Knarr Gas Pipeline Decommissioning Comparative Assessment

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2.1 Abbreviations

BEIS	UK Department of Business, Energy & Industrial Strategy
CA	Comparative Assessment
DP	Decommissioning Program
FLAGS	Far North Liquids and Associated Gas System
FPSO	Floating production, storage and offloading vessel
GRP	Glass fibre reinforced protection
IA	Impact Assessment
KGP	Knarr Gas Pipeline
LPP	Layer polypropylene
NCS	Norwegian Continental Shelf
NPD	Norwegian Petroleum Directorate
NSTA	North Sea Transition Authority
OGA	Oil Gas Authority
OPPC	Oil Pollution Prevention and Control
OPRED	Offshore Petroleum Regulator for Environment and Decommissioning
OSPAR	Oslo and Paris Convention
PLEM	Pipeline end manifold
PLET	Pipeline end template
SSIV	Subsea Isolation Valve
ToP	Top of pipe
UKCS	United Kingdom Continental Shelf

2.2 Executive Summary

The 12” Knarr Gas Pipeline (KGP) is operated by Gassco AS on behalf of the pipeline Joint Venture owners, and the pipeline passes through the Norwegian Continental Shelf to the UK Continental Shelf. Production from the Knarr Field started in 2015 and ceased in May 2022. The pipeline was then cleaned and made ready for decommissioning.

Following detailed engineering, the final project execution plan for the complete decommissioning of the KGP and associated facilities will occur in three phases. Phases 1 and 2 form the current decommissioning programme (DP) planned for completion in 2024-2026. Phase 3 will occur after cessation of production (CoP) of the FLAGS pipeline, currently anticipated to be in 25-30 years' time, and will be the subject of a future, separate DP.

Although this Comparative Assessment covers all three phases of decommissioning, all Phase 3 decommissioning options, the EA, and this CA will be completely re-assessed in line with UK and international regulations and guidance in place at the time of submission of the DP for Phase 3.

The three decommissioning phases are:

1. Following CoP of the Knarr Field. The KGP was isolated at the Knarr Tee and PLEM from downstream infrastructure, a pigging spread was installed at the Knarr PLEM, and the KGP was flushed and cleaned back to the Knarr FPSO. Phase 1 was performed from 1st - 18th of May 2022 from Knarr Field CoP to FPSO sail-away respectively. This phase was completed under the PWR submitted by Gassco AS on 29/04/2021.
2. A minor section of the spool #7 will physically be cut and disconnected from PLEM, retrieved, and transported to shore (Norway). This is scheduled to be completed before December 2026 and most likely during Q3/Q4 2024.
3. At FLAGS CoP: Pipe Spool #8 and all GRP covers would be removed at the same time as the PLEM. Due to the proximity of UKCS subsea infrastructure, the Knarr Tee and Knarr PLEM, to the operational FLAGS gas pipeline, the removal of these items will be undertaken when the FLAGS gas pipeline enters CoP. This will eliminate risks attendant with removal works near live, hydrocarbon containing infrastructure.

A first DP for the Knarr facilities in the UK sector covers phases 1 and 2. A second, separate DP will be submitted for Phase 3 once FLAGS has reached CoP, in addition to a re-assessment of this CA and the supporting EA. This Comparative Assessment report examines the full suite of decommissioning options considered.

This Comparative Assessment report:

- Describes the nature and current condition, in the UK sector, of the Knarr Gas Pipeline and associated infrastructure, such as PLEM, concrete mattresses, GRP covers and pipeline crossings.

- Discusses feasible decommissioning options.
- Considers and examines these decommissioning options to understand the safety, environmental, technical, economical, and societal risk associated with them.
- Examines the results, such that robust conclusions and recommendations can be made regarding the preferred decommissioning solutions.

This report concludes that leaving the Knarr Gas pipeline *in situ* under the existing rock cover is the preferred decommissioning option, as it is safer, cheaper, easier, and better for the environment.

The differences between the decommissioning options are much less clear-cut for the pipe Spools/GRP covers than for the Knarr Gas Pipeline. Owing to the proximity of live FLAGS pipelines to the Spools/GRP covers, if they were to be removed it would be safer to delay removal until after FLAGS is decommissioned. As such, this Comparative Assessment recommends that most of the decommissioning activity is delayed until the FLAGS gas pipeline is decommissioned; this will eliminate risks attendant with removal works near live, hydrocarbon containing infrastructure.

3 Introduction

The Knarr Gas Pipeline is being decommissioned. This comparative assessment report reviews the nature and current condition of the Knarr Gas Pipeline and associated infrastructure, and identifies feasible decommissioning options. This report then considers these decommissioning options to understand the safety, environmental, technical, economical and societal risk associated with them, such that robust conclusions and recommendations can be drawn.

Planning for decommissioning was initiated in 2018. The Comparative Assessments performed and described are based on a multi-discipline workshop held in 2019. Updates on activities taken place since 2019 and any associated changes are described to present the status of 2023.

All feasible decommissioning options were reviewed in 2023 and found to be valid.

Following detailed engineering, the final project execution plan for the complete decommissioning of the KGP and associated facilities will occur in three phases. Phases 1 and 2 form the current decommissioning programme (DP) planned for completion in 2024-2026. Phase 3 will occur after cessation of production (CoP) of the FLAGS pipeline, currently anticipated to be in 25-30 years' time, and will be the subject of a future, separate DP.

Although this Comparative Assessment covers all three phases of decommissioning, all Phase 3 decommissioning options, the EA, and this CA will be completely re-assessed in line with UK and international regulations and guidance in place at the time of submission of the DP for Phase 3.

3.1 Knarr Field Description

The Knarr Field is located in Block 34/3 of the Norwegian Continental Shelf (NCS) in the northern North Sea, 50 kilometres northeast of the Snorre field. The Knarr Field is approximately 93 km from the UK-Norway median line (Figure 1) at a water depth of approximately 410 m.

The Knarr Field comprises 2 subsea well templates (in water depth of approximately 410 m) connected to a floating production, storage and offloading vessel (FPSO), with shuttle tankers for oil export. Rich gas was exported from the Knarr FPSO in the Norwegian sector to the UK via the Knarr Gas Pipeline (KGP), which passes through NCS to enter UKCS, and connects to the Far North Liquids and Associated Gas System (FLAGS) pipeline. The KGP enters the UK sector at KP 94.1 and between KP 94.1-105.7 the pipeline is surface lain and completely rock covered, has no free spans, and is at a water depth of approximately 140 m. The KGP was installed in 2013, and field production started in 2015.

Cessation of production (CoP) on the Knarr field occurred on 1st of May 2022 and FPSO sail away was on 18th of May 2022.

Figure 1 The Knarr Field and Knarr Gas Export Pipeline

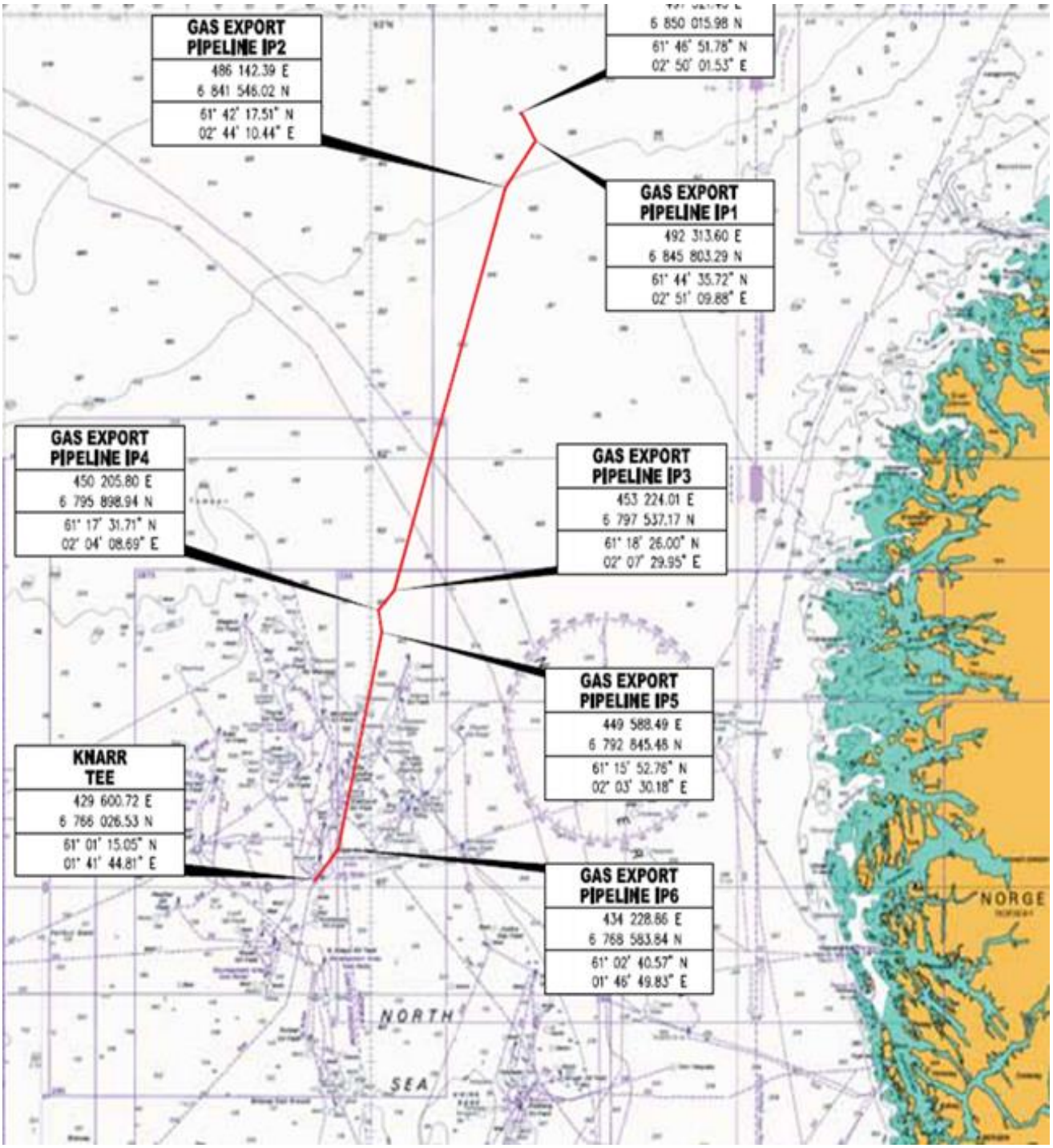

Figure 2 Coordinates of Knarr Gas Pipeline route from NCS to UKCS

The Knarr FPSO flexible riser was connected to a Subsea Isolation Valve (SSIV) inside the Knarr FPSO safety zone on the NCS (safety zone terminated after FPSO sail away). A rigid spool mated the SSIV structure with the main Pipeline End Termination (PLET). The main length of KGP route (approximately 105.7 km) consists of 12" rigid pipeline which connects (on UKCS) to the Knarr Pipeline End Manifold (PLEM) and Knarr Tee through a series of 12" rigid spools. The final tie-in from the Knarr Tee to FLAGS is through a single 16" rigid spool. 11.6 km of the KGP extends into the UKCS (Block 211/29 and 211/30).

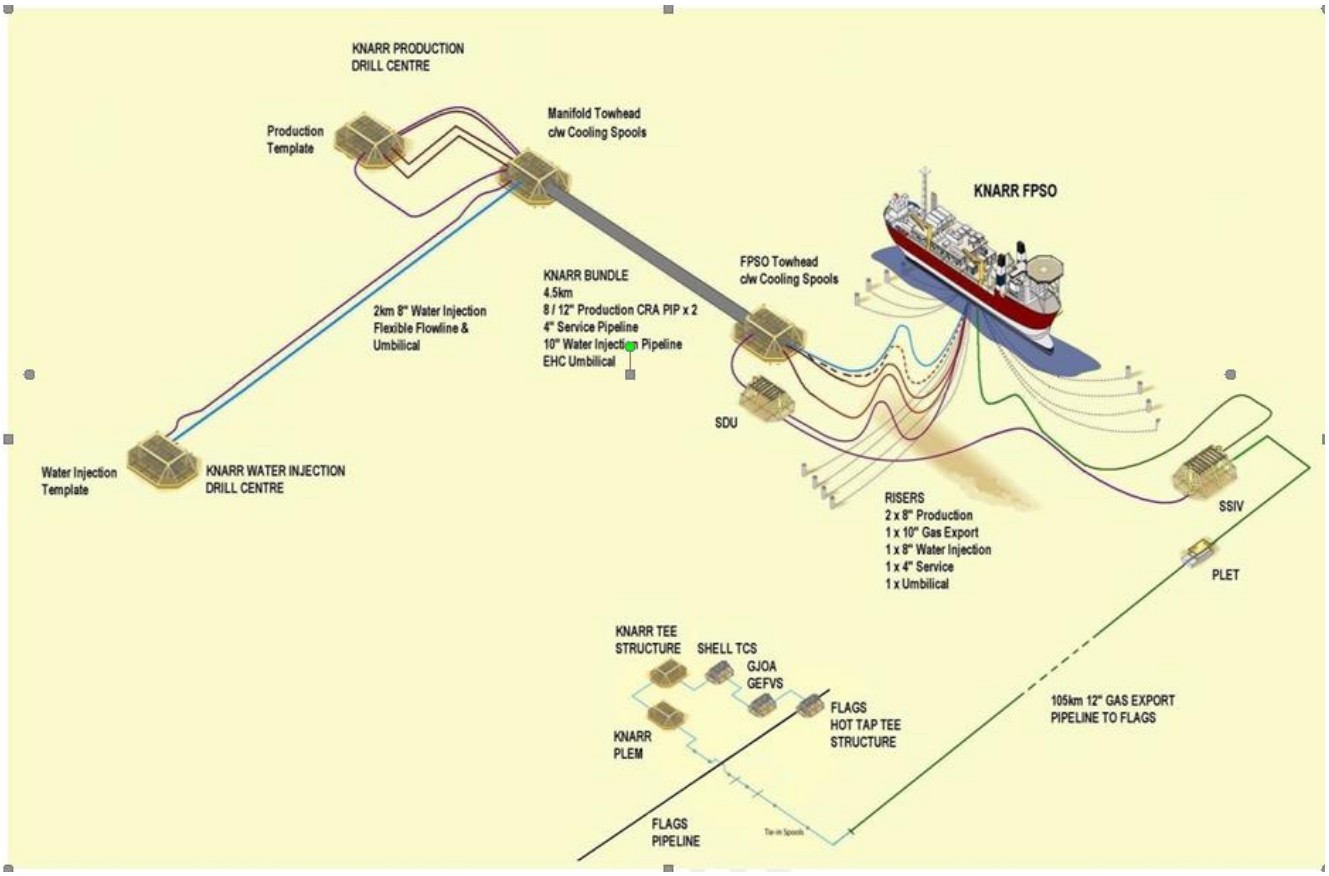

Figure 3 Knarr Field Layout

As illustrated in Figure 4, the Knarr Field was operated by A/S Norske Shell; the 12" KGP (PL3039) is operated by Gassco AS on behalf of the pipeline Joint Venture (JV) owners (A/S Norske Shell, INPEX Idemitsu Petroleum Norge AS, Wintershall DEA Norge AS). The KGP enters the UKCS to join the Knarr Tee structure before entering the FLAGS system, operated by Shell UK.

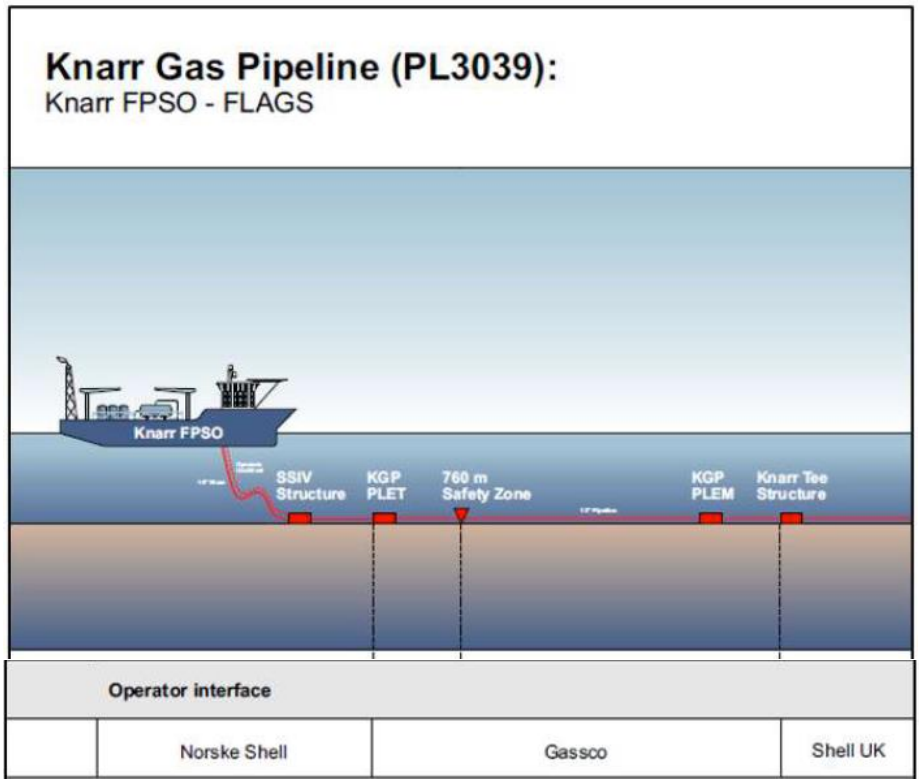

Figure 4 FPSO, Knarr Gas Pipeline and Operator Interface

3.2 Knarr Field Decommissioning Project

Production from the Knarr field started in 2015 and ceased in May 2022.

A notification from A/S Norske Shell as Knarr Field operator regarding initiation of a Knarr Decommissioning Plan was received by Gassco AS as KGP Operator in late December 2018. The Knarr FPSO was the only user of the KGP. Gassco AS initiated planning according to Norwegian Petroleum Act section 5-1 which states a decommissioning plan shall be submitted at the earliest of 5 years, but at the latest 2 years prior to the time when the use of a facility is expected to be terminated permanently.

Decommissioning Plans for the Knarr field and KGP were prepared, based on the requirements of the Oslo Paris (OSPAR) Convention and Norwegian Petroleum law, by A/S Norske Shell and Gassco AS respectively. As part of this, A/S Norske Shell and Gassco AS developed separate Impact Assessment (IA) reports and issued these for consultation. Developing these IAs took about one year and was completed before the decommissioning plans were submitted for approval to the Norwegian Ministry of Petroleum and Energy in early 2020. Norwegian authorities made a disposal decision for the Knarr field in February 2021 and for KGP in March 2022 (following dialogue with UK authorities).

As 11.6 km of the KGP infrastructure extends into the UKCS, additional requirements of the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) and North Sea Transition Authority (NSTA) also need to be addressed. This Comparative Assessment report comprises one component of the necessary documentation required by the UK regulator, the Department for Energy Security & Net Zero (DESNZ).

3.3 Knarr Gas Pipeline in brief

The KGP is 12" in diameter and 105.7 kilometers long, and passes through the NCS to enter UKCS, where it connects to the FLAGS pipeline. 11.6 km of the KGP is in the UKCS, all of which is laid on the seabed and is covered by rock. Approximately 30% of the KGP on the UK side passes through the Brent Field.

3.4 Regulatory Guidance on Pipeline decommissioning

Guidance on decommissioning pipelines and subsea structures falls under DESNZ in the UK. BEIS Guidance Notes on the Decommissioning of Offshore Oil and Gas Installations and Pipelines 2018 /1/ require a comparative assessment for all UK pipeline decommissioning programmes, while Section 10.19 states "Where rock-dump has previously been used to protect a pipeline it is recognised that removal of the pipeline is unlikely to be practicable and it is generally assumed that the rock-dump and the pipeline will remain in place".

The BEIS Guidance Notes state that stabilisation features, such as mattresses or grout bags, which have been installed to protect pipelines during their operational life should be removed, and if the operator considers this is not the optimal solution, they must provide evidence through a comparative assessment.

3.5 Purpose & Scope of Comparative Assessment

The purpose of this CA report is to support and enable decision-making for the KGP decommissioning programme. It does this by comparing alternative decommissioning options to identify the preferred option.

The Knarr Decommissioning project has infrastructure in both the Norway and UK sectors of the North Sea. The focus of this CA is the UK sector (the transition point of the KGP UK/Norwegian median line is Latitude 61°06'07.23" N, Longitude 01°51'09.21" E).

The scope of decommissioning in the UKCS includes:

- 11.6 km of the 12" KGP (of a total pipe length of 105.7 km).
- Knarr PLEM. Although Gassco AS will remove the PLEM, and hence it does not need to be considered within this CA, the timing of the PLEM removal is relevant and is considered.
- Pipeline crossings (4x) in UK sector.

- Concrete mattresses (22x) at 3 of the pipeline crossings in the UK sector.
- Pipeline Spools (x8) that are under rock dump or GRP covers.
- GRP covers.

Debris caused by Gassco AS within 50 metres either side of the KGP will be removed, and as such is not within the CA scope.

3.6 Report Structure

This report describes:

- The KGP and associated infrastructure that are planned for decommissioning, such as concrete mattresses, spools, PLEM and GRP covers.
- The decommissioning options considered.
- The CA methodology, workshop and results.

The report concludes by recommending the preferred decommissioning approach.

4 Knarr Gas Pipeline & Associated Facilities

This section provides the following:

- consideration of alternative use of KGP after decommissioning.
- a description of the KGP infrastructure to be decommissioned in the UKCS sector.
- the feasible decommissioning options considered.

4.1 Alternative use of KGP

Gassco AS has a mandate under the Norwegian Petroleum Regulation Section 66A to assess gas transportation needs on the NCS from an overall perspective. Under this mandate, Gassco AS looked into the possible re-use of the KGP by other fields, as the KGP, PLET and the PLEM were designed for sour service environment for 20 years lifetime.

Gassco AS performed an area assessment to investigate potential for further utilization of the KGP after decommissioning. The assessment was based on information received from operators in the area and in dialogue with the Norwegian regulator, NPD. The study did not identify any new fields, discoveries or projects which could benefit from reuse of the KGP in the NCS. As only a small proportion of the KGP (<11%) is located on the UKCS, such a conclusion is considered to remain valid. The issue was discussed in a meeting with the UK Oil and Gas Authority (OGA) and no reuse potential was identified.

4.2 Description of KGP infrastructure

4.2.1 Knarr Gas Pipe

Rich gas was exported from the Knarr FPSO via the KGP, which passes through the NCS to enter the UKCS, and connects to the FLAGS pipeline.

The 105.7 km 12” KGP is a steel rigid pipeline which connects, on the UKCS side, to the Knarr PLEM and Knarr Tee through a series of 12” rigid spools before feeding into FLAGS.

Table 1 provides some details about the KGP.

The downstream end of the KGP is at the flange into the Knarr Tee of the 12” tie-in spool downstream of the PLEM.

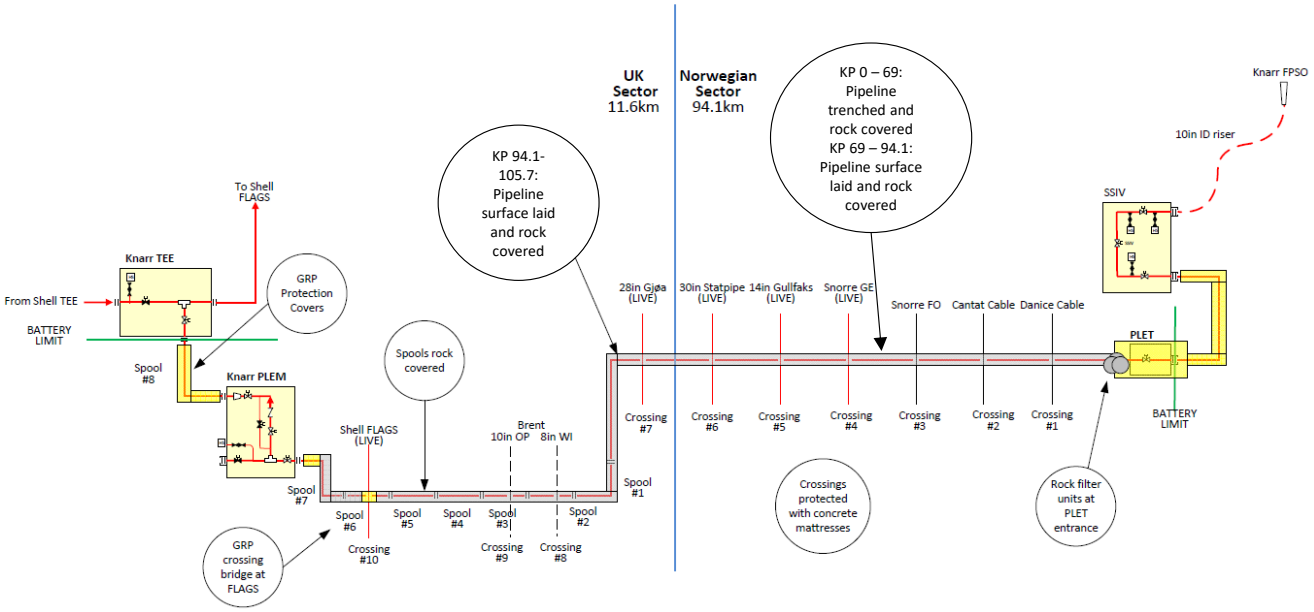

Figure 5 Knarr Gas Pipeline and Pipeline Crossings (Crossings 7 – 10 in UKCS) /9/

Table 1 Features of the 12" KGP

Feature	Detail	Comments
Length (km)	105.7 including spools	11.6 km of the pipeline is in UKCS. In the UKCS, the pipeline is surface laid with rock cover. Pipeline has no concrete cap.
Inner Diameter (inch)	12	
Outer Diameter (inch)	13	Wall thickness generally 12.7mm, 13mm in certain areas.
Depth max (m)	411	Maximum depth at start of pipeline in NCS
Depth Min (m)	137	All of the KGP on UKCS is at water depth of approximately 140 m.
Material	DNV HFI 450 SFD	Steel
Coating (mm)	3LPP* 3 mm thick (min)	• Base coat: fusion bonded epoxy primer • Intermediate: polymeric adhesive • Top coat: polypropylene • Heat shrink sleeves were selected for the field joint coating • KGP has no concrete coating, as it is either trenched with natural backfill (NCS) or rock covered (UKCS)
Steel in UKCS (t)	1,139	Approximate weight for the 11.6 km KGP on UKCS only, plus 1 tonne of anodes. The entire KGP is approximately 10,381 tonnes steel.
Plastic in UKCS (t)	32	This is the weight of the polypropylene coating.

*3LPP – 3-layer polypropylene

The water depth varies along the length of the KGP, as it moves from the NCS to the UKCS (Figure 6). From KP 0.15 to KP 69 (NCS) the KGP is trenched with natural cover.

In 2016/2017 an additional rock cover campaign was performed to give necessary cover in the area KP 40 - KP 69 based on trawl activity mapping of the area showing trawling in an area where little trawling was assumed during design. From KP 69 the pipeline is laid on the seabed with rock cover (0.5m of ToP) to prevent fishing gear interaction. All spools between the PLEM and the KGP to the point of full trench depth are rock dumped.

The KGP enters the UK sector at KP 94,1 and between KP 94,1-105,7 the pipeline is completely rock covered, has no free spans, and is at a water depth of approximately 140 m.

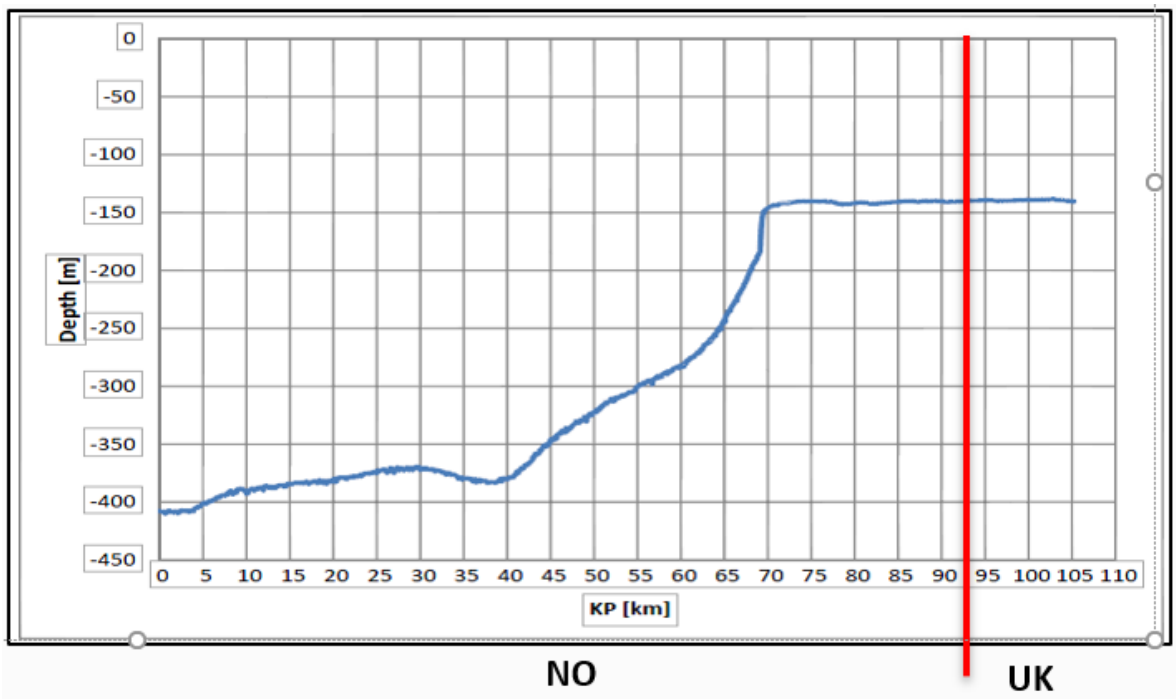

Figure 6 KGP pipeline sections at different water depths.

4.2.2 PLEM

The KGP UKCS PLEM (Figure 7) is about 10 metres long, weighs approximately 114 tonnes (including entrance and exit GRP covers, which weigh 22.6 tonnes) and is located at KP 105.640 to KP 105.650. The 2018 survey report /4/ found the PLEM to be in good overall condition.

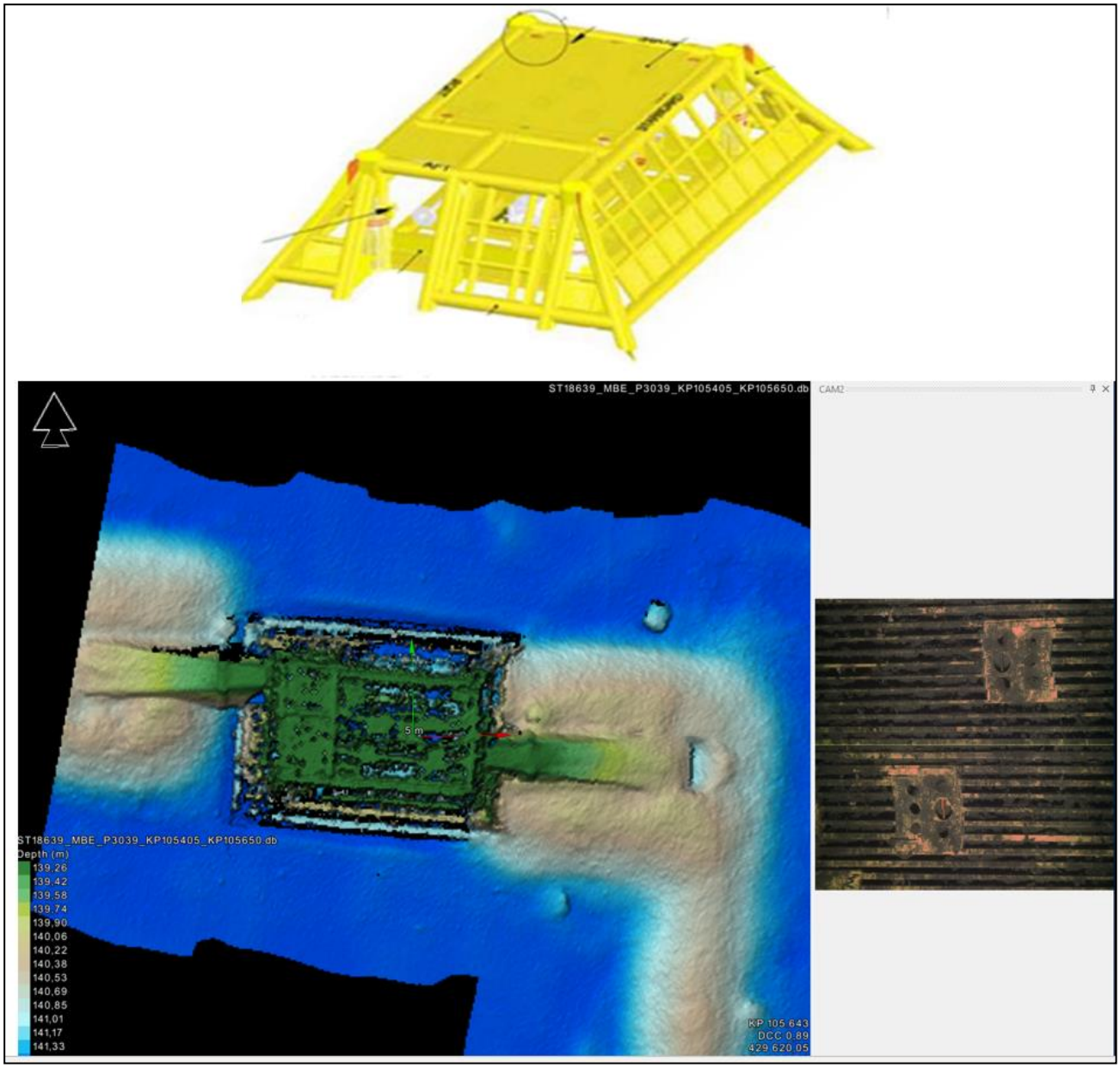

Figure 7 PLEM image from the 2018 survey

Figure 8 Knarr Tee (left) and PLEM (right), showing rock cover and GRP covers

4.2.3 Spools and GRP cover

The KGP connects to the PLEM and Knarr Tee (in UKCS) through eight 12” rigid steel pipe spools as illustrated in

Figure 9. Seven of the spools are upstream of the PLEM, with one spool located between PLEM and Knarr Tee structure. The wall thickness of the spools is 12.7 mm, and they are coated with 3 mm of 3LPP. Table 2 summarises the spool features.

Spools and GRP cover

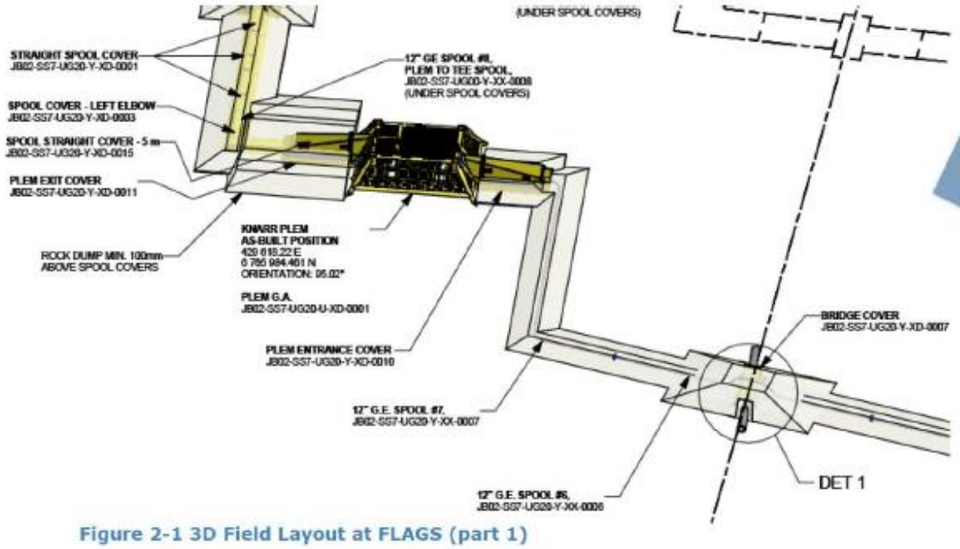

Figure 2-1 3D Field Layout at FLAGS (part 1)

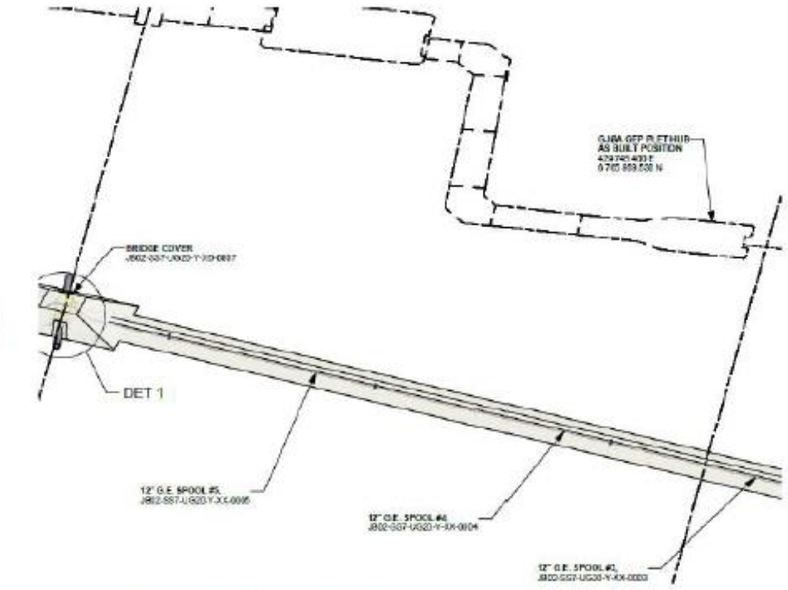

Figure 2-2 3D Field Layout at FLAGS (part 2)

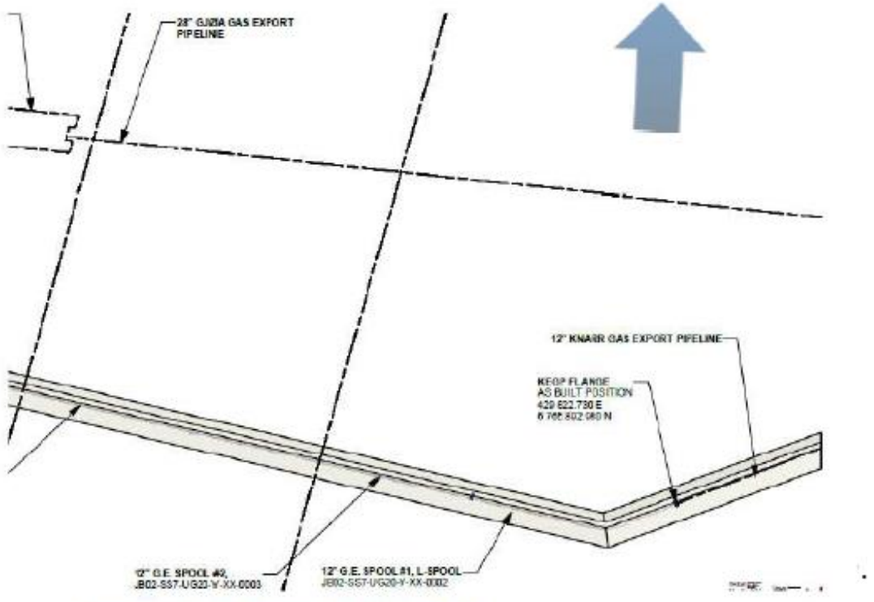

Figure 2-3 3D Field Layout at FLAGS (part 3)

Figure 9 Spools and GRP covers in the KGP UKCS

Table 2 Spools 1 – 8 & GRP Details

Spool #	Weight (t)	Interface and cover
1	4	L-type spool, interface between Spool 2 & KGP. Swivel flange at each end. Rock cover
2	4.1	I-type spool, connected by flanged connection and rock cover
3	4.1	I-type spool, connected by flanged connection and rock cover
4	4.0	I-type spool, connected by flanged connection and rock cover
5	3.6	I-type spool, connected by flanged connection and rock cover
6	4	I-type spool, connected by flanged connection and rock cover
6 (crossing)	3.8	GRP cover over FLAGS 36" gas export pipeline (crossing 10)
7	5.7	Z-type spool, interface between Spool 6 & PLEM. Swivel flange at PLEM end & weld neck at other end. Rock cover + PLEM GRP entrance cover.
8	5.9	L-type spool, located between PLEM and Knarr Tee structure, fitted with swivel flange at each end. Protected by GRP cover (see below).
8 Cover #1	2.8	Spool 8 GRP straight cover #1
8 Cover #3	3.1	Spool 8 GRP Left elbow cover #3
8 Cover #15	2.4	Spool 8 GRP straight cover #15

The 2018 KGP survey /4/ shows the 12” spools (either buried by GRP protection, or rock dumped, or both) to be in good condition with no debris, significant recent scars or evidence of other third-party threats. Figure 10 shows some details of the GRP cover at the PLEM exit, and at pipe crossing 10 (see 4.2.4).

GRP cover

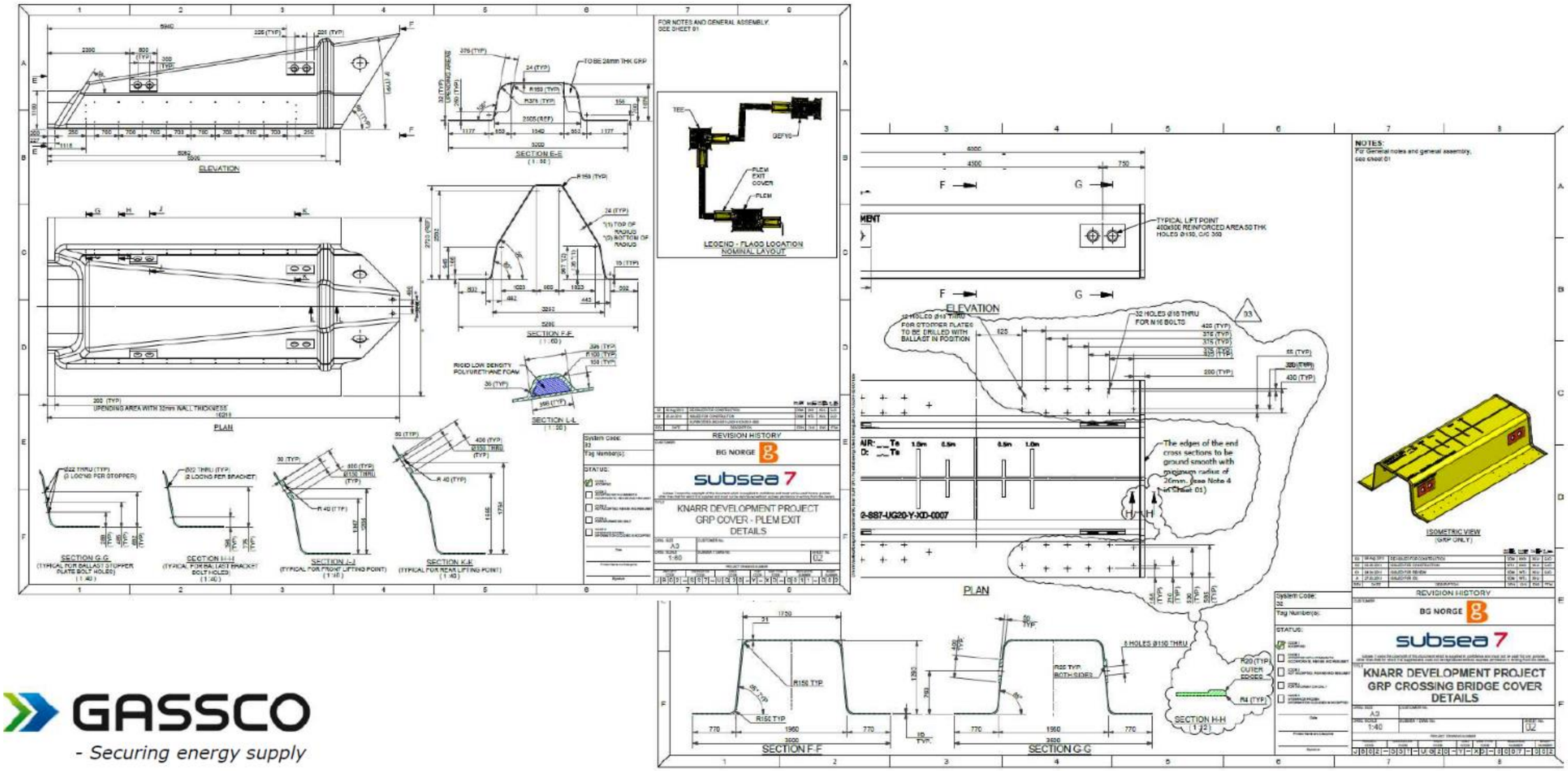

Figure 10 GRP Cover

4.2.4 Pipeline Crossings and Concrete Mattresses

Along the pipeline route to FLAGS, the KGP crosses the following 4 pipelines and cables in the UK sector (crossings 7-10):

- Crossing 7: Gjøa 26" gas export pipeline (live).
- Crossing 8: Brent South 10" oil pipeline (no longer in operation).
- Crossing 9: Brent South 8" water injection line (no longer in operation).
- Crossing 10: FLAGS 36" gas export pipeline (live).

The KGP crosses over at all 4 pipeline crossings. A physical, vertical separation of 300 mm minimum is ensured between the KGP and the other pipeline at the crossings (whether originally exposed or buried) and with consideration to both short-term and long-term settlement at the crossings. The separation is provided at crossings 7, 8 and 9 by 300 mm thick flexible concrete mattresses as detailed in Table 3. There are no mattresses over the FLAGS 36" gas export pipeline (crossing 10), as separation is provided by GRP cover /5/.

Table 3 Concrete mattresses located in KGP UKCS

		Concrete Mattresses					
Pipe crossings		No.	Dimensions (m)	Weight (t in air)	Submerged Weight (t)	Density (kg/m^3)	Additional Specs
7	Gjøa 26" gas export pipe	20	6x 3 x 0.3	9.6	5.9	2,400	20mm polyprop rope
8	Brent South 10” Oil Pipe	1	6x 3 x 0.3	9.6	5.9	2,400	20mm polyprop rope
9	Brent South 8” water inject	1	6 x 3 x 0.3	9.6	5.9	2,400	20 mm polyprop rope

The concrete mattresses in the FLAGS area were installed under the spools and rock dumped post tie-in to cover all mattresses. The GRP cover at crossing 10 is also under rock cover. Latest survey 2018 /4/ showed that all of these crossings are stable.

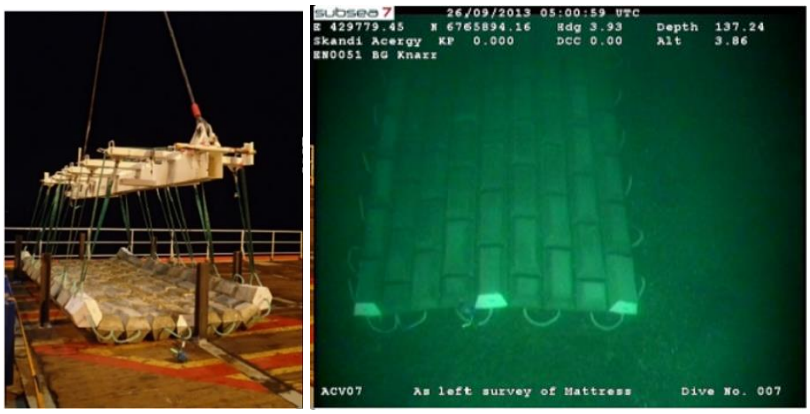

Figure 11 Photos from installation of concrete mattresses in the FLAGS area

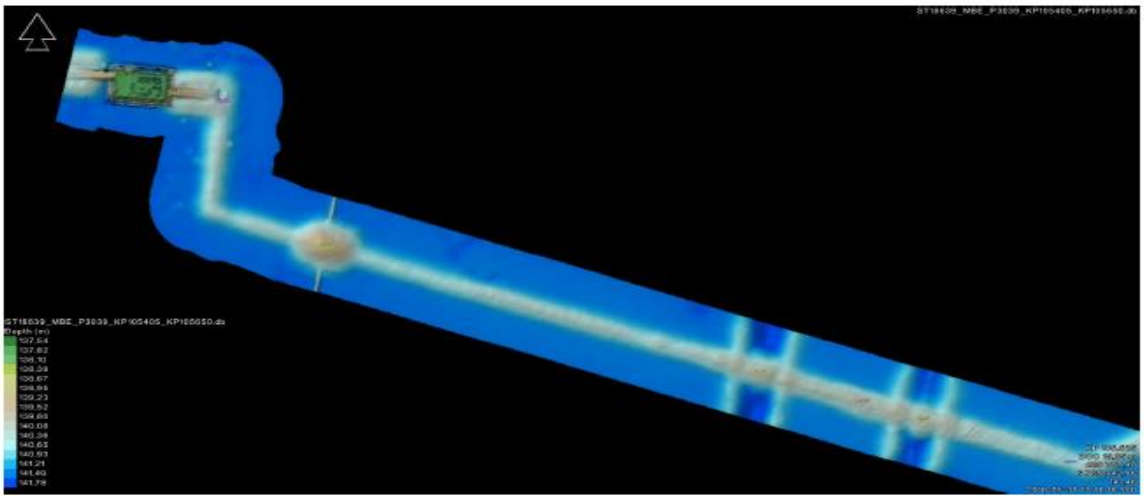

Figure 12 KGP showing PLEM, Pipeline Crossings & rock dump in UKCS, 2018 survey

4.2.5 Rock cover on UK sector

The entire length of the KGP on the UK sector is covered by rock. Approximately 97,000 Te of rock was installed as stabilisation and cover on the KGP in the UK sector. The rock is generally laid with a 1:3 slope and with a top of pipe average coverage of 0.58m (Figure 13). The installed rock size varies between 1-5” /6/. An as-laid survey was undertaken in 2015 /2/, with later external inspections in October 2015, 2016, 2017 and 2018, which document sufficient coverage along the entire length of the pipeline.

The areas approaching the Knarr PLEM (GRP covers and spools) are all rock covered, apart from the entrance and exit GRP covers of the PLEM (Figure 14 and Figure 15), which are only partially covered with rock. About 54,000 Te of rock was installed in this area, covering the crossings, spools and PLEM /6/.

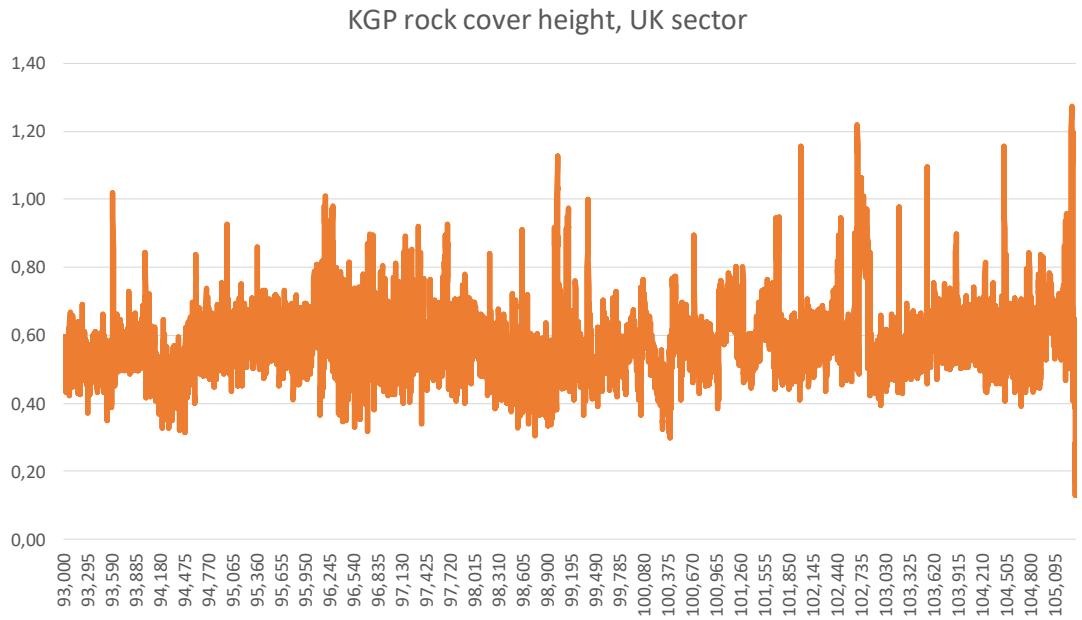

Figure 13 Rock Cover height above pipe (m), UK sector.

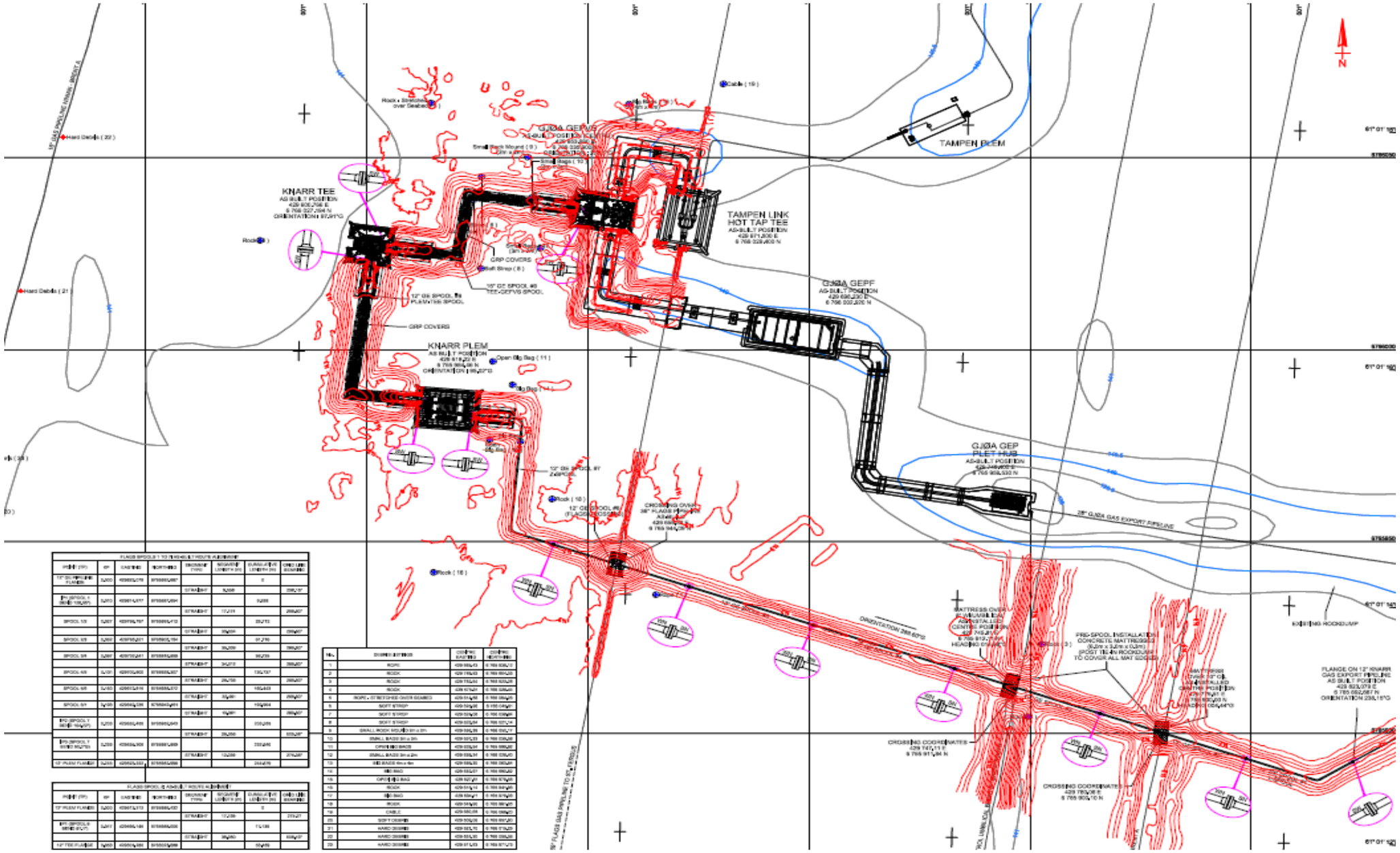

Figure 14 Area layout for the tie in of KGP to FLAGS.

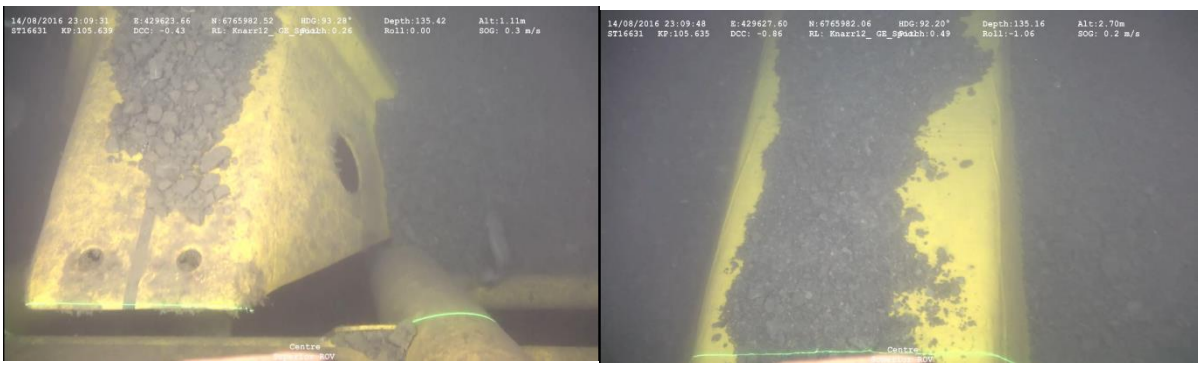

Figure 15 GRP covers close to the PLEM

4.2.5.1 Trawl Scars

The KGP survey in 2015 /2/, identified extensive trawling, and trawl scars can be seen between KP 60 (NCS) to approximately KP 100 (UKCS) where the pipeline is surface laid with rock cover. Several external inspections have been performed in this area to monitor the development of the trawl scars to the rock protection. The pipeline coverage\protection is still considered as intact.

4.3 Preparation for Decommissioning

Under the terms of the PWR submitted by Gassco AS on 29/04/2021, Phase 1 of the decommissioning activities were carried out in May 2022. The KGP was cleaned by pigging from Knarr PLEM (UK sector) towards Knarr FPSO (Norwegian sector) to displace any residual hydrocarbons and contaminants from the pipeline during decommissioning in May 2022. A 4 off pig train was propelled by filtered seawater from the PLEM to the Knarr FPSO. All piping between the Knarr Tee and the PLEM header was filled with 100% MEG and pressurized to 90 barg prior to pigging. After pigging, the Knarr PLEM main header was flushed with MEG and valves closed to provide additional barriers between KGP and FLAGS.

The cleaning process conformed to industry standards to ensure that the lines are adequately cleaned. Cleaning reduced the hydrocarbon content to as low as reasonably practical and complied with best available techniques and industry practice. Cleaning was managed environmentally under the relevant regulations (e.g. Offshore Chemical Regulations 2002, Offshore Petroleum Activities (Oil Pollution Prevention and Control, OPPC) Regulations 2005). A chemical permit and an OPPC permit were granted by BEIS prior to execution of the cleaning activities.

While the pigging and cleaning of the KGP is out of the scope of this CA, any potential impact associated with the decommissioning of the KGP is within scope (e.g. discharge during removal, or long-term release from KGP decommissioned in situ).

4.4 Decommissioning Options

4.4.1 Knarr Gas Pipeline

Two alternative decommissioning methods were examined in the workshop for the pipe:

Option A: Leave KGP in situ:

- The KGP in UK sector would be left *in situ*
- There would be a small amount of cutting activity, because the KGP would require disconnecting upstream of the PLEM. This would also require the disturbance of a small quantity of rock dump local to the area to permit access. After disconnecting, the KGP cut-end would be re-covered with the rock.
- Apart from this short duration (and low complexity) activity, there would be very few operations required, so low vessel density, no lifting, few resources, etc.

Option B: Remove KGP:

- The KGP in UK sector would be removed.
- Trenching of the KGP is difficult in UKCS owing to ground conditions, so trenching was discounted as a decommissioning method. That is why the KGP in UKCS was rock covered and not trenched.
- There are different ways to remove the KGP (e.g. cut and lift, reverse reel, reverse S-lay) and there are some differences in impact/cost associated with these different methods. Workshop attendees noted such differences in the scoring of Option B where relevant.

4.4.2 Pipe Spools, Pipe Crossings, Mattresses & GRP covers

The 12” Pipe spools #1-6 are under more than 0.5 m rock cover. Pipe spool #7-8 are under GRP covers, with rock cover on top. Alternative decommissioning methods were examined for the pipe spools, crossing, mattresses and GRP covers, as described below. Spool #8 (and associated GRP covers) is considered separately to Spools #1-7, owing to its location between the PLEM and Knarr Tee. Spools #1-7 are all located upstream of the PLEM.

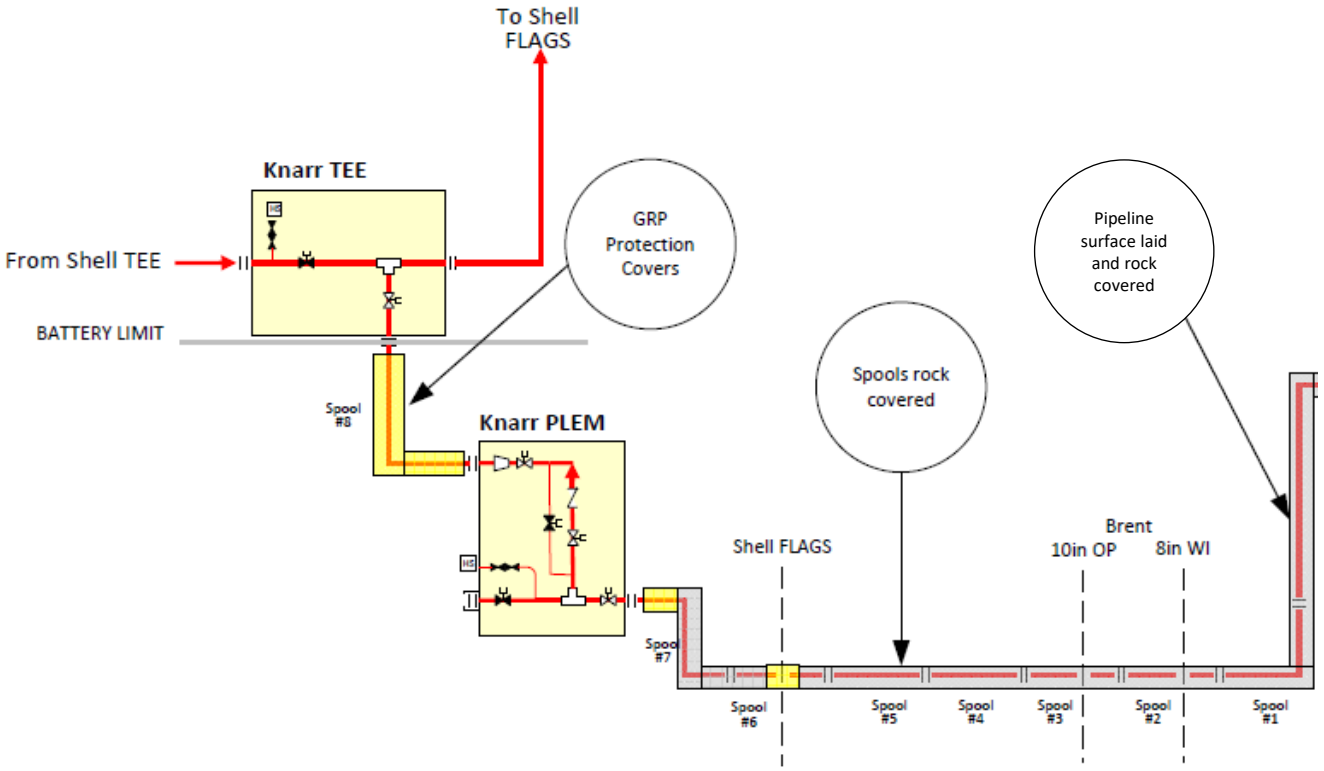

Figure 16 KGP layout UK sector showing location of spools and GRPs (yellow) /8/

4.4.2.1 Spool #8

The following three alternative decommissioning options were considered:

Option A: Leave pipe spool #8 & associated GRP covers *in situ* under rock cover

- Pipe spool #8 (under rock dump and GRP covers) in UK sector would be left *in situ.*
- There would be a small amount of activity near the PLEM, because the KGP pipe spools would require disconnecting upstream and downstream of the PLEM (to allow for PLEM removal). This would require the disturbance of a small quantity of rock cover local to the area to permit access. After disconnecting, the cut-ends would be re-covered with the rock.
- Apart from this short duration (and low complexity) activity, there would be very few operations required, so low vessel density, no lifting, no resources, etc.

Option B: Remove Pipe Spool #8 & GRP covers - at same time as KGP decommissioning & PLEM removal

- The KGP pipe spool #8 and GRP covers in UK sector would be removed.

- The pipe spool #8 and GRP covers would be uncovered (requiring the disturbance of a small quantity of rock dump), cut into sections (if necessary) and lifted.
- There is more activity required than Option A, but still low activity.

Option C: Remove Pipe Spool #8 & GRP covers - delay until after FLAGS cessation of production, and remove PLEM at same time

- Option C involves the same activities as Option B, but with activities taking place at a later date, after FLAGS cessation of production (hence safer).

4.4.2.2 Spools #1-7, Pipe Crossings, Mattresses & GRP cover

The 3 pipeline crossings, all the concrete mattresses and the GRP cover at pipe crossing 10 are all within the length of the pipeline covered by pipe spools #1-7.

Option A: Leave pipe spools #1-7, pipe crossings, and mattresses *in situ* under rock cover. Remove GRP cover at crossing 10 (Shell FLAGS pipeline crossing). Disconnect at spool #7 to separate KGP from the UK gas infrastructure.

- Pipe spools #1-7 in UK sector would be left *in situ.* All the spools are under rock cover, or GRP covers and rock cover.
- As the concrete mattresses are under rock cover at the pipeline crossings, so their fate is bound up with the pipeline crossings. Hence in this option they would also be left *in situ*.
- This decommissioning option would require very few operations, so very low vessel density, minimal lifting and resources, etc.

Option B: Remove Pipe Spools #1-7, GRP cover (at crossing 10) and mattresses, at the same time as KGP decommissioning & PLEM removal

- Pipe spools #1-7, GRP cover (at crossing 10), and mattresses would be removed. The pipe spools, mattresses and GRP cover would be uncovered (requiring the disturbance of a small quantity of rock cover). The pipe spools would be cut into sections, and lifted. The mattresses and GRP cover would be lifted.
- As the concrete mattresses are under rock cover at the pipeline crossings, so their fate is bound up with the pipeline crossings. Hence in this option they are considered as an integral part of the removal activities.
- This option involves more activity than Option A, but still relatively low activity, as the length of the pipe spools is not large.

Option C: Remove Pipe Spools #1-7 GRP cover (at crossing 10) and mattresses - delay until after FLAGS cessation of production, and remove PLEM at same time

- Option C involves the same activities as Option B, but with activities taking place at a later date, after FLAGS cessation of production (hence safer).

5 Comparative Assessment Methodology

5.1 Overall Approach

The comparative assessment process considered the decommissioning options identified in Section 4.4 to understand the safety, environmental, technical, economical and societal risk associated with it, such that robust conclusions as to the preferred decommissioning option can be drawn.

Oil & Gas UK *Guidelines for Comparative Assessment in Decommissioning Programmes* /7/ recommend the 7 steps listed below:

1. **Scoping:** The operator met with OPRED and agreed that the simplest CA methodology would be applied ("Evaluation Method A: Narrative + Red-Amber-Green", a mainly qualitative approach using relatively broad-brush comparisons across each decommissioning option). This was agreed owing to the small scale of this decommissioning project, and because pipeline CA are generally accepted to be less comprehensive than more complex decommissioning projects involving structures such as jackets, GBS, etc.
2. **Screening:** Gassco AS has not been able to identify any alternative uses for the KGP (see Section 4.1). The proposed decommissioning options are presented in Section 3.4.
3. **Preparation:** Gassco AS provided technical and environmental information about the KGP and study area to DNV GL. DNV GL reviewed and supplemented this with additional information available in the public domain. The study area was not found to be very environmentally sensitive (further details can be found in Gassco AS report Environmental Appraisal of Knarr Gas Pipeline Decommissioning). DNV GL prepared Terms of Reference for workshop attendees to inform them with all necessary background information ahead of the workshop.
4. **Evaluation:** DNV GL facilitated a CA workshop with Gassco AS and the findings are presented in this report.
5. **Recommendation:** This report contains emerging recommendations.
6. **Review**: This draft report will be sent to external stakeholders (SFF, JNCC, OGA incl. Decom and Pipeline consents team) prior to formal submission to the regulator.
7. **Submit** to regulator.

5.2 Comparative Assessment criteria

The comparative assessment process used the 5 main assessment criteria (Safety, Environment, Technical, Societal and Economic) described in the BEIS Guidelines. Sub-criteria specific to the Knarr decommissioning project were developed and are shown in Table 4 and Table 5.

Sub-criterion is assessed individually in turn and by comparison across the decommissioning options, before moving onto the next sub-criterion. Decommissioning options that scored red would be considered the worst option, while those that scored green would be considered the most preferred. Where there is no significant difference across the decommissioning options, the sub-criterion would be coloured grey.

Table 4 Comparative Assessment Criteria – Safety

Main Criteria	Sub-Criteria	Differentiator	Best Option	Moderate	Worst Option
Safety	**Project Risk to Personnel - Offshore**	Preparatory Activity	Minimal activity required prior to start of decommissioning.	Some preparatory work before start of decommissioning	Extensive preparatory work, with multiple vessels, work locations prior to decommissioning.
		Materials Handling	Low level of materials handling. Automated processes with minimal manual handling.	Moderate level of materials handling / manual handling.	Piece small removal of materials. High level of materials handling / manual handling.
		Lifting Operations	Simple lifting operations. Low dropped object potential.	Complex lifting operations / some dropped object potential.	Complex lifting operations / high dropped object potential.
		Crane Operations	Low level of crane operations.	Moderate level of crane operations.	High level of crane operations.
		Diving Operations	Low level of diving operations or diver intervention required.	Diver intervention / operations required	High levels of diver intervention / diving operations required.
	Project Risk to Other Users of the Sea	Activity levels	Activities within defined exclusion zone.	Multiple activities across multiple locations in series/sequence.	Multiple activities across multiple locations simultaneously.
		Activity levels	Low density of project support & marine movements/transits	Moderate density of project support & marine movements	High density of project support & marine movements/transits
		Port Calls	Low level of transits to / from port facilities.	Intermediate level of transits to / from port facilities.	High level of transits to / from port facilities.
	Project Risk to Personnel - Onshore	Material Volume returned to shore	Minimum number/volume of materials returned to shore.	Moderate number/volume of materials returned to shore.	Large number/volume of materials returned to shore.
		Ship to Shore Transfer	Minimum number of ship to shore transfers / lifting operations in port.	Moderate number of ship to shore transfers / lifting operations in port.	Large number of ship to shore transfers, lifting operations in port.
		Contaminated Materials	No contaminated materials to be returned to shore.	Contaminated materials to be returned to shore (within permitted estimates).	Large volume of contaminated materials to be returned to shore (in excess of permit estimates).
	Potential for a high consequence Event	Campaign length	Shortest vessel campaign.	Moderate vessel campaign.	Longest vessel campaign.
		Campaign window	Summer daylight operations.	Full Spring-Summer-Autumn operations / planned daylight winter operations.	Full year operations.
		Ship collision potential	Lowest density of vessels / high level of vessel planning.	Moderate density of vessels / low level of vessel planning.	Highest density of vessels.
		Operations complexity	Low impact / simple simultaneous operations.	Moderate impact / simultaneous operations.	High impact / complex simultaneous operations.
		Lifting Operations	Low level of lifting operations.	Moderate level of lifting operations.	High level of lifting operations.
		Helicopter Operations	No Helicopter operations.	Occasional Crew Transfer Helicopter operations.	High level of Helicopter operations/shuttling.
		Diving Operations	Essential Diving operations only.	Moderate Diving support / operations.	Full Diving support required.
		Residual Infrastructure	All infrastructure subsea requiring removal is removed during campaign.	Remaining infrastructure - removal scheduled according to lowest time option.	Infrastructure left *in situ* without monitoring

Main Criteria	Sub-Criteria	Differentiator	Best Option	Moderate	Worst Option
	Residual Risk to Other Users of Sea	Post-removal surveys	Planned surveys of infrastructure left *in situ*	Planned surveys of infrastructure left *in situ*	Ad-hoc surveys based on incident reports.

Table 5 Comparative Assessment Criteria – Environment, Technical, Socio-economic, Economic

Main Criteria	Sub-Criteria	Differentiator	Best Option	Moderate	Worst Option
Environment	**Marine Impacts of Operations** (seabed disturbance, underwater noise from vessels, risk of spills etc.)	Not a significant differentiator	Few vessel operations. Limited seabed disturbance. No sea discharges.	Increased vessel operations. Some seabed disturbance.	Significant numbers of vessel operations. Moderate seabed disturbance.
	Impacts on Marine end points (legacy): quantity of material left on seabed, toxicity & persistence of materials	Not a significant differentiator	All/most materials on seabed collected and taken to shore	Some materials are left *in situ* but are not hazardous or toxic.	Large quantities of materials on seabed are left *in situ* and are hazardous/persistent
	Energy & emissions (e.g. vessels), resource consumption (e.g. rock)	Not a significant differentiator	Small number of vessels, small volume of resource use.	Moderate numbers of vessels. Some resource use.	Large number of vessels, large volumes of resource use.
Technical	**Risk of project failure or cost overruns**	Not a significant differentiator	Confidence of no schedule slippage or cost over-runs due to low risks.	Small risks of schedule slippage or cost overruns	Significant risk project will not be completed successfully. Delays possible as are costs overrun.
	Technology demands/track record	Not a significant differentiator	A few simple operations required	More significant operations are required but similar work has been successfully implemented in the past many times	The proposed operations are novel and the concept is not mature.
Socio-economic	**Commercial impact on fisheries** (residual impact post-decommissioning)	Not a significant differentiator	The status of the area post-decom will have no effect on commercial fisheries.	The status of the area post-decom will result in fishing areas becoming inaccessible/difficult to fish to a minor extent	The status of the area post-decom will result in fishing areas becoming inaccessible/difficult to fish to a significant extent
	Socioeconomic impact on communities (negative)	Not a significant differentiator	No impact.	Minor negative impact, with some nuisance (e.g. noise, dust) for temporary period.	Some negative impact, with nuisance (e.g. noise, dust) for longer period.

Main Criteria	Sub-Criteria	Differentiator	Best Option	Moderate	Worst Option
	Socioeconomic impact on communities (positive)	Not a significant differentiator	Significant employment created.	Minor employment created (positive).	No employment generated
Economic	**Cost**	Not a significant differentiator	Lowest cost option	Middle cost option	High cost option
	Cost risk/uncertainty	Not a significant differentiator	Scope well defined	Some uncertainty	Uncertainty in many areas, significant information gaps.

6 Comparative Assessment Workshop & Results

6.1 CA Workshop

DNV GL facilitated and scribed a 4-hour CA workshop on 20 May 2019 at Gassco AS offices in Bygnes, Norway to consider the most appropriate method of decommissioning the KGP.

The workshop was attended by the following:

- Leo Westerneng, Gassco AS (Project Manager)
- Vigdis Hjertaker Hope, Gassco AS (Pipeline Asset Manager KGP)
- Per-Atle Strømme, Gassco AS (Technical authority, pipelines)
- Steinar O. Lervik, Gassco AS (Cost Estimation)
- Stian Bjerknes, Gassco AS (Commercial)
- Kirsten Halvorsen, Gassco AS (Environmental)
- Berit Linga-Sørensen, Gassco AS (HSE)
- Steinar Nesse, DNV GL (Environmental/decommissioning expertise)
- Colin Howes, DNV GL (Decommissioning expertise, Scribe)
- Mark Purcell, DNV GL (Environmental/decommissioning, Facilitator)

It was agreed with OPRED that it was not necessary to have external consultees at the workshop owing to the simple nature of the KGP decommissioning project on the UK side.

At the start of the workshop, there was a presentation by Gassco AS to describe the pipeline, pipeline crossings, spools, PLEM, mattresses, rock dump status and the summarise the Gassco AS surveys that have been conducted.

Also, DNV GL presented an overview of the environmental and socioeconomic sensitivities in the study area (as summarised in Section 7 of the Environmental Appraisal report), such that these could be borne in mind during the evaluation.

6.2 CA Results

During the workshop, the decommissioning alternatives described in Section 4.4 were assessed, using the methodology described in Section 0, against Safety, Environment, Technical, Societal and Economic criteria as detailed in Table 4 and Table 5.

The decommissioning alternatives were scored by attendees using expert judgement, having consideration of the activities involved, and the sensitivity of the surrounding environment and socioeconomic activities in the study area.

6.2.1 Knarr Gas Pipeline

The comparative assessment process produced the results shown in Table 6 for the KGP decommissioning options assessed against criteria, and the reasoning for the scoring is documented within the table.

Green colour represents best option, red worst, with grey colour illustrating that the sub-criteria is not a significant differentiator. Table 6 clearly shows leaving the KGP in situ under the existing rock dump is the preferred option, as it is safer, cheaper, easier and better for the environment.

Table 6 CA Results for Knarr Gas Pipeline decommissioning options

Main Criteria	Sub-Criteria	Differentiator	Option A: Leave KGP in situ	Option B: Remove KGP (including at crossings at later stage)
Safety	**Project Risk to Personnel - Offshore**	Preparatory Activity	Disconnection upstream of PLEM. Remove rock cover local to disconnection point.	Recovery of pipeline would require excavation of rock cover on top of pipeline along complete 11.6km length to enable access to the pipe (P/L cannot be removed through rock cover). Seawater flooding required. Will increase weight of P/L unless isolated at cut location. Offshore activity to remove P/L will require subsea excavator which is controlled from the surface - so no diving required. Sectional cutting: ROV work, CSV work offshore
		Materials Handling	Minimal material handling at surface.	P/L cutting - requires section return and handling at surface. Reverse S-Lay: cutting required on deck. Potential exposure to trace NORM / heavy metals (Hg) (although risk is considered to be low)
		Lifting Operations	No lifting of P/L from seabed	P/L Cutting: Lifting operation requires handling operations. Reverse Reeling: High potential energy in returned P/L.
		Crane Operations	Minimal crane operations - only excavator handling	P/L cutting over 11.6 km would mean many crane operations are required. Return of baskets to surface.
		Diving Operations	Minimal diving. Flange cut connection only.	Hyperbaric Diving: Diving only in essential unplanned interventions.
	Project Risk to Other Users of the Sea	Activity levels - execution phase	Low vessel activity. Notice to Mariners	Operations would involve significantly more vessel activity - CSV. Notice to mariners would be issued. But there is only low vessel activity by other users of the sea in this area.
		Activity levels - marine transit	Low vessel density.	Only a small number of vessel shipments required.
		Port Calls	Low vessel density.	Only a small number of vessel shipments required.
	Project Risk to Personnel - Onshore	Material Volume returned to shore	No impact.	11.6km of P/L returned to shore.
		Ship to Shore Transfer	No impact.	Lifting operations. Potentially limited to sub-sea basket transfers.
		Contaminated Materials	No impact.	Low risk of handling of contaminated materials during processing. Disposal of removed material.
	Potential for a high consequence Event	Campaign length	Short duration campaign. 1 day survey/excavation campaign.	Multiple vessels. Possibly 2 km/day depending on removal method. Several vessel weeks including prep activities.
		Campaign window	Planned summer.	Planned summer.
		Ship collision potential	Low density of shipping/ offshore installations.	Low density of shipping/ offshore installations.
		Operations complexity	Operations not close to live P/Ls. Low complexity.	Operations not close to live P/Ls. But higher complexity than Option A.
		Lifting Operations	Operations not close to live P/Ls. Low complexity. No lifting of P/L from seabed.	Operations not close to live P/Ls / crossings. But higher complexity than Option A. Multiple lifts.
		Helicopter Operations	No helicopter operations.	No helicopter operations.
		Diving Operations	No difference in MAH Diving risk.	No difference in MAH Diving risk.
	Residual Risk to Other Users of the Sea	Residual Infrastructure	Low fishing activity in study area. P/L not exposed. Rock dump intact (as shown by surveys) - safe for fishing.	Low fishing activity. P/L removed. Rock left in situ.
		Post-removal surveys	Periodic survey of P/L on a risk-based approach. Recent over trawl survey data.	Post-disposal baseline/over trawl survey may be required to eliminate long term liability risks.

Environment	**Marine Impacts of Operations** (seabed disturbance, underwater noise from vessels, risk of spills etc.)	Preparatory Activity	Very small movement of rock dump to expose cut location.	Potentially full 11.6km of rock dump disturbance, which will impact local marine environment.
		Rock cover - add/disturb	The P/L cut ends will be re-covered with the existing rock, so no additional rock dump required. Isolated disturbance of seabed local to single cut.	Disturbed P/L rock cover left in situ. Crossing removal - disturbed rock to be redistributed on seabed to ensure no over trawl hazard.
		Vessel Operations	Very limited operations.	More operations.
		Cut/Lift	Very limited operations.	More operations.
	Impacts on Marine end points (legacy): quantity of material left on seabed, toxicity & persistence of materials	Legacy impacts (enviro)	Will clean P/L prior to decommissioning. It is a gas P/L, hence has limited toxic content to have a legacy impact. It is a covered P/L with rock cover, low impact of PP wrapping.	Fully removed.
	Energy & emissions (e.g. vessels), resource consumption (e.g. rock)	During rock cover, cutting, lifting, transit, recycling etc.	Minimal vessels required.	Larger number of vessels. Materials recycled following removal - part of EA.
Technical	**Risk of project failure or cost overruns**	During rock cover, cutting, lifting, transit, recycling etc.	Minimal project scope, likely within summer operations window.	More vessel operations. More activities - potential for overrun, but still likely within summer operations window.
	Technology demands/track record	During rock cover, cutting, lifting, transit, recycling etc.	Minimal project scope. Likely within summer operations window.	Rock covered P/L typically left in situ. To remove would be novel situation.
Socio-economic	**Commercial impact on fisheries** (residual impact)	Post-decom impact on fisheries	No significant difference from current situation. Surveys show rock dump is in good condition.	No impact.
	Socioeconomic impact on communities (positive or negative)	Onshore	No onshore work.	Minimal activity in handling and treating materials.
	Socioeconomic impact on communities (positive)	Employment	No onshore work.	Minimal additional employment opportunity in handling and treating materials. Scrap value of pipe only.
Economic	**Cost**	Overall	Minimal Cost.	High cost option.
	Cost risk/uncertainty	Overall	Residual risk from infrastructure left in-situ. Potential for future requirements to change such that need to remove P/L?	Infrastructure removed. No residual risk.

6.2.2 KGP Spools & GRP covers

The comparative assessment process produced the results shown in Table 8 for the 3 decommissioning options for Spools #1-7, pipe crossings, mattresses and GRP cover, and in Table 7 for the 3 decommissioning options for the pipe spool #8 and GRP covers.

The decommissioning options are assessed against criteria, and the reasoning for the scoring is documented within the table. Green colour represents best option, red worst, with grey colour illustrating that the sub-criteria is not a significant differentiator.

The results presented in Table 7 and Table 8 show that the differences between the decommissioning options are much less clear-cut for the spools/GRP covers than for the KGP.

In both Table 8 and Table 7, Option C involves exactly same removal activities as Option B, but with the removal activities taking place at a later stage, and the results for Option C are only shown when different than Option B. It should be noted that in both tables, Option C shows some advantages over Option B (owing either to the proximity of the PLEM/Spool #8/GRP covers to the live FLAGS pipeline, or to the proximity of several spools within Spools #1-7 to live pipeline crossings). It would be safer to delay removal until after FLAGS cessation of production.

Table 7 CA Results for Phase 2; Spools #1-7, Pipe Crossings, mattresses & GRP cover decommissioning options

Main Criteria	Sub-Criteria	Differentiator	Option A: Leave Spools #1-7, pipe crossings, mattresses & GRP cover in situ (remove PLEM only)	Option B: Remove Spools #1-7, pipe crossings, mattresses & GRP cover - at same time as KGP decommissioning & PLEM removal	Option C: Remove Spools #1-7, pipe crossings, mattresses & GRP cover - delay until FLAGS cessation of production, & remove PLEM at same time **
Safety	**Project Risk to Personnel - Offshore**	Preparatory Activity	No activity.	Uncover spool sections. Cut spools into sections for removal.	
		Materials Handling	No activity	Replace displaced rock cover at P/L end. Disperse rock cover from spool section on seabed. Handling of recovered materials on vessel.	
		Lifting Operations	No activity.	Recover GRP covers, cut spool section to surface.	
		Crane Operations	No activity.	Locate GRP covers, spool sections on vessel.	
		Diving Operations	No activity.	Essential intervention diving only.	
	Project Risk to Other Users of the Sea	Activity levels - execution phase	Minor rock cover only. Notice to Mariners	More vessel activity, but still low activity - CSV. Notice to mariners.	
		Activity levels - marine transit	Low vessel density.	Low vessel density. Small number of vessel shipments required.	
		Port Calls	Low vessel density.	Low vessel density. Small number of vessel shipments required.	
	Project Risk to Personnel - Onshore	Material Volume returned to shore	No activity onshore	Limited to 8 spools and covers	
		Ship to Shore Transfer	No activity onshore	Limited to 8 spools and covers	
		Contaminated Materials	No activity onshore	Limited to 8 spools and covers	
	Potential for a high consequence Event	Campaign length	Minimal activity.	Minimal activity.	
		Campaign window	Summer operations.	Summer operations.	
		Ship collision potential	Low vessel density.	Low vessel density.	
		Operations complexity	No activity	Live pipeline in the construction area.	All live pipeline crossing will have been decommissioned at time of removal.
		Lifting Operations	No activity.	Live pipeline and sub-sea structures in the construction area.	Recovery of spools and GRP cover post-decommissioning of area.
		Helicopter Operations	No activity.	No activity.	
		Diving Operations	No activity.	Essential intervention diving only in support of removal operations.	
		Residual Infrastructure	Residual rock dump	Replace displaced rock dump at P/L end.	

	Residual Risk to Other Users of the Sea	Post-removal surveys	No differentiation	No differentiation	
Environment	**Marine Impacts of Operations** (seabed disturbance, underwater noise from vessels, risk of spills etc.)	Preparatory Activity	Minimal activity	Displace rock cover. Remove GRP covers and cut spools.	
		Rock cover - add/disturb	None	Disperse rock cover. Cover P/L end.	
		Cut/Lift	No cut or lift.	Remove 8 spools and covers.	
	Impacts on Marine end points (legacy): quantity of material left on seabed, toxicity & persistence of materials	Legacy impacts (enviro)	GRP cover would be removed over crossing 10.	GRP covers and spools removed. Research re-use and/or recycle potential.	
	Energy & emissions (e.g. vessels), resource consumption (e.g. rock)	During rock cover, cutting, lifting, transit, recycling etc.	Minimal activity.	Small number of vessels. Materials recycled following removal - part of EA.	
Technical	**Risk of project failure or cost overruns**	During rock cover, cutting, lifting, transit, recycling etc.	Minimal project scope.	More vessel operations - but with defined scope. Small number of activities. Work authorisations required for activities near FLAGS pipeline and 'live' structures.	All nearby adjacent subsea structures are decommissioned at time of removal of spools.
	Technology demands/track record	During rock cover, cutting, lifting, transit, recycling etc.	No significant differentiator	No significant differentiator	
Socio-economic	**Commercial impact on fisheries** (residual impact)	Post-decom effect on fisheries	No significant difference from current situation. Surveys show rock dump in good condition.	No impact.	
	Socioeconomic impact on communities (negative)	Onshore	No onshore work.	Minimal activity in handling and treating materials. Scrap value of materials only.	
	Socioeconomic impact on communities (positive)	Employment	No onshore work.	Minimal additional employment opportunity in handling and treating materials. Scrap value of materials only.	
Economic	**Cost**	Overall	Very low cost.	Moderate cost.	Deferred cost. Pooling of resources during infrastructure removal.
	Cost risk/uncertainty	Overall	Residual risk from infrastructure left in-situ. Potential for future requirement to remove.	Infrastructure removed. No residual risk.	Residual risk from infrastructure left in-situ. Potential for future requirement to remove.

** Option C involves the same activities as Option B, but with activities taking place at a later date. The results for this option are only shown when found to be different than for Option B.

Table 8 CA Results for Phase 3; Spool #8 & GRP covers decommissioning options

Main Criteria	Sub-Criteria	Differentiator	Option A: Leave Spool #8 & GRP Covers in situ (remove PLEM only)	Option B: Remove Spool #8 & GRP Covers - at same time as Knarr Gas Pipe Decommisssioning & PLEM removal	Option C: Remove Spool #8 & GRP Covers - delay until FLAGS cessation of production, & remove PLEM at same time **
Safety	**Project Risk to Personnel - Offshore**	Preparatory Activity	No activity.	Uncover spool #8 and may need to cut spools into sections for removal.	
		Materials Handling	Potential rock covering to replace cover of exposed spool section either side of PLEM.	Replace displaced rock cover at P/L end. Disperse rock cover from spool section on seabed. Handling of recovered materials on vessel.	
		Lifting Operations	No activity.	Recover GRP covers, and cut spool sections to surface.	
		Crane Operations	No activity.	Locate GRP covers, spool sections on vessel.	
		Diving Operations	No activity.	Essential intervention diving only.	
	Project Risk to Other Users of the Sea	Activity levels - execution phase	Minor rock dump only. Notice to Mariners	More vessel activity, but still low activity - CSV. Notice to mariners.	
		Activity levels - marine transit	Low vessel density.	Low vessel density. Small number of vessel shipments required.	
		Port Calls	Low vessel density.	Low vessel density. Small number of vessel shipments required.	
	Project Risk to Personnel - Onshore	Material Volume returned to shore	No activity onshore	Limited to 1 spool and associated GRP covers	
		Ship to Shore Transfer	No activity onshore	Limited to 1 spool and covers	
		Contaminated Materials	No activity onshore	Limited to 1 spool and covers	
	Potential for a high consequence Event	Campaign length	Minimal activity.	Minimal activity.	
		Campaign window	Summer operations.	Summer operations.	
		Ship collision potential	Low vessel density.	Low vessel density.	
		Operations complexity	Live pipeline and sub-sea structures in the construction area. PLEM to Tee section would need to be flushed with inhibitor to prevent degradation during period from Knarr Decommissioning to FLAGS cessation of production.	Live pipeline and sub-sea structures in the construction area.	All pipelines and sub-sea structures decommissioned at time of removal.
		Lifting Operations	No activity.	Live pipeline and sub-sea structures in the construction area.	Recovery of spool #8 and GRP covers post-decommissioning of area.
		Helicopter Operations	No activity.	No activity.	
		Diving Operations	No activity.	Essential intervention diving only in support of removal operations.	
		Residual Infrastructure	Residual rock dump at PLEM ends to same coverage level.	Replace displaced rock dump at P/L end.	

	Residual Risk to Other Users of the Sea	Post-removal surveys	No differentiation	No differentiation	
Environment	**Marine Impacts of Operations** (seabed disturbance, underwater noise from vessels, risk of spills etc.)	Preparatory Activity	Discharge permit required for inhibitor. Minimal activity	Displace rock cover. Remove GRP covers and cut spools.	
		Rock cover - add/disturb	Small quantity of additional rock cover required at PLEM spool ends. Permit required.	Disperse rock cover. Cover P/L end.	
		Cut/Lift	No cut or lift.	Remove spool #8 and covers.	
	Impacts on Marine end points (legacy): quantity of material left on seabed, toxicity & persistence of materials	Legacy impacts (enviro)	GRP cover over spool #8 left in situ (with rock cover). Reputational risk from leaving GRP in situ.	GRP covers and spool removed. Research re-use and/or recycle potential.	
	Energy & emissions (e.g. vessels), resource consumption (e.g. rock)	During rock cover, cutting, lifting, transit, recycling etc.	Minimal activity.	Small number of vessels. Materials recycled following removal - part of EA.	
Technical	**Risk of project failure or cost overruns**	During rock cover, cutting, lifting, transit, recycling etc.	Minimal project scope. Likely within summer operations window. Work authorisations required for PLEM activities near FLAGS pipeline and 'live' structures.	More vessel operations - but with defined scope. Small number of activities. Work authorisations required for activities near FLAGS pipeline and 'live' structures.	All nearby adjacent subsea structures will be decommissioned at time of removal of spools.
	Technology demands/track record	During rock cover, cutting, lifting, transit, recycling etc.	No significant differentiator	No significant differentiator	
Socio-economic	**Commercial impact on fisheries** (residual impact)	Post-decom effect on fisheries	No significant difference from current situation. Surveys show rock cover in good condition.	No impact.	
	Socioeconomic impact on communities (negative)	Onshore	No onshore work.	Minimal activity in handling and treating materials. Scrap value of materials only.	
	Socioeconomic impact on communities (positive)	Employment	No onshore work.	Minimal additional employment opportunity in handling and treating materials. Scrap value of materials only.	
Economic	**Cost**	Overall	Low cost.	Moderate cost.	Deferred cost. Pooling of resources during infrastructure removal.
	Cost risk/uncertainty	Overall	Residual risk from infrastructure left in-situ. Potential for future requirement to remove.	Infrastructure removed. No residual risk.	Residual risk from infrastructure left in-situ. Potential for future requirement to remove.

** Option C involves the same activities as Option B, but with activities taking place at a later date. The results for this option are only shown when found to be different than for Option B.

7 Recommendations

7.1 Knarr Gas Pipeline

Two main decommissioning options were considered:

A) leaving KGP *in situ*

B) Completely remove KGP

A comparative assessment of the decommissioning options was conducted considering all relevant criteria (safety, environmental, technical, socioeconomic and economic) before drawing conclusions.

The comparative assessment clearly shows that leaving the KGP *in situ* under the existing rock cover is the preferred decommissioning option, as it is safer, cheaper, easier and better for the environment.

7.2 Spools & GRP covers

7.2.1 Phase 2; Spools #1-7, Pipe Crossings, Mattresses & GRP Cover

Three main decommissioning options (A, B & C) were considered:

A) Leave Pipe Spools #1-7, pipe crossings & mattresses in situ under rock cover. Remove GRP cover at crossing 10.

B) Remove Pipe Spools #1-7, pipe crossings, mattresses & GRP covers - at same time as KGP decommissioning & PLEM removal

C) Remove Pipe Spools #1-7, pipe crossings, mattresses & GRP cover - delay until after FLAGS cessation of production, and remove PLEM at same time

The results presented in Table 7 show that the differences between the decommissioning options are much less clear-cut for pipe spool #1-7/mattresses/GRP cover than for the KGP.
A variation of Option B was also considered in the workshop, Option C, which would involve exactly the same removal activities as Option B, but with the removal activities taking place at a later stage.

Option C shows some advantages over Option B owing to the proximity of several spools within Spools #1-7 to live pipeline crossings, as it would be safer to delay removal until after FLAGS is decommissioned.

Gassco AS consider that either Option A (leave in situ) or Option C (remove after FLAGS cessation of production) to be the preferred solutions as it is best to minimise activity in this area until after all pipeline crossings have been decommissioned.

Option A is the preferred option, with Spools #1-7, pipe crossings & mattresses left in situ under rock cover. The GRP cover at crossing 10 would be removed, which would mean that ultimately there would be no GRP covers on the KGP UKCS left in situ.

7.2.2 Phase 3; Spool #8

Three main decommissioning options (A, B & C) were considered:

A) Leave Pipe Spool #8 & associated GRP covers in situ under rock dump

B) Remove Pipe Spool #8 & GRP covers - at same time as KGP decommissioning & PLEM removal

C) Remove Pipe Spool #8 & GRP covers - delay until after FLAGS cessation of production, and remove PLEM at same time

The results presented in Table 8 show that the differences between the decommissioning options are much less clear-cut for pipe spool #8/GRP covers than for the KGP.

Gassco AS propose to remove pipe spool #8 and GRP covers, although it is safer to minimise activity in this area until after FLAGS cessation of production. Hence, a variation of Option B was also considered in the workshop, Option C, which would involve exactly the same removal activities as Option B, but with the removal activities taking place at a later stage.

Option C shows some advantages over Option B owing to the proximity of the PLEM/Spool 8/GRP covers to the live FLAGS pipeline, as it would be safer to delay removal until after FLAGS cessation of production. Option C is the preferred option as it will eliminate risks attendant with removal works near live, hydrocarbon containing infrastructure.

The KGP was cleaned in Phase 1, Spool #8 has been isolated (valves shut at Knarr Tee downstream, and at PLEM upstream), and Spool #8 and PLEM have been injected with MEG.

7.3 Summary

This Comparative Assessment recommends that the decommissioning of the Knarr Gas Pipeline and associated facilities occurs in three phases:

1. At Knarr Cessation of Production, Phase 1 (May 2022): The Knarr Gas Pipeline was pigged and cleaned; the PLEM valves closed and PLEM/Spool#8 flooded with MEG to protect the Knarr tee from seawater

2. Phase 2, a small section of Spool#7 would be cut and taken to shore to separate the KGP from the UK sector.

3. At FLAGS cessation of production, Phase 3: Pipe Spool #8 & all GRP covers would be removed, and the PLEM would also be removed at this time.

A first Decommissioning Programme (DP) for the Knarr facilities in the UK sector covers phases 1 and 2, and a second DP will be submitted for phase 3. This Comparative Assessment report examines the full suite of decommissioning options considered.

8 References

/1/ BEIS Guidance notes on the Decommissioning of the Offshore Oil and Gas Installations and Pipelines 2018.

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/3/ A/S Norske Shell, Decommissioning of Knarr and Knarr Gas Export Pipeline: Proposal for Program for Impact Assessment, KN50-BGNO-Z-FD-0003, Rev 02M, February 2019.

/4/ Deepocean, May – July 2018, KNARR – P3039 12" Gas export pipeline 1875-DEO-1801-A-RA-0001, Pipeline – Acoustic Deep water / visual inspection.

/5/ Subsea 7, BG Development Project Knarr Layout gas export line FLAGS tie-in Project drawing no: JB02-SS7-UG20-U-XE-0001-001-06-001, Sept 2014.

/6/ Van Oord, As built report for FLAGS, 2014. Report number JB02-SS7-U-VA-0115.

/7/ Oil & Gas UK Guidelines for Comparative Assessment in Decommissioning Programmes.

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/9/ Wood 2020. KGP Decommissioning Concept Study. J003034-01-PL-REP-002.