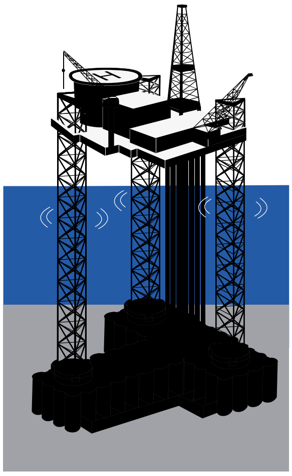
Base caisson extending above sea level (surface piercing caisson)

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



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 relatively 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 is further detailed in Appendix 2.

Stability of the CGBS on the seabed is enabled 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) that 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 remains floating.
- **Dry build** – the entire concrete sub-structure (base and shafts) is constructed in the dry dock. This method has been used for CGBS designs for water depths up to around 100 m.

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 suitable docks and facilities is an important factor when selecting the preferred decommissioning option (see section 5).

2.3 Installation of CGBS

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

During installation the cells within the CGBS base are progressively flooded with sea water to cause it to sink to the seabed. Successful re-float would reverse this process whereby water would be displaced with air, or an inert gas mixture, to re-create buoyancy. The cells would need to be completely watertight at pressures sufficient to displace the seawater content. However, the original ballast systems were not designed to be used after installation, so the mechanical pipework and fittings were commonly constructed from carbon steel which is susceptible to corrosion after prolonged immersion in seawater. This corrosion, along with other penetrations into the cells such as well conductors which were driven after installation, will compromise the potential to re-float 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 twenty-seven CGBSs in the OSPAR Maritime area have under-base grouting to ensure even contact pressure between the concrete base and the seabed, preventing “high spot” stress concentrations.

The variations in the installation technique of the CGBS have a significant bearing on the options available for its removal (see sections 5 and 6).

Figure 2.3: The tow-out of the Troll A CGBS – two thirds of the structure is underwater *(Photo: Norsk fly og flyfoto).*

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 when 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 not required maintenance and regular inspections have confirmed continued integrity and allowed the original design life to be extended. Many CGBSs have undergone facility modifications with the addition of new process modules and pipeline risers (adding weight) without any adverse impact on structural integrity.

Rock cuttings produced during the well drilling operations have been discharged overboard under disposal permit. These can surround portions of the CGBS base and lie several metres deep on the top of the storage cells and in some cases within the drilling shafts. Some of these cuttings are coated 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 oil and 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 can accumulate as sediment 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 would require careful evaluation if a re-float 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 London Convention 1972 and the 1996 protocol to the London Convention or conventions and other instruments agreed by 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.

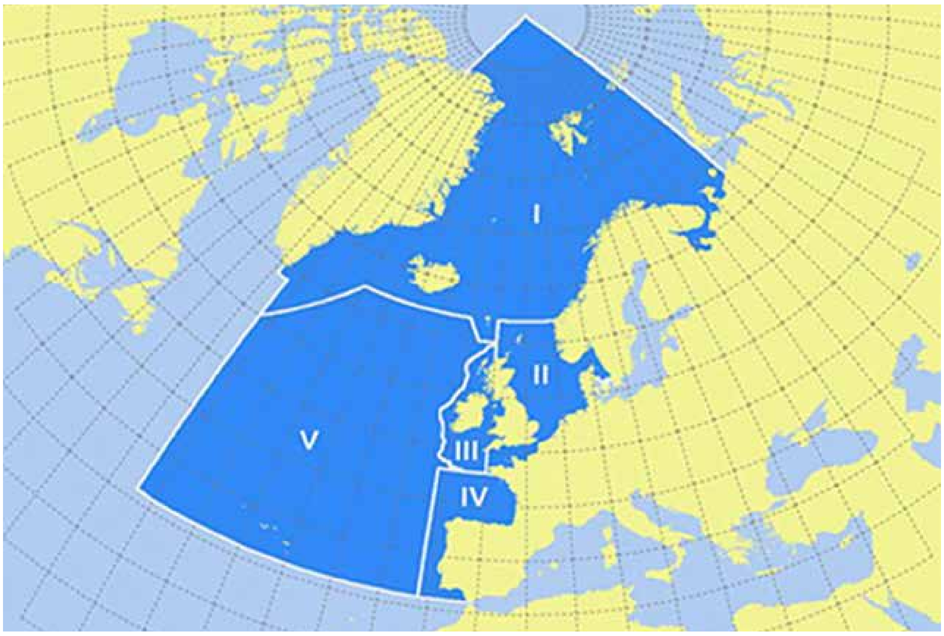


Figure 3.1: The extent of the OSPAR region which broadly covers the NE Atlantic and includes the North Sea.

Work under the Convention is managed by the OSPAR Commission (www.ospar.org) which comprises government representatives from the 15 Contracting Parties plus the European Commission. OSPAR produces decisions, recommendations and other agreements relating to marine operations including the decommissioning of oil and gas installations.

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 a national government) may, after consultation with international signatories, 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 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) is primarily concerned with safety at sea and safe maritime navigation and has set worldwide standards and 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 100 m 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 55 m 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 are members of IMO and therefore the '55-m criterion' may vary in different parts of the world.

3.3 National guidance

United Kingdom – The Department for Business, Energy and Industrial Strategy (BEIS) 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 BEIS states: *'As with other installations, the topsides of concrete installations must be returned to shore for re-use, recycling or disposal'.*

BEIS 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 subscribe 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 helped to address conflicting aspects for the benefit of industry, stakeholders and the Regulatory Authorities.

4. CGBS Population

More than 40 CGBSs have been installed worldwide with one further scheduled to be installed by 2022 offshore Canada. 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.

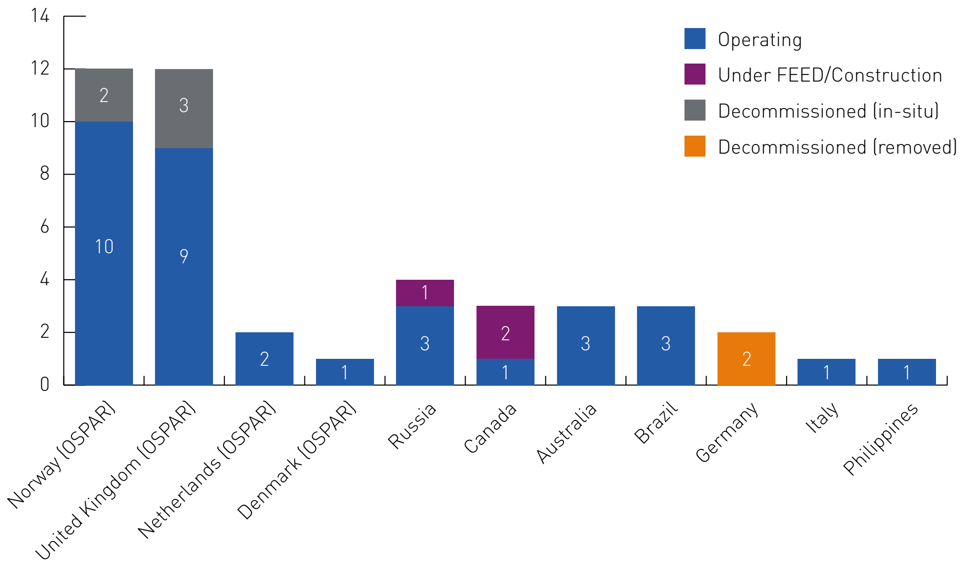


Figure 4: Population of CGBSs denoting those in OSPAR area.

Note Germany is an OSPAR signatory but its platforms were in the Baltic and thus outside the OSPAR area.

4.1 CGBS locations outside the OSPAR Maritime Area

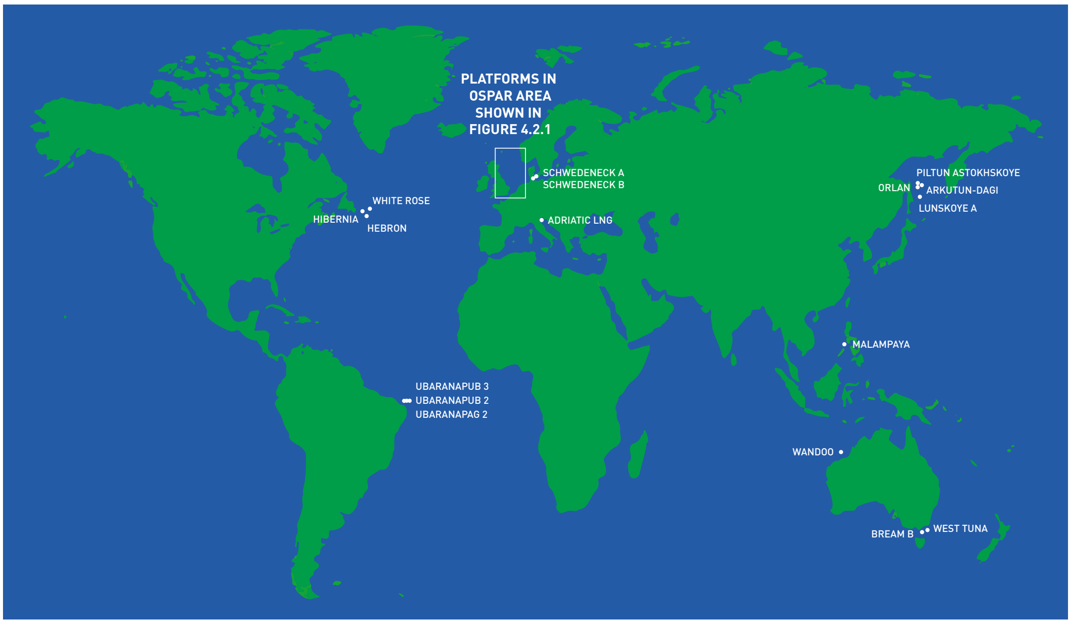


Figure 4.1: Locations of CGBSs outside the OSPAR area.

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 often utilised in remote regions subject to extreme weather, wave or ice conditions, where existing infrastructure is limited.

4.2 CGBSs installed within the OSPAR Maritime Area

27 CGBSs have been installed in the OSPAR Maritime Area, including the structures decommissioned to date.

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

The UK sector has 12 CGBSs in water depths between 43 m and 151 m. All were installed in the 1970s with the exception of the Harding platform which was installed in 1995.

Figure 4.2.1: Locations of CGBS installations within and adjacent to the OSPAR area.

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

Of the 27 CGBSs located in the OSPAR region, 17 were designed with oil storage capability, although this capability was not used in some cases as regional pipeline infrastructure expanded.

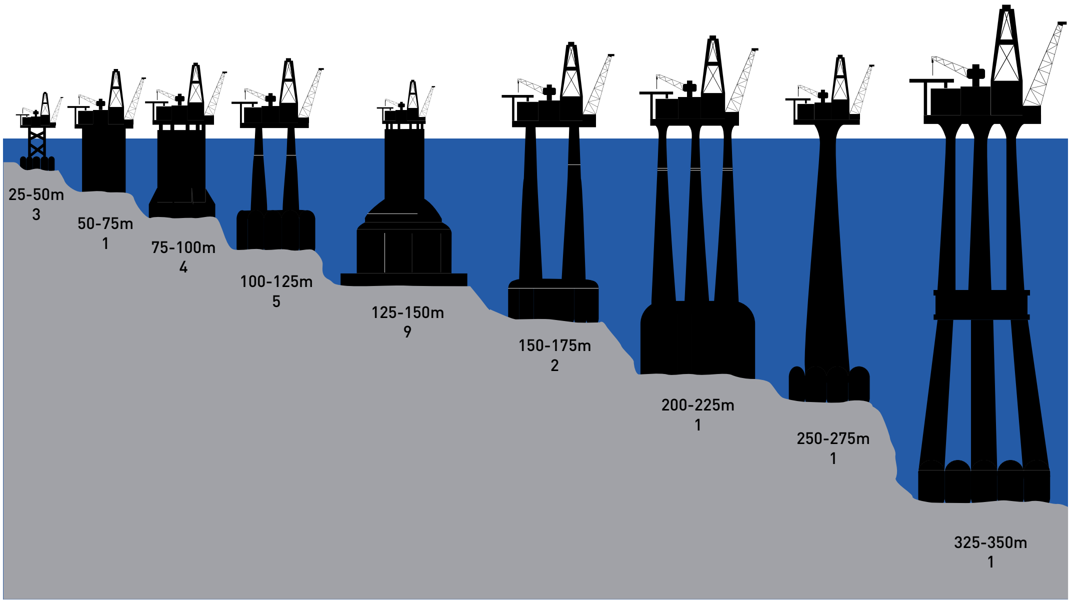


Figure 4.2.2: The type, number and water depths of CGBSs within the OSPAR Maritime Area.

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 the following generic decommissioning options, having regard to the design and working conditions of specific CGBS structures.

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 safe navigational purposes

Leave wholly in place

- With topside removed and with suitable navigational aids installed

Operators should investigate the viability of each of the above 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 BEIS does not allow disposal at sea.

ASSESSMENT CRITERIA	Matters to be considered	DECOMMISSIONING OPTIONS											
		Complete removal to land			Partial removal to land			Leave wholly in place			Disposal at sea		
Safety	risk to personnel												
	risk to other users of the sea												
	risk to those on land												
Environmental	marine impacts												
	other environmental compartments (including emissions to the atmosphere)												
	energy/resource consumption												
	other environmental consequences (including cumulative effects)												
Technical	risk of major project failure												
Societal	fisheries impacts												
	amenities												
	communities												
Economic													
	HIGH	MEDIUM						LOW					

Over the last 10-15 years extensive engineering studies have been undertaken by operators in an effort to understand and reduce 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 (not involving moving the structure) would be for a non-hydrocarbon venture. This option assumes the design life of the CGBS could be extended and topside replaced or 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 CBGSs and include:

- Energy related: carbon dioxide sequestration hubs, centres for wind or wave power generation and electrical power distribution hubs
- 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 and logistics 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 legal and commercial issues to enable transfer of liabilities to a new user
- The requirement for structures to operate far beyond the original design life
- Structural integrity, maintenance and logistics 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 re-float

Full removal options using a re-float 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 re-float have to be analysed and if a re-float is feasible, the costs estimated for the purposes of OSPAR's comparative assessment.

Re-floating a CGBS is dependent on seven critical and interdependent parameters:

- Continued structural integrity
- Accurate determination of structural weight and centre of gravity
- Restoration of water-tightness and buoyancy control during re-float, 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 re-floating a CGBS could be attempted.

Primary Technical Risks and Consequences

Structural Integrity

- 'In place" structural and watertight integrity cannot be guaranteed for re-float purposes although the CGBS will remain fit for purpose as a topside support
- Some re-float operations could impose load conditions not considered in the original design

Weight

- The weight of a CGBS will have altered during installation and throughout its working life: 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, grounding or even total loss of the CGBS
- 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. Such an operation is likely to be interrupted by periods of adverse weather

Towing

- Towing a re-floated 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 proven integrity and could reliably control any inclination of the structure (or the trim) and the draught of the floating CGBS. As these systems were not required to remain functional during the working life of the structures the pipework was constructed from carbon steel which is susceptible to corrosion in seawater. The location limits the ability to inspect the system, but condition is almost certain to be degraded such that it will not have the necessary level of integrity that could be relied upon during decommissioning.

The process of re-floating 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 re-float a CGBS.

Weight

The weight of a CGBS has to be calculated accurately in order to re-float 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. The Brent Delta CGBS was surveyed in 2014 prior and was estimated to contain around 17,000m^3 of sediment. Determining the exact quantity and density required for re-float would be highly challenging; the volume of sediment will vary from cell to cell depending on the production arrangement and would influence the trim of the structure in the event of a re-float.

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 re-float, 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 re-floating of the two small Schwedeneck-See platforms each weighing around 15,000 tonnes. However, to re-float 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 would be experienced due to currents and the action of wind and wave.

Jacking

Increasing buoyancy may be insufficient to free the structure from the seabed. 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 can be undertaken during periods of favourable 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 behaviour 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 limitations.

Towing, offshore disposal/inshore dismantling and onshore disposal

Whilst there have been significant advances in the industry capability to lift and transport very large structures in recent years, notably the commissioning of Allseas *Pioneering Spirit*, even this largest "single-lift" vessel is not capable of lifting and transporting a large CGBS structure. *Pioneering Spirit's* maximum lifting capability is 48,000 metric tonnes which is intended to be capable of removing and transporting the largest topsides and steel jacket structures but the larger CGBS structures exceed this weight by a factor of ten. Re-float therefore remains the only potentially feasible concept for removal and transport.

Where re-floating 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 limited control of the timing of the CGBS's release from the seabed, the tow-in cannot be scheduled to avoid poor weather conditions.

To achieve a safe re-float the ballast control system would need to be sufficiently sophisticated to assist the re-float and to monitor and control the structure's trim continuously during the tow-in and throughout the deconstruction phase. Inshore deconstruction of such a large structure 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 re-commissioned before deconstruction work could be completed.

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

5.4 Complete removal by offshore demolition

Where re-floating 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 span several years as operations would be limited to acceptable weather and sea state operating thresholds.

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 as it may not be practical to remove all these items due to access/egress constraints and safety issues.

Studies and tests undertaken by the Brent Decommissioning project indicated that, whilst concrete cutting under high compressive loads was possible at small scale (1.2 metres x 1.6 metres) and in onshore conditions, extensive further development and testing will be required to develop reliable technologies capable of cutting legs up to 20 metres in diameter and 70 metres high in challenging marine environments. 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 enable diverless technology to be considered for these decommissioning options.

Figure 5.4: CGBS Leg Cutting Trial (Diamond Wire Cutting (DWC) 1.2m x 1.6m test block under 500 tonnes compressive force *(Photo Credit Shell)*.

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 issues allowing the structures to be left wholly or partly in place.

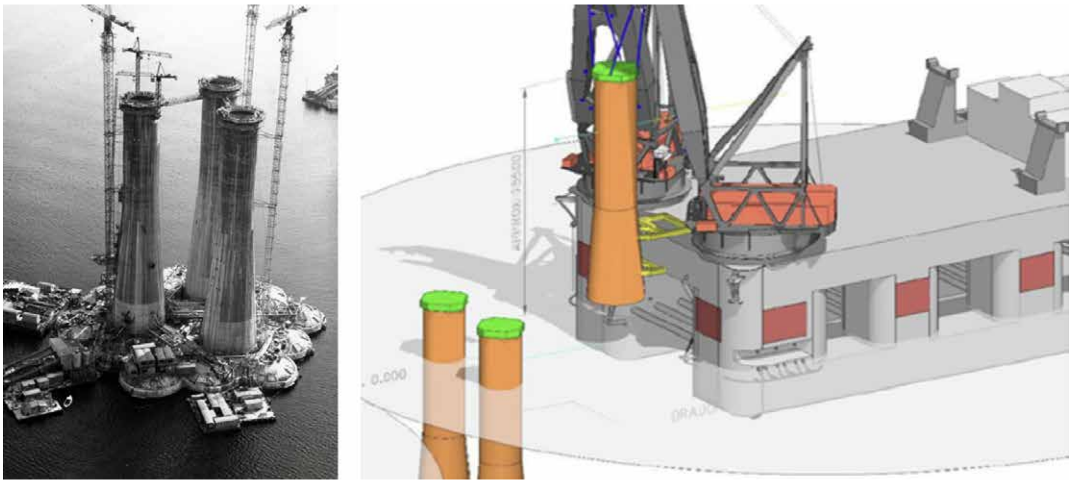


Figure 5.5: CGBS legs during construction & concept of semisubmersible crane vessel removing a 20 metre diameter x 70 metre high x 6000 metric tonne concrete leg *(Photos: Shell).*

Partial deconstruction of CGBS refers to removing the shafts. This could enable operators to meet the IMO's requirement for 55m of clear water above the structure. The removed material could be either placed on the seabed or transported onshore for recycling. Placement on the seabed, by toppling or lowering, could result in an underwater obstacle creating a potential hazard to navigation and fishing activity. This would requiring effective measures to minimise risk such as marking the site on marine maps. Given the size of the primary structure, the additional hazard from placing the shafts on the seabed in the vicinity of the CGBS base would be small.

Removal of CGBS shafts and transport to shore using a large crane vessel may be potentially feasible but the ability to overcome the significant engineering and execution challenges of cutting and removing such large and slender structures (typically weighing around 10,000 tonnes and 70 metres high), remains unproven. Such an undertaking would require the largest marine vessels to operate for extended durations. The environmental footprint of such an undertaking would be significant; for each CGBS leg transported to shore, around 1000 tonnes of marine fuel would be consumed. Concrete recovered to shore could be processed as aggregate but this would also be energy intensive. The recovered material would be contaminated with salt and would be of limited suitability for re-use in construction applications.

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

Figure 5.6: The remains of a decommissioned CGBS in the Frigg field *(Photo: Saipem).*

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 and in the databases upon which modern electronic ship navigation warning systems increasingly depend. 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, long-term 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 potential 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 eliminate or manage 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.

Figure 6: Brent Delta during removal of its 23,500 tonne topsides from the GBS by Allseas "Pioneering Spirit" single lift vessel

Each decommissioning option poses safety challenges especially for 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 MCP-01 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 53% (Ref 12) but if the structure was left wholly in place with its topside removed, the chance of a fatality was less than

1%. Re-float was 11.1%, this being far higher than acceptable industry norms for complex marine undertakings. Such operation were estimated to present an aggregate 112% probability of a worker fatality, this being around 30-40 times that of the recommended leave in place option.

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 re-floating 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 diver-less 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 re-float 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 MCP-01, 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 gear.

For CGBSs that remain in place with the topsides removed, 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 minimises the need to place 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 is minimal as the protruding structure itself presents a visible obstruction and a warning to fishing boats sailing close by. Over the very long term, however (expected to be hundreds of years), the shafts of the CGBS will start to break down near to and below the sea surface. This could then create a hazard to ship traffic and fisheries in the future and will require alternative methods of marking to be deployed.

In its proposal for the three Brent GBS structures to be left wholly in place, Shell described the results of studies that it had commissioned in support of its proposals. These had concluded the probability of fatalities arising from fishing vessel collision with any one of the GBS's was in the range 2.2 - 4.7 every ten thousand years. The frequency of an incident causing more than ten fatalities, such as a large passenger vessel collision, was estimated at 1.1 million years. These risks are far below the risks to workers that might be involved in any removal operation and lower than the probability of collision with existing and foreseeable marine traffic. Further, it is likely that ship navigation technology will continue to advance such that further reduction in the probability of marine collision will materialise.

7. Environmental Impact

Introduction

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 platform *(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 Re-use

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

7.2 Re-float for onshore disposal

Re-float 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 2011, the Norwegian Climate and Pollution Agency (Klif) published the results of a study it had commissioned 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 Re-float for deep-water disposal

If the re-float of a CGBS is considered feasible, towing it to a deep-water site for disposal by sinking might be a more environmentally favourable option than removal 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 consideration of the option of seeking derogation for deep-water disposal, it should be noted that UK government policy has strongly discouraged the deep-water disposal of UK installations.

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 largest 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, this option would result in the highest fuel consumption and therefore result in the highest level of CO_2 emissions. Large dynamically-positioned marine construction vessels of the type required to operate in harsh environments typically consume 30-60m³ of marine fuel per day. The fuel consumed during a two hundred day deployment would compare to that consumed by more than 10,000 passenger cars in a year.

7.5 Partial removal/partly leave in place

A CGBS partly left in place would have its shafts removed below the surface to provide a free navigation depth of 55m (in accordance with IMO Guidelines and Standards). 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

The Norwegian Climate and Pollution Agency report 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 re-floating 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 rock fragments from the geological formations extracted when drilling a well.

Some drill cuttings may be contaminated with hydrocarbons because of the type of drilling fluid used when the well was drilled. The muds (a combination of a drilling fluid and other additives, referred to as a drilling mud) are pumped into the wellbore to provide cooling, stabilise the hole and flush the cuttings out of the well. Before 1990, oil-based and synthetic-based muds were routinely used while now more environmentally friendly water-based muds predominate. The cuttings were normally washed to recover the free fluids prior to discharge to sea. Such discharges resulted in large accumulations on the seabed around many offshore installations. In 1999, this practice was largely stopped for all but those cuttings lubricated with water-based muds. Cuttings coated with oil and/or synthetic drilling fluids were either re-injected into the well, brought onshore for secure disposal or, exceptionally, discharged under permit.

Management options for the legacy 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 environmentally 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 re-float operation. Where removal of the CGBS is considered, the controlled re-location of some cuttings will be required.

7.8 Content of storage cells

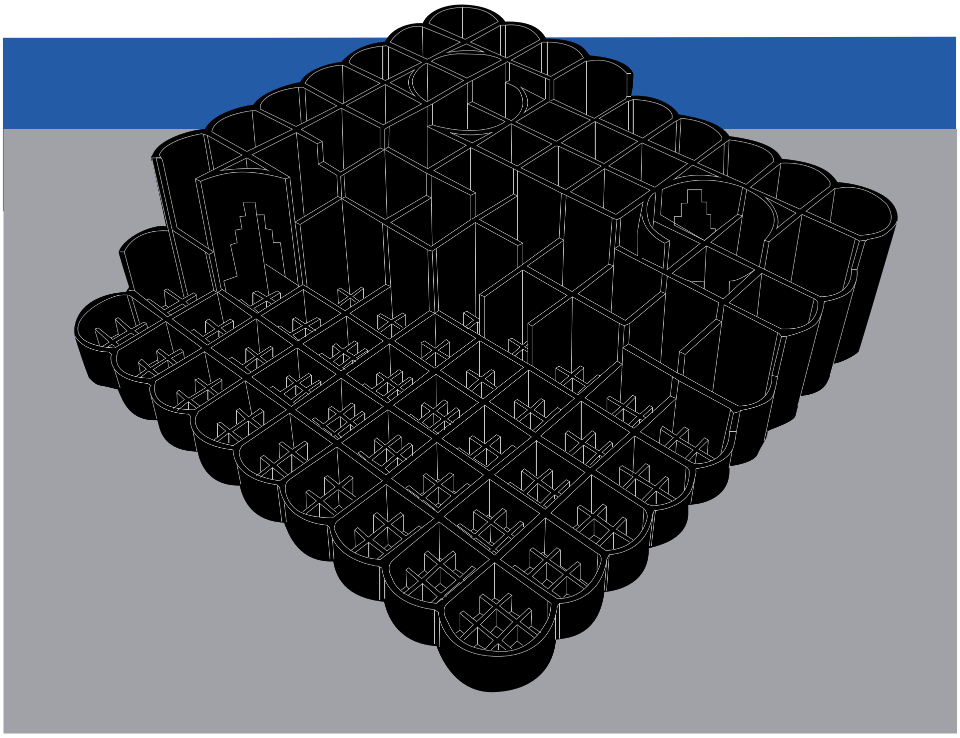


Figure 7.8: A cut-away section illustration of the layout of storage cells within a CGBS base *(Image: Fairfield Energy).*

Oil storage within CGBS cells

Of the 27 CGBS structures deployed within the OSPAR maritime area, 15 were provided with oil storage capability.

The residual 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 and these vary in size and shape from 11m square by 30m high to 18m in diameter by 60m in height. The cells provide total oil storage capacities ranging from 500,000 to 2 million barrels.

The cells within a CGBS that has been used for oil export direct from topsides to pipeline or gas production are normally flooded with water. Those within platforms used for oil production were often utilised for oil storage. At cessation of production cells might contain an accumulation of sediments, waxes and hydrodynamically-trapped pockets of oil known as "attic oil". Some oil might be deposited as wax on the surface of the cells and may 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.

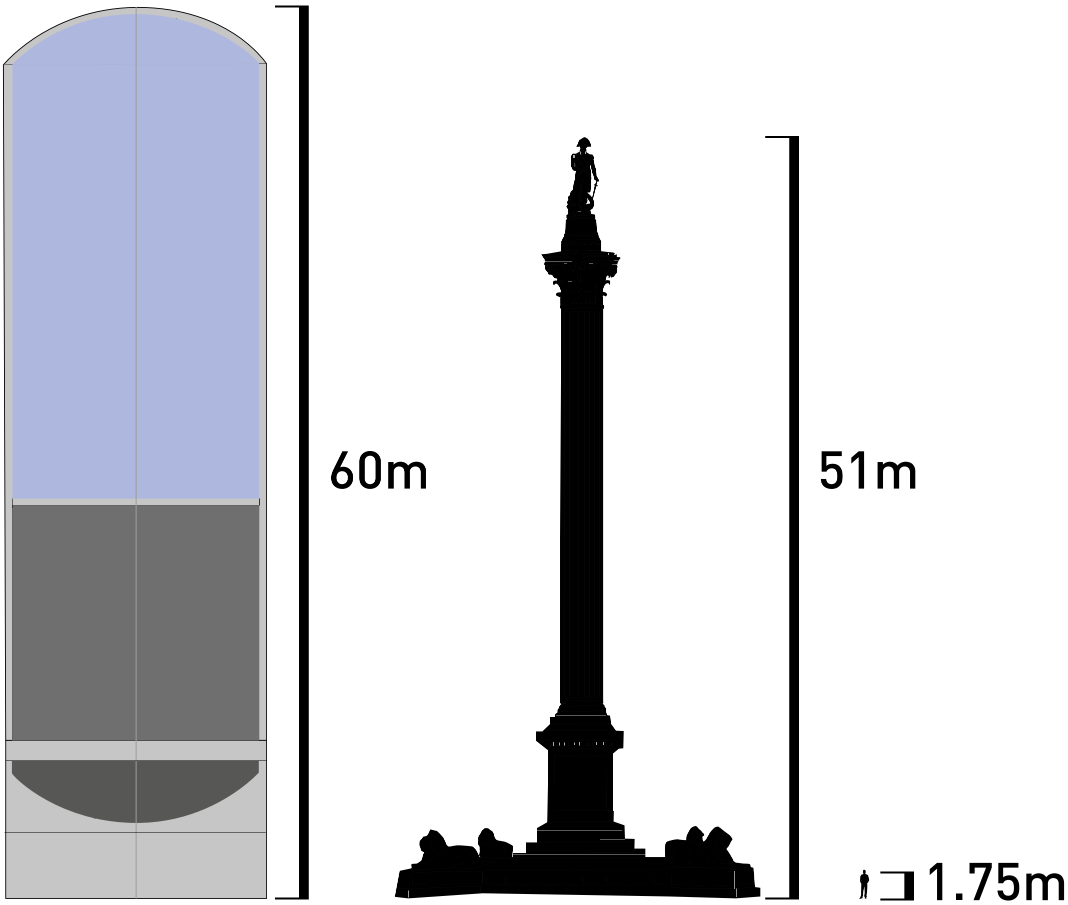


Figure 7.8.1: Comparative illustration of the size of storage cells within a CGBS.

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.

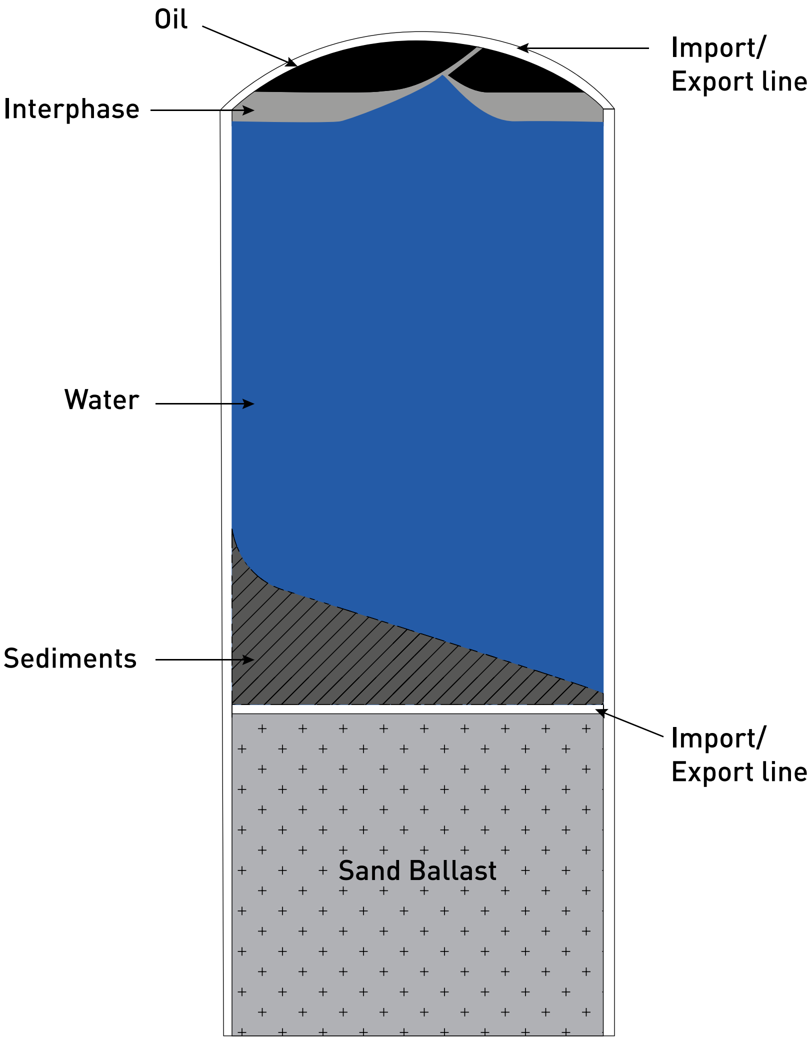


Figure 7.8.2: A cross section illustration of the contents of a typical storage cell within a CGBS

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 broadly-determined from the chemical composition of the produced fluids and samples obtained from accessible parts of the production system.

Analysis of the "Dunlin Alpha" CGBS 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.

During development of its proposals for decommissioning the Brent GBS structures Shell commissioned development of specialist equipment that was capable of drilling through the 1-metre thick reinforced concrete structures and deploying a range of survey and sampling equipment into the 60-metre high cells. Three cells were surveyed on Brent Delta, indicating sediment to be present at around 4 metres depth, equating to around 17,000m³ of sediment contained within the structure. These sediments were found to contain a mixture of approximately 50% water, 25% oil and 25% sand.

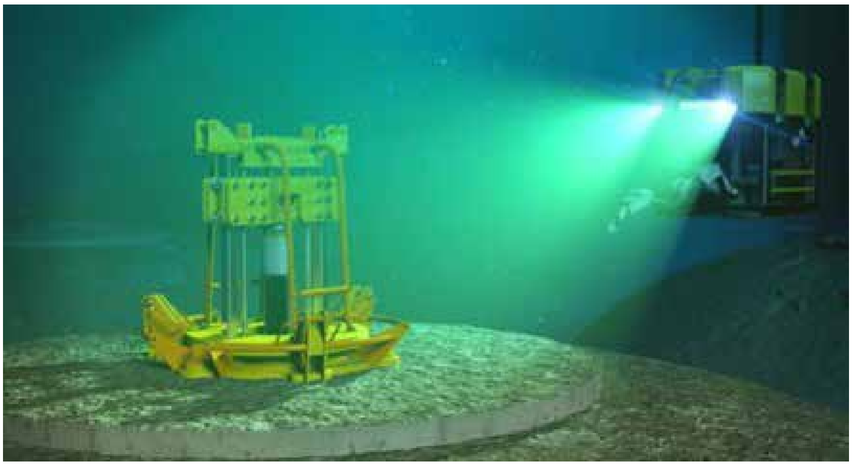


Figure 7.8.3: ROV operated equipment located on the top of GBS cell to drill and deploy survey equipment *(Photo: Enpro Subsea Ltd).*

Whilst limited survey of GBS storage systems has been undertaken to date, it is expected that this may represent the highest such accumulations since the Brent field was known to produce untypically high volumes of sand fines during producing operations.

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 residual 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 develop an effective and efficient means 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 if large volumes of sediment are involved.

Leaving the cell contents in place may be permitted if the sediment is unlikely to result in unacceptable impact to the environment. Sediments left within a CGBS would be subjected to an initial phase of long term containment, as the concrete structures are expected to remain largely intact for hundreds of years. After several hundreds of years, long-term degradation of the structure is likely to result in debris falling into the sediment accumulation. Disturbance will cause dispersion and slow leaching into the marine environment a rate that would permit natural bio-degradation. Studies undertaken by the Brent Decommissioning Project described a small to moderate negative local impact that would be unlikely to have any effect on benthic fauna at a regional level.

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 re-float analyses as part of the front-end design in an effort to facilitate an eventual removal. There remain considerable challenges, however, to re-floating 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 disproportionate 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 decision-making process of the relevant competent authorities (see section 4.2).

Over the last 17 years, 7 concrete structures have been decommissioned, 5 in the North Sea which followed the "OSPAR process" and 2 in the Baltic Sea. Details of the specific decommissioning projects and a brief description of the project outcomes are provided below:

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

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.

Figure 8.2: TCP2 being prepared for removal of the module support frame by a heavy lift vessel *(Photo: Total).*

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 re-float, including risk to neighbouring 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 situ* 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.

8.4 Brent Field – UK North Sea

The Brent field contains three concrete gravity base structures. Shell has completed public consultation within the UK. Proposals to derogate from the OSPAR 98/3 full removal requirement are anticipated to be subject to international consultation during 2018.

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. Reinforced concrete in the splash zone will however, 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. The combination of low energy LED lighting, improving battery storage and renewable energy power systems (solar) has enabled significant advancement in the efficacy of such systems in recent years.

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.

Installation-specific environmental monitoring programmes will be developed, consulted on, and agreed with the relevant host government at the time of decommissioning. The owners commitment to implement such monitoring will be a condition of its approval of the Decommissioning Programme.

Studies of the manner or long-term CGBS degradation suggest that, due to the inherent integrity of the design, little change in the gross integrity will be evident in the decades following decommissioning. After consultation and in agreement with host governments, sufficient monitoring will be conducted to ensure that hazards presented by long-term degradation to other users of the sea are adequately mitigated.

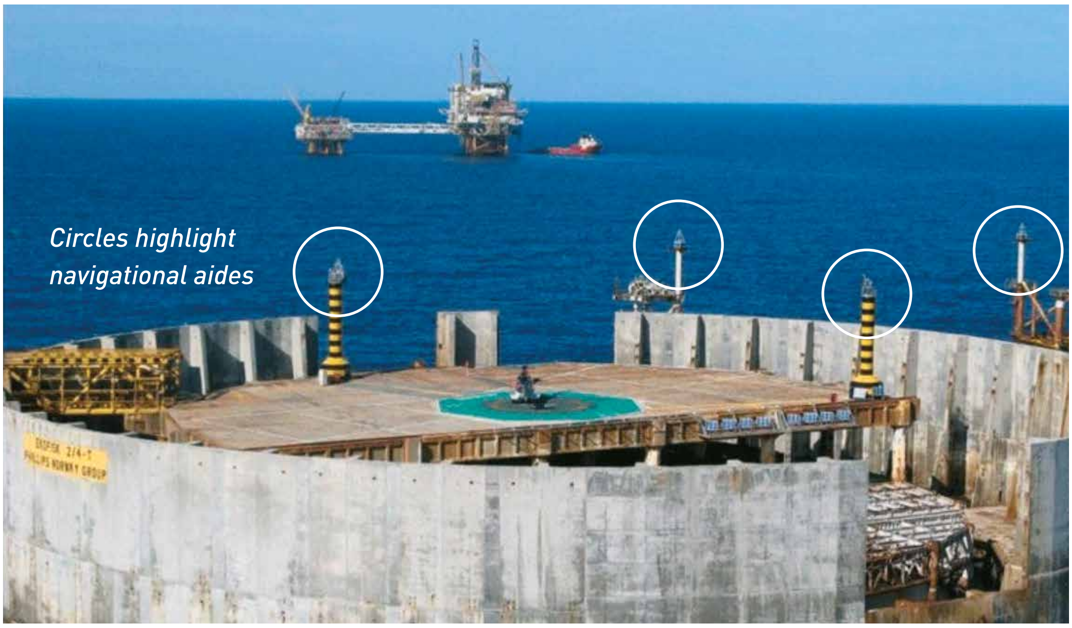


Figure 9.1: Long service interval navigational aids on the decommissioned Ekofisk Tank
(Photo: ComPower/ConocoPhillips)

9.2 Legacy management

Where required by the legislative regime, operators accept responsibility for decommissioned facilities in perpetuity. The continued existence of corporate entities however, 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/.

10. Costs

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, decommissioning costs will vary and will have to be estimated on an individual basis near to the time of execution. 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 intended to represent order of magnitude estimates only.

National fiscal frameworks, upon which large and long-term field development investment commitments are made, typically allow expenditure incurred during development, operation and decommissioning of oil and gas infrastructure to be offset against tax on revenue. The cost of decommissioning will therefore 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.

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 most significant 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.

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 MCP-01 (Ref 8) by leaving the CGBS wholly in place with the topside removed was reported as €119 million (2004 prices).

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).

In its comparative assessments supporting its proposals for the Brent Decommissioning programme, Shell indicated that partial removal (removal of CGBS legs to 55 metres below sea level) on the Brent Bravo GBS would cost €95 million. Removal of comparatively more slender legs on Brent Charlie was estimated to cost €53 million. This was based on a series of technical studies that formed the basis for estimates that were compiled according to standard industry cost estimating guidance. This compares to around €0.5 million to leave the structures in place with permanent navigation aids. If the remaining 22 CGBSs in the OSPAR area entailed similar complexity, then the total cost of partial removal would likely exceed €1 billion in the OSPAR region.

Partial removal (removal or the CGBS legs) typically entails recovery of less than 5% of the CGBS weight from the part of the structure that is most accessible for cutting and to lifting vessels. If the technical challenges that prevent full re-float and tow that have been described in this report cannot be overcome, and full removal and return to shore by demolition in place is therefore required, then it is reasonable to conclude that cost of such operations would exceed €1 billion per structure, or more than €20 billion in the OSPAR region.

11. 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 gathering a broad selection of concerns and opinions of all interested parties proactively 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 has been a widely adopted strategy while developing proposals. Dialogue does not mean that all stakeholders will agree with recommended outcome. It is. however, 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.

12. Appendix

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 1: Table of CGBSs installed in the OSPAR area and outside the OSPAR area.

CGBSs in OSPAR region

Existing CGBSs in Norwegian Sector

	Platform	Number of shafts	Function	Operator	Water Depth m	Installation Date	Topsides Weight at installation thousand te	Sub-structure weight incl. ballast thousand te	Oil storage million bbl	Length of skirts m	Under-base grouting	Solid ballast	Decommissioning Status
1	Ekofisk Tank	Caisson	P/Q	Phillips Petroleum Norway	72	1973	4	215	1.0	0.4	No	Sand; 20k te in closed cells	Derogation granted 2001
	Protective Barrier		–			1989	–	897	–			Gravel; 621k te in closed cells	
2	Frigg TCP2	3	P/C	Elf Petroleum Norge	103	1977	14	230	No storage	3	Yes	Olivine; 70k te in closed cells	Derogation granted 2003
3	Statfjord A	3	DPQ	Statoil	145	1977	20	316	1.2	3	Yes	Sand; 85k te in closed cells	Study stage
4	Statfjord B	4	DPQ	Statoil	145	1981	40	532	1.9	4	Yes	Olivine; 150k te in open cells	
5	Statfjord C	4	DPQ	Statoil	145	1984	40	588	1.9	3.8	Yes	Iron ore; 231k te in closed cells	
6	Gullfaks A	4	DPQ	Statoil	135	1986	42	561	1.95	3.4	Yes	Iron ore; 216k te in closed cells	
7	Gullfaks B	3	DPQ	Statoil	142	1987	28	447	No storage	1.3	Yes	Gravel; 187k te in closed cells	
8	Oseberg A	4	PQ	Norske Hydro	109	1988	38	575	No storage	1.4	Yes	Iron ore; in closed cells	
9	Gullfaks C	4	DPQ	Statoil	217	1989	50	830	2.0	22	Yes	Iron ore; 185k te in closed cells	
10	Sleipner A	4	DPQ	Statoil	82	1992	37	463	No storage	1	Yes	Olivine; 240k te in closed cells	
11	Draugen	1	DPQ	Norske Shell	251	1993	21	232	1.4	9	Yes	Olivine; 3k te in closed cells	
12	Troll A	4	DPQ	Statoil	303	1995	23	683	No storage	36	Yes	–	

Existing CGBSs in UK Sector

	Platform	Number of shafts	Function	Operator	Water Depth m	Installation Date	Topsides Weight at installation thousand te	Sub-structure weight incl. ballast thousand te	Oil storage million bbl	Length of skirts m	Under-base grouting	Solid ballast	Decommissioning Status
13	Frigg CDPI	Caisson	D/P	Elf Petroleum Niorge	96	1975	11	416	No storage	n/a	No	Sand, gravel and concrete; 269k te	De-commissioned 1990. Derogation granted in 2003
14	Brent B	3	DPQ	Shell UK Exploration and Production	139	1975	10	331	1.1 (no longer in use)	4	Yes	Sand; 142k te in closed cells	Subject to consultation
15	Beryl A	3	DPQ	Apache North Sea	117	1975	14	251	0.9	3.5	Yes	Sand; 123k te in closed cells	
16	Frigg TPI	2	P	Elf Petroleum Norge	103	1976	8	162	no storage	2	Yes	Concrete; 35k te in closed cells	Derogation granted in 2003
17	Brent D	3	DPQ	Shell UK Exploration and Production	142	1976	14	301	1.1 (no longer in use)	5	Yes	Sand; 110k te in closed cells	Topsides removed. Subject to consultation
18	MCP01	Caisson	M/C	Total	94	1976	16	374	No storage	n/a		Sand; 220k te	Derogation Granted in 2008
19	Dunlin A	4	DPQ	Fairfield Energy	151	1977	23	320	0.84	4	Yes	Granular; 91k te in closed cells	Production Ceased. Proposals being developed.
20	Ninian Central	Caisson	DPQ	Canadian Natural Resources	135	1978	28	345	1.0	3.5	Yes	-	
21	Cormorant A	4	DPQ	TAQA	150	1978	21	341	1.0	3	Yes	-	
22	Brent C	4	DPQ	Shell UK Exploration and Production	141	1978	18	288	0.6 (no longer in use)	3	Yes	-	Subject to consultation
23	Ravenspurn North	3	PQ	BP	43	1989	9	46	No storage	2	No	Olivine; 5k te in open cells	
24	Harding	Submerged caisson	DPQ	BP	109	1995	23	120	0.57	2.3	No	Granite; 15k te in open cells	

Existing CGBSs in Denmark and Netherlands

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

Type of Platform

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

Main references used

(note: some references provide contradictory information, therefore information presented should be considered indicative only)

1. Gordon Jackson, et al., 2001 Survey of Gravity Based Offshore Structures, Arup Energy, London 2001
2. Oilfield Publications Ltd., The North Sea Development Guide, 1998
3. Operators websites and publications
4. Offshore Technology Conference papers

CGBSs outside OSPAR region

Existing CGBSs outside the OSPAR Area

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

Existing CGBSs outside the OSPAR Area *(continued)*

	Platform / Country	Number of shafts	Function	Operator	Water Depth m	Installation Date	Topsides Weight at installation thousand te	Sub-structure weight incl. ballast thousand te	Oil storage million bbl	Length of skirts m	Under-base grouting	Solid ballast	Decommissioning Status
42	Hebron, Offshore Newfoundland	1	DPQ	Exxon Mobil Canada	95	Production	42	782	1.45	0.7	No	Oregrout; 105,300m^3	
43	Arkutun-Dagi, Berkut, Coast of Sakhalin Island, Russia	4	DPQ	Exxon Neftgas	34	Production	28	156	No storage	1.5	No	Not known	

Planned CGBSs outside the OSPAR Maritime Area

	Field	Number of shafts	Function	Operator	Water Depth m	Installation Date	Topsides Weight at installation thousand te	Sub-structure weight incl. ballast thousand te	Oil storage million bbl	Length of skirts m	Under-base grouting	Solid ballast	Decommissioning Status
44	White Rose, Offshore Newfoundland	Not known	DQ	Husky Energy	Not known	2021	Not known	Not known	n/a	Not known	Not known	Not known	

Type of Platform

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

Main references used

(note: some references provide contradictory information, therefore information presented should be considered indicative only)

1. Gordon Jackson, et al., 2001 Survey of Gravity Based Offshore Structures, Arup Energy, London 2001
2. Oilfield Publications Ltd., The North Sea Development Guide, 1998
3. Operators websites and publications
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 Ubarana 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 Frigg TP1
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 Lunskoye-A
40 Piltun Astokhskoye PA-B
42 Hebron
43 Arkutun-Dagi
44 White Rose

Type 3: Base Ciasson supporting jack-up deck

24 Harding
27 Halfweg

13. References and Other Relevant Sources of Information

References

Note: The references listed in Report 484 (2012) are cited by hyperlinks to web site locations that are largely no longer accessible by those links. The texts to which the citations refer are still, however available. We are therefore giving a brief description of the reference here along with a higher level URL. Readers are directed to use an appropriate search engine to locate the web site of the relevant company, government department, organisation, or project. If the material cannot be found, the reader is encouraged to contact IOGP.

Ref 1: OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations (see www.ospar.org)

Ref 2: UK Department for Business, Energy and Industrial Strategy guidance on decommissioning of offshore installations and pipelines (see www.gov.uk)

Ref 3: Norwegian Petroleum Directorate report on the disposal of concrete gravity-based structures (see www.npd.no)

Ref 4: Dunlin field decommissioning programme (www.fairfieldenergy.com)

Ref 5: Dunlin field decommissioning report on cell contents (www.fairfieldenergy.com)

Ref 6: Norwegian Climate and Pollution agency (KLIF) report "Study of the environmental impact of disposing of concrete installations.

Ref 7: OSPAR (OSPAR Recommendation 2006/5 on a management regime for offshore cuttings piles (see www.ospar.org)

Ref 8: Cost estimates for installation decommissioning (see www.total.com)

Ref 9: UK Department for Energy and Climate Change (now BEIS) report on decommissioning costs (see www.gov.uk)

Ref 10: Norwegian Petroleum Directorate report on disposal of concrete installations (www.npd.no)

Ref 11: UK Department for Energy and Climate Change report on Total's Frigg field decommissioning (see www.gov.uk)

Ref 12: Report from Total on safety risks associated with the Frigg field decommissioning programme (see www.uk.total.com)

Ref 13: Report from Shell on Brent filed decommissioning studies (see www.shell.com)

Other relevant sources of information

- http://www.npd.no/en/Publications/Facts/Facts-2010/Chapter-7/
- http://www.npd.no/en/news/News/2012/Disposal-of-concrete-facilities/
- http://www.fairfield-energy.com/pages/view/dunlin-stakeholder-engagement

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.

1) Dr Tech. Olav Olsen; *Removal of Offshore Concrete Structures*, rev. 4, Oslo 2001.

2) WS Atkins; *Joint Industry Project: UKCS Decommissioning Study*, report No. 4017-ER; Aberdeen 2002.

3) International Association of Oil and Gas Producers; *Disposal of disused offshore concrete gravity platforms in the OSPAR Maritime Area*. Report No. 338, February 2003.

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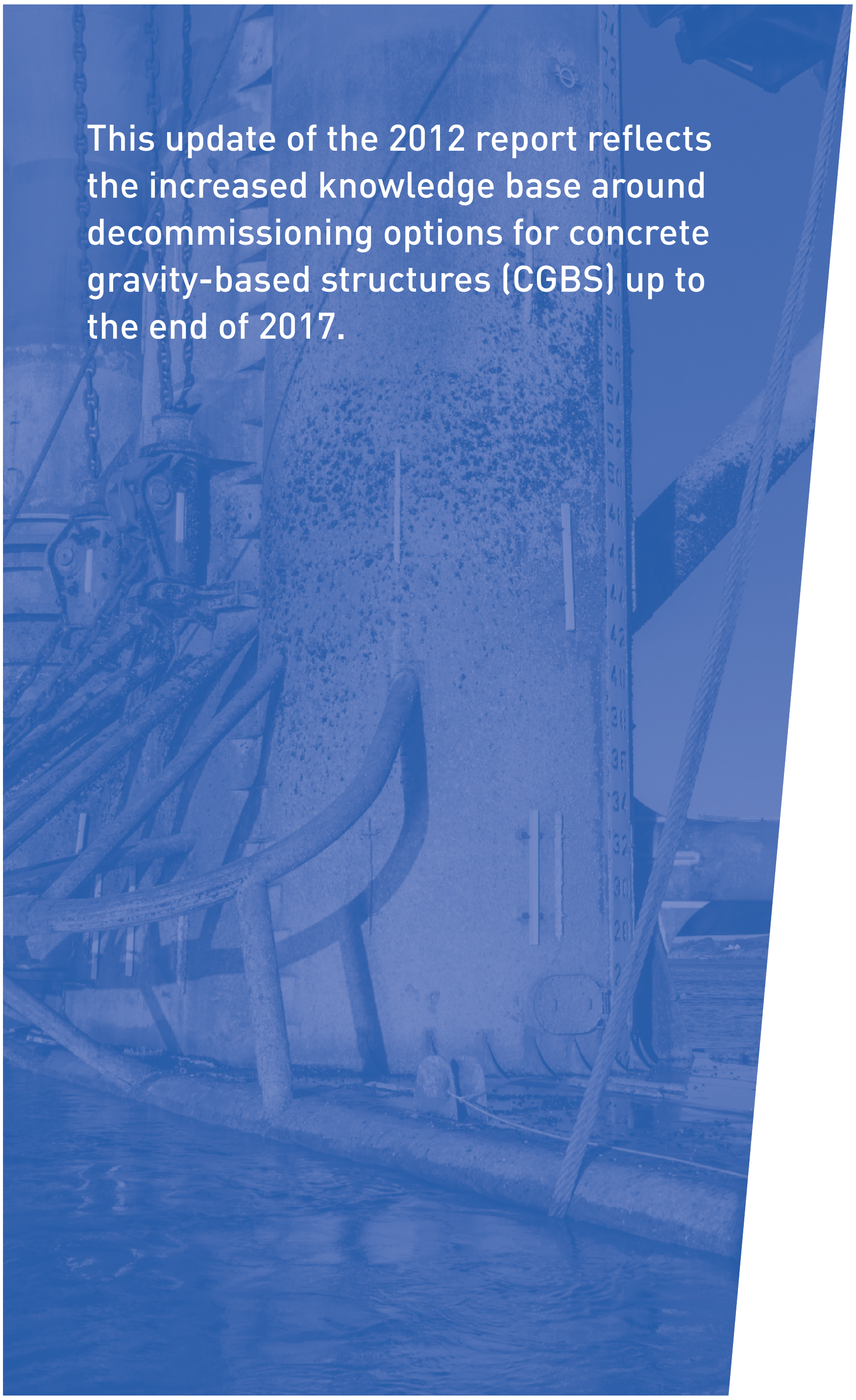

This update of the 2012 report reflects the increased knowledge base around decommissioning options for concrete gravity-based structures (CGBS) up to the end of 2017.