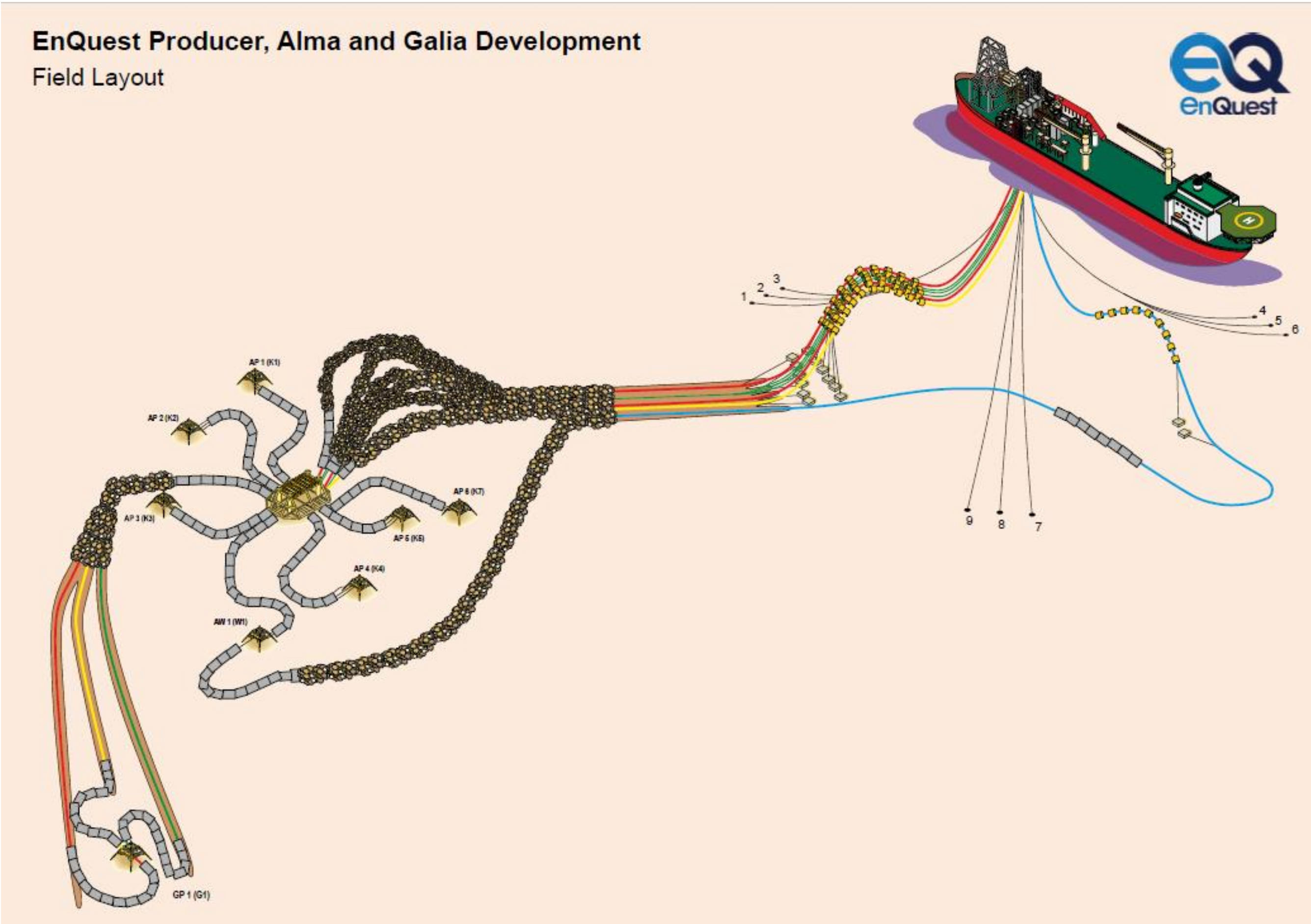
Alma & Galia Decommissioning Comparative Assessment



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1. EXECUTIVE SUMMARY

A Comparative Assessment of the pipeline and mooring system decommissioning options is a key consideration within the Decommissioning Programmes submitted to the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED).

The Alma and Galia Fields are located 315km southeast of Aberdeen in Blocks 30/24b, 30/24c & 30/25c in the Central North Sea. The fields were initially the Ardmore and Duncan fields and were redeveloped as Alma and Galia. The Alma and Galia fields are tied back to the EnQuest Producer FPSO through flexible flowlines and risers.

EnQuest Producer FPSO

The FPSO is moored in location using three clusters of three mooring lines connected to mooring piles 84in diameter. The piles in each of the three pile clusters are 32m long, 40m long and 34m long respectively. Each of the mooring lines comprises an upper and lower chain connected with wire rope. The upper and lower chains are 700m and 130m long respective, and the wire is 1150m long. The lower mooring chains rest on or are buried in the seabed from the dip down point to the padeyes on the mooring piles. The padeyes on the mooring piles are buried several metres below the seabed.

Alma

The Alma Drill Centre comprises six production wells (AP1-AP6) tied into the Alma manifold via flexible 6" production jumpers. Each of the production jumpers are protected by a series of concrete mattresses between the Alma manifold and the Alma production wells (AP1-AP6). Production from the Alma and Galia fields is routed through the Alma manifold to the EnQuest Producer FPSO via two 10" flexible production flowlines, **PL3006** and **PL3007.** There is a single water injection well (AW1) which is connected to the EnQuest Producer FPSO via an 8" flexible riser and 8" flexible flowline, **PL3008**. The Alma and Galia production and water injection wells are controlled via a single length Electro-Hydraulic Control (EHC) umbilical, **PLU3009** to the Alma manifold and then individual jumpers to each tree.

The production wells have Electrical Submersible Pumps (ESPs) installed which are serviced via three single length flexible power cables, **PL3011, PL3012** and **PL3013**.

Excluding pipespools, all of the main pipelines are manufactured using composite materials such as Kynar® PVDF/HDPE or Nylon PA12/HDPE. Each of the pipelines are independently trenched and have been left to naturally backfill over time. On approach to the Alma manifold (approximately 350m) the pipelines have been stabilised by deposited rock and concrete mattresses.

Galia

The Galia Drill Centre is located approximately 5km South West of the Alma manifold and comprises a single production well, GP1. An 8" production flexible, **PL3014** routes the process fluids from GP1 to the Alma manifold. The umbilical **PLU3015** provides chemicals and the power cable, **PL3016** provides power to the ESP. The Galia pipelines are independently trenched with the approaches to the Alma manifold (~200m) being stabilised using deposited rock and concrete mattresses. The approaches to the Galia well (~100m) are stabilised and protected using concrete mattresses.

Pipeline Burial Status

The flexible flowlines, umbilical pipelines and power cables at Alma and Galia were installed in 2012 and left to naturally backfill over time. The as-built installation survey shows depth of lowering within the trenches to be generally around 1.5m. A pipeline status survey was carried out in 2018 and the results showed that the trenches have at least partially backfilled naturally since installation. The depth of cover varies but the survey results indicated that ~35% of the total length of all the trenched pipelines found to have a depth of cover less than 0.6m. The survey data also indicated that exposures and buckled sections contribute to a length of 152m; this represents ~0.6% of the total length of the trenched and buried sections of the pipelines.

Mooring pile and mooring system decommissioning options

This document summarises a comparative assessment of the most feasible options for decommissioning the nine mooring piles and associated mooring lines. Three decommissioning options are considered for the mooring system:

- **Complete removal –** This will involve fully recovering the mooring pile and mooring line. Excavation of the mooring pile, internally and externally may be required in order to allow its recovery. All spoil heaps generated through excavation will be used to backfill the excavation of the lower mooring chain and mooring pile;
- **Partial removal –** This will involve performing a cut of the lower mooring chain and the mooring pile at 3m depth below seabed. This option will involve removing the cut sections of mooring chain and mooring pile with the remaining section of mooring chain and mooring pile remaining *in situ*. All spoil heaps generated through excavation will be used to backfill the excavation of the mooring line and mooring pile;
- **Leave *in situ*** – This involves leaving the cut end of the lower mooring chain and mooring piles *in situ* with remedial burial works carried out at the cut end of the mooring chain to ensure it is buried to 1m below seabed.

Since the decommissioning of the mooring lines between the FPSO and the dip down point is the same irrespective of which option is pursued, decommissioning of these particular sections of mooring lines is not included within the assessment.

Pipeline decommissioning options

This document summarises a comparative assessment of the most feasible options for decommissioning the following pipelines:

- Alma pipelines **PL3006**, **PL3007**, **PL3008**, **PLU3009**, **PL3011**, **PL3012**, and **PL3013**;
- Galia pipelines **PL3014**, **PLU3015** and **PL3016**.

Three decommissioning options are considered for the pipelines and cables:

- **Complete removal** – This involves the complete removal of the pipelines by whatever means would be most practicable and acceptable from a technical perspective;
- **Partial removal** – This will involve removing exposed or potentially unstable sections of pipelines. Necessary remedial work would be carried out to make the remaining pipeline safe for leaving the remainder *in situ.* Please note, this option is only relevant for those pipelines that have known exposures, either because of upheaval buckling or because of poor depth of cover. There will likely be a need to verify their status via future surveys;
- **Leave *in situ*** – This involves leaving the pipeline(s) *in situ* with no remedial works, but possibly needing to verify their status via future surveys.

The method for decommissioning of the risers or surface laid sections of pipelines and pipeline approaches is the same irrespective of which option is pursued. Therefore, decommissioning of these parts of the pipelines are not included in the assessment. All options include removal of features such as pipespools, surface laid pipelines, jumpers, concrete mattresses and grout bags in accordance with mandatory requirements.

Comparative assessment

The options were assessed using the OPRED Decommissioning guidance notes. During the assessment process, evaluations were made principally on a qualitative basis using the EnQuest established corporate risk assessment tables. The following components were assessed from a short-term (project) and longer-term (legacy) perspective:

- Technical;

- Safety;
- Environmental;
- Societal;
- Cost.

Mooring piles and mooring system assessment

Recognising that there is a trade-off between the amount of excavation versus technical feasibility, the results of the comparative assessment showed the risks and impacts of complete removal of the mooring piles to be unacceptably high from an environmental perspective and non-preferred from a technical perspective. This is primarily due to the risk of major project failure through excessive dredging and unknown loads required to recover the mooring piles. Furthermore, there is no known experience in recovering driven mooring piles either within EnQuest or within the industry. To a lesser extent the partial removal option also carries a higher technical risk due to the uncertainty around the locating of the mooring chains at 3m below seabed and the potential need for more extensive dredging to locate the mooring chain.

When assessing the options against health and safety risk, the main differences would be attributed to vessel durations and onshore material handling. The leave *in situ* option would require significantly less vessel duration and material handling than either the partial or complete removal options and would be preferred.

The environmental impacts such as energy use, emissions to air and discharges to the water column are directly related to vessel use and durations and as such would be less for leave *in situ* than for either partial removal or complete removal. However, the energy and emissions saved for the leave *in situ* option would be offset slightly by the manufacture of any replacement materials. The main differentiator when assessing the environmental impact would be seabed disturbance. The complete removal and partial removal options would involve excavation of larger volumes of seabed materials to gain access to the lower mooring chain and mooring piles in comparison to the leave *in situ* option.

When examining the societal impacts, the complete removal option would be preferred due to continuation of employment opportunities associated with vessel activities and waste management. Over the longer term however, the leave *in situ* option would be favourable due to the potential requirement for future surveys. This should not, however, be considered sufficient justification for preferring the leave *in situ* option.

The incremental cost of complete removal and partial removal options are higher than leave *in situ* by £5.37 MM and £1.44 MM respectively, dominated by vessel time.

In summary, the complete removal and partial removal options would incur much more technical risk compared to the leave *in situ* option. Finally, the leave *in situ* option would cost less to adopt.

EnQuest Producer Mooring System Summary

Decommissioning of the different mooring system components are summarised below, with the selected options highlighted with a green spot.

Mooring Piles and Associated Mooring Line Ends	Leave *in situ*	Partial removal	Complete removal
Top chain between FPSO spider and spiral strand wire rope section, 700m long.	n/a	n/a	●
Spiral strand wire rope section between top chain and bottom chain, 1150m long.	n/a	n/a	●
Bottom chain between spiral strand wire rope and dip down point, cluster 1 (107.5m), cluster 2 (91m), cluster 3 (115.5m).	n/a	n/a	●

Mooring Piles and Associated Mooring Line Ends	Leave *in situ*	Partial removal	Complete removal
Bottom chain between dip down point and the mooring pile, cluster 1 (22.5m), cluster 2 (39m), cluster 3 (14.5m). The leave *in situ* scenario would be achieved either by burying the remaining lengths of chain to at least 1m below seabed or by chasing and cutting the chain to at least 1m below seabed and recovering the rest of the chain not attached to the mooring pile.	●		
Mooring Pile, cluster 1 (32m long), cluster 2 (40m long), cluster 3 (34m long).	●		

Pipeline decommissioning assessment

From a technical perspective there is little to differentiate the complete removal, partial removal or leave *in situ* decommissioning options. Complete removal would present a marginally higher risk due to the non-standard operation of pulling flexible flowlines, umbilical pipelines and power cables through deposited rock and naturally backfilled trenches, but this is an activity that has been done before. Furthermore, there are contingency methods available such as use of a mass flow excavator that could be used to disperse overlying deposited rock and sediment and so the complete removal option is seen as broadly acceptable from a technical perspective. The partial removal option would involve excavating the buckled and exposed lengths of pipeline locally and removing the short sections of flowline and power cable using the 'cut and lift' method but this is a relatively inefficient method for recovering flowlines that could otherwise be recovered using reverse reeling or reverse s-lay, and so would not be preferred. The leave *in situ* approach to decommissioning has been done before and is technically feasible.

From an environmental perspective, lower risks and impacts would be incurred for the leave *in situ* option than for any of the other decommissioning options, as environmental impacts would be directly related to vessel durations and extent of activity on the seabed.

The societal assessments showed that complete removal would be marginally beneficial because of a continuation of employment due to an extension of vessel use and onshore waste management activities. In the short-term, fishing activities might proportionately be disrupted as decommissioning activities increase. Conversely, fishing activities could be affected by legacy pipeline surveys and possible remedial work in future, but there is nothing significant to differentiate the options.

The results the assessment showed the short-term risks and impacts of all pipeline decommissioning options to be broadly acceptable. Just the two umbilical pipelines (**PLU3009** and **PLU3015**) and the Galia power cable (**PL3016**) have no exposures along the trenched and buried sections of their length. The four flowlines **PL3006**, **PL3007**, **PL3008** and **PL3014** each exhibit multiple exposures and spans that have resulted from upheaval buckling. As a result, leaving these *in situ* would present significant snagging hazards for fishing activity over the longer-term, and is unlikely to be acceptable and would likely warrant more pipeline surveys in future. Each of the three Alma power cables (**PL3011**, **PL3012** and **PL3013**) also suffer from a short exposure along their length and these could also pose a snagging hazard for fishing activity over the longer-term. Potentially these are not as significant as the buckled sections of the flowlines. There is less potential for snagging associated with leaving the trenched and buried sections of the remaining umbilical pipelines and power cables *in situ*.

Finally, although the leave *in situ* option would cost less to achieve than either complete removal or partial removal in the short-term, the gains are marginal when considering the longer-term requirement for pipeline status surveys. In the case of the four flowlines and to a lesser extent the three Alma power cables, we believe that the uncertainties associated with legacy elements are such that the cost of addressing future legacy elements could offset any short-term financial savings associated with removing the buckled and exposed elements rather than completely removing the four flowlines and three power cables.

All of the pipelines will need at least the surface laid sections to be removed. We believe that the trenched and buried sections of just three out of the ten pipelines could be left *in situ* without some form of remedial work, while all the remaining pipelines would benefit from being either partially or completely removed. However, should either the leave *in situ* or partial removal decommissioning options be pursued there will be a requirement for pipeline status surveys and possible intervention work over the longer-term.

All the decommissioning options would be technically achievable. There is little to differentiate the options from a safety, environmental, societal or cost perspective and therefore, in order to remove the uncertainty concerning the requirement for pipeline status surveys in future, the recommendation is that the infrastructure be fully recovered to shore.

It is perhaps worth noting that it is likely that in adopting the partial removal and leave *in situ* decommissioning options that more ‘cut and lift’ activities would be required for lengths of surface laid pipelines that would be too short to be removed using the reverse reeling method of recovery.

Summary of decommissioning proposals

Decommissioning of the different pipeline components are summarised below, with the selected options highlighted with a green spot.

Alma Pipeline Summary:

PL3006 10in Production Flowline, P1 2203m long	Leave *in situ*	Partial removal	Complete removal
PL3006. 8in production riser between FPSO and ‘hot-tap’ tee (355m long), suspended in seawater using buoyancy modules.	n/a	n/a	●
The section of 10in flowline that is surface laid between the hot tap tee and trench transition but currently within the existing FPSO 500m zone (~115m long).	n/a	n/a	●
The section of 10” flowline that is trenched and buried but with upheaval buckling exposures and then buried under deposited rock nearer the Alma manifold (~1305m long).			●
6in flowline jumpers. PL3006JAP1 (61.8m long), ‘JAP2 (57.6m), JAP3 (44.7m), JAP4 (64m), JAP5 (40m), JAP6 (57m) between various wellheads and Alma production manifold, protected and stabilised using concrete mattresses and grout bags.	n/a	n/a	●

PL3007 10in Production Flowline, P2 2151m long	Leave *in situ*	Partial removal	Complete removal
PL3007. 8in production riser between FPSO and ‘hot-tap’ tee (352m long), suspended in seawater using buoyancy modules.	n/a	n/a	●
The section of 10in flowline that is surface laid between the hot tap tee and trench transition but currently within the existing FPSO 500m zone (~130m long).	n/a	n/a	●
The section of 10” flowline that is trenched and buried but with several upheaval buckling exposures and then buried under deposited rock nearer the Alma manifold (~1291m long).			●

PL3008 8in Water Injection Flowline, 2454m long	**Leave *in situ***	**Partial removal**	**Complete removal**
PL3008. 8" water injection riser between FPSO and WI flowline tie-in flange (343m long), suspended in seawater using buoyancy modules.	n/a	n/a	●
The section of 8in flowline that is surface laid between the hot-tap tee and trench transition but currently within the existing FPSO 500m zone (~516m long). Part of the flowline is overlain by eight concrete mattresses that serve as dropped object protection near the FPSO.	n/a	n/a	●
The second section ~1420m long between the trench transition and the Alma water injection wellhead AW1 is trenched and buried albeit having experienced upheaval buckling and has several exposures, and part is buried under deposited rock. The final section ~52m long is surface laid and overlain and protected by concrete mattresses and grout bags.			●

PLU3009 200mm diameter Electro-Hydraulic-Control Umbilical Pipeline, 2.138m long	**Leave *in situ***	**Partial removal**	**Complete removal**
PLU3009. EHC umbilical pipeline between FPSO and 'touch down point' (346m long), suspended in seawater using buoyancy modules.	n/a	n/a	●
The surface laid section of umbilical between 'touch-down point' and trench transition point (~262m long)	n/a	n/a	●
The section of umbilical that is trenched and buried in the seabed but is also buried under deposited rock nearer the Alma manifold (~1295m long).			●
The section of umbilical between the end of the deposited rock trench transition and the Alma manifold (~19m long).	n/a	n/a	●
Umbilical jumpers PLU3009/JAP1 (78m long), 'JAP2 (72m), JAP3 (60m), JAP4 (79m), JAP5 (56m), JAP6 (72m) between various wellheads and Alma production manifold, protected and stabilised using concrete mattresses and grout bags.	n/a	n/a	●

PL3011 200mm diameter ESP A Power Cable, 2177m long	**Leave *in situ***	**Partial removal**	**Complete removal**
PL3011. Power cable between FPSO and 'touch down point', (346m long) suspended in seawater using buoyancy modules.	n/a	n/a	●
The section of power cable between 'touch-down point' and trench transition point (~265m long).	n/a	n/a	●
The section of power cable that is trenched and buried in the seabed but is also buried under deposited rock nearer the Alma manifold (~1280m long).			●
The section of power cable between the end of the deposited rock trench transition and the Alma manifold (~19m long).	n/a	n/a	●
Power cable jumpers. PL3011JAP1 (2x75m long), 'JAP2 (2x74m), 'JAP3 (2x68m), 'JAP4 (2x83m), 'JAP5 (2x59m), 'JAP6 (2x76m long) between Alma manifold and various wellheads, protected and stabilised by concrete mattresses and grout bags on the approaches.	n/a	n/a	●

PL3012 251mm ESP B Power Cable, 2150m long	Leave *in situ*	Partial removal	Complete removal
Power cable between FPSO and 'touch down point' (346m long), suspended in seawater using buoyancy modules.	n/a	**n/a**	●
The section of power cable between 'touch-down point' and trench transition point (~265m long).	n/a	**n/a**	●
The section of power cable that is trenched and buried in the seabed but is also buried under deposited rock nearer the Alma manifold (~1285m long).			●
The section of power cable between the end of the deposited rock trench transition and the Alma manifold (~19m long), protected and stabilised by concrete mattresses and grout bags.	n/a	**n/a**	●

PL3013 251mm ESP C Power Cable, 2135m long	Leave *in situ*	Partial removal	Complete removal
Power cable between FPSO and 'touch down point' (346m long), suspended in seawater using buoyancy modules.	n/a	**n/a**	●
The short section of power cable between 'touch-down point' and trench transition point (~266m long).	n/a	**n/a**	●
The section of power cable that is trenched and buried in the seabed but is also buried under deposited rock nearer the Alma manifold (~1290m long).			●
The section of power cable between the end of the deposited rock trench transition and the Alma manifold (~19m long), protected and stabilised by concrete mattresses and grout bags.	n/a	**n/a**	●

Note: Final pipeline lengths are as-built lengths and as such may vary slightly from lengths detailed within the PWAs.

Galia Pipeline Summary:

PL3014 8in Production Flowline, 5134m long	Leave *in situ*	Partial removal	Complete removal
The 8in production flowline between Alma manifold and the trench transition or deposited rock is overlain protected by concrete mattresses and grout bags. Total length of this section ~65m.	n/a	n/a	●
The 8in production flowline that is trenched and buried (total ~4884m long), mostly in the seabed, but partly buried under deposited rock (~205m long). The flowline has experienced upheaval buckling and therefore several parts are exposed.			●
The surface laid section between the trench transition and the Galia production wellhead GP1 (~65m long) that is overlain and protected by concrete mattresses and grout bags.	n/a	n/a	●

PLU3015 118.5mm diameter Electro-Hydraulic-Control Umbilical, 5060m long	**Leave *in situ***	**Partial removal**	**Complete removal**
The EHC production control umbilical between Alma manifold and the trench transition or deposited rock is overlain protected by concrete mattresses and grout bags. Total length of this section ~175m.	n/a	n/a	●
The umbilical that is trenched and buried (total ~4825m long), mostly in the seabed, but partly buried under deposited rock (~158m long).			●
The surface laid section between the trench transition and Galia GP1 (~150m long) that is overlain and protected by concrete mattresses and grout bags.	n/a	n/a	●
PLU3015 EHC production control umbilical jumper between the Galia SUTU and the Galia GP1 Xmas tree, 8m long.	n/a	n/a	●

PL3016 145mm diameter ESP Power Cable, 5050m long	**Leave *in situ***	**Partial removal**	**Complete removal**
The ESP power cable between Alma manifold and the trench transition or deposited rock is overlain protected by concrete mattresses and grout bags. Total length of this section ~275m.	n/a	n/a	●
The ESP power cable that is trenched and buried (total ~4690m long), mostly in the seabed, but partly buried under deposited rock (~235m long).			●
The surface laid section between the trench transition and Galia GP1 (~90m long) that is overlain and protected by concrete mattresses and grout bags.	n/a	n/a	●
PL3016 ESP power cable jumpers 01 and 02 between the Galia GP1 Xmas tree and the Galia SPCDU SP01 & SP02 protected and stabilised using concrete mattresses and grout bags, 8m long;	n/a	n/a	●
PL3016 ESP power cable jumpers 01 and 02 between the Alma manifold SPCDU and the Galia SPCDU protected and stabilised using concrete mattresses and grout bags, 20m long.	n/a	n/a	●

Note: Final pipeline lengths are as-built lengths and as such may vary slightly from lengths detailed within the PWAs.

Post-decommissioning clear seabed verification

Post- decommissioning verification of a clear seabed will be carried out in accordance with the commitments made in the Decommissioning Programmes.

TABLE OF CONTENTS

FIGURES AND TABLES

ABBREVIATION	EXPLANATION
AHV	Anchor Handling Vessel
ALARP	As Low As Reasonably Practicable
AP1 through 9	Alma mooring pile AP1 through to AP9
AP1 through AP6	Alma Production Wells K1 through K7 respectively, noting that K6 is partially decommissioned with infrastructure rerouted to K7
Approach	Initial or final stretch of pipeline, umbilical pipeline or power cable as it leaves its point of origin or reaches its destination. Typically a pipeline will be protected and stabilised using concrete mattresses and grout bags in the approaches
AW1 & AW2	Alma Water Injection Wells (AW2 - future not installed)
CSV	Construction Support Vessel
Cut and lift	The 'cut and lift' method of recovery would involve local excavations and cutting followed by recovery of the pipeline in manageable lengths. The length retrieved will depend on the diameter of the pipeline, materials of manufacture and stiffness
dia.	Diameter
DOC	Depth of Cover
DOL	Depth of Lowering
Driven pile	Piles that are installed using an hydraulic hammer to achieve the required depth
DSV	Diving Support Vessel
EA	Environmental Appraisal
EHC	Electro-Hydraulic Control
ESP	Electrical Submersible Pump
EnQuest	EnQuest Heather Limited
FishSAFE	The FishSAFE database contains a host of oil & gas structures, pipelines and potential fishing hazards. This includes information and changes as the data are reported for: pipelines and cables, suspended wellheads, pipeline spans, surface & subsurface structures, safety zones & pipeline gates (www.fishsafe.eu)
Flowline	Pipeline that connects a wellhead to a manifold or process equipment. In this context manufactured from a mixture of steel and composite materials
FPSO	EnQuest Producer Floating, Production, Storage, Offloading (Vessel)
HAZID	Hazard Identification
HSEQ	Health, Safety, Environment and Quality
"	Inch; 25.4 millimetres
Jumper(s)	Relatively short lengths of pipespools, flowline, umbilical pipeline cores or power cables connect oil field equipment such as main pipelines, Xmas trees, and manifolds.
km	Kilometre
KP	Kilometre Post (Distance along pipeline from point of origin)
LAT	Lowest Astronomical Tide
m	Metre(s)
MM	Million
Mooring line	Comprises an upper and lower chain connected with wire rope

ABBREVIATION	EXPLANATION
N,S,E,W	North, South, East, West
n/a	Not Applicable
N/A	(Data) Not Available
NORM	Naturally Occurring Radioactive Material
OPRED	Offshore Petroleum Regulator for Environment and Decommissioning
P1, P2	Production Flowline Identifier
Pipeline(s)	Generic term to include flexible flowline, umbilical pipeline and power cable as defined by OPRED.
Pipespool(s)	Short sections of rigid pipe that may be flanged and bolted or welded together
PL	Pipeline Identification numbers (UK). Used to identify pipelines, flowlines, umbilical pipelines and power cables
Power	Electrical power (using copper as a conductor) as opposed to hydraulic power
PVDF/PA12	Polyvinylidene fluoride (Kinar® PVDF/PA12 Polyamide 12) resins are used for chemical resistance
PVDF/HDPE	Polyvinylidene fluoride/High Density polyethylene; flexible plastic pipe
PWA	Pipeline Works Authorisation
Qualitative	Result determined using judgement and use of risk and impact matrices
Quantitative	Result determined using numerical data and by calculation
Reverse Reel	Flexible pipelines can be recovered from the seabed by reeling them from the seabed onto a pipeline reel mounted on to a suitable vessel. The method is known as "reverse reeling”
Riser	A conduit that provides an extension of a subsea oil well to a surface production facility
SFF	Scottish Fishermen’s Federation
SPCDU	Subsea Power & Communications Distribution Unit
Suction pile	Once a suction pile has been positioned, rather than using hydraulic hammers, suction pumps are used to evacuate seawater from within the top of the enclosed pile pulling the pile into the seabed
UK	United Kingdom
Umbilical	An umbilical pipeline has multiple functions, including: 1. Provides hydraulic power to subsea control systems, such as to open/close valves 2. Provides electric power and control signals to subsea control systems 3. Delivers production chemicals for subsea injection at tree or downhole.
WI	Water Injection
x	Number of (e.g. 16x = 16 in Number)

Intolerable / High	Impacts are intolerable. Controls and measures to reduce impact to ALARP (at least to Medium) and require identification, documentation, implementation and approval.
Tolerable / Medium	Risks are tolerable and managed to ALARP. Controls and measures to reduce risks to ALARP require identification, documentation and approval by responsible leader.

Broadly Acceptable / Low & least preferred	Risks broadly acceptable but controls shall be subject to continuous improvement through the implementation of the HSEQ Management System and in light of changes such as technology improvements; performance in other ‘broadly acceptable’ options marginally better.
Broadly Acceptable / Low & in-between least & most preferred	As above, but performance of this option is marginally better or marginally worse than others.
Broadly Acceptable / Low & most preferred	As above but performance in other ‘broadly acceptable’ options marginally worse.

2. INTRODUCTION

2.1 Overview

The Alma and Galia Fields are located 315km southeast of Aberdeen in Blocks 30/24b, 30/24c & 30/25c in the Central North Sea. The fields were initially the Ardmore and Duncan fields and were redeveloped as Alma and Galia. The water depth at Alma Galia is ~80m. Figure 2.1.1 shows the overall field layout.

The Alma Galia development comprises:

- FPSO;
- Six subsea production wells at the Alma Drill Centre;
- A single water injection well at the Alma Drill Centre;
- A single production well at the Galia Drill Centre;
- Alma Production Manifold;
- Flexible flowlines (Production, Water Injection, EHC Umbilical, ESP) between the FPSO and Drill Centres.

Subsea wells are tied back to the FPSO through flexible flowlines and risers.

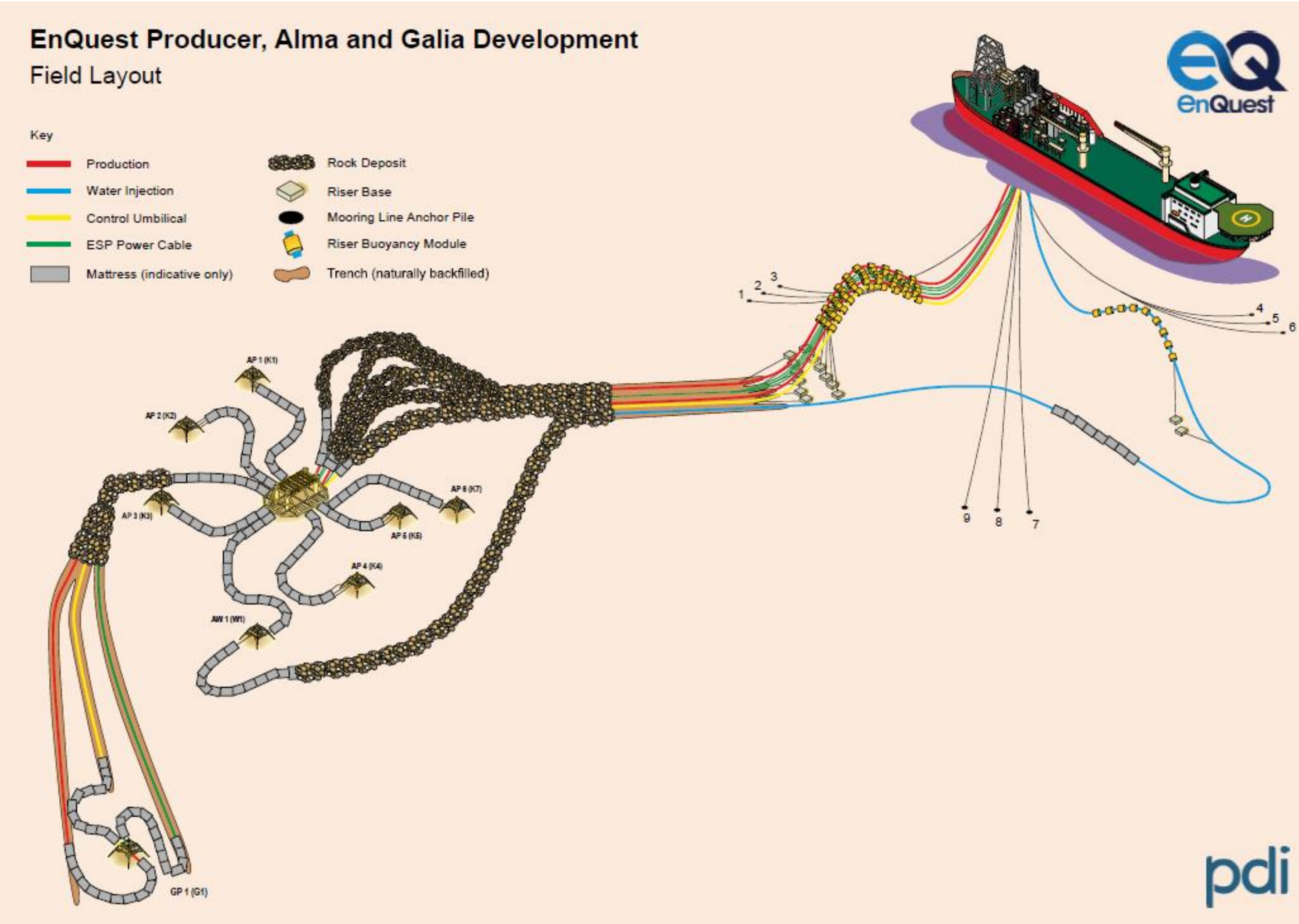

Figure 2.1.1: Alma Galia Field Layout

2.1.1 Alma Pipelines

PL3006 and **PL3007** are the production flowlines from the FPSO to the Alma manifold made up of an 8" dynamic riser section and a 10" static flowline section. **PL3008** is the 8" water injection flowline between the FPSO and the AW1 water injection tree. The Alma production trees are fitted with ESPs and derive their power from the FPSO via three single length buried and trenched power cables, **PL3011**, **PL3012** and **PL3013** respectively. The Alma manifold and Xmas trees derive their power, hydraulic controls and chemicals from the FPSO via a trenched and buried EHC umbilical, **PLU3009**. Individual flexible production jumpers, power cables, hydraulic and chemical jumpers are connected between the Alma manifold and the Xmas trees, stabilised and protected by concrete mattresses. The flexible production jumpers are connected to the Xmas trees via rigid drop down pipespools. The Alma pipeline lengths are detailed below in Table 2.1.1.

Pipeline ID	Description, Size & Quantity
PL3006	Alma 8"/10" P1 production flowline, 2203m long, excluding jumpers[1]
PL3007	Alma 8"/10" P2 production flowline, 2151m long
PL3008	8" Alma water injection flowline, 2454m long
PLU3009	Alma EHC production control umbilical pipeline, 2138m long, excluding jumpers[2]
PL3011	Alma ESP power cable A, 2177m long, excluding jumpers[3]
PL3012	Alma ESP power cable B, 2150m long
PL3013	Alma ESP power cable B, 2135m long
	For details of pipeline stabilisation features please refer Decommissioning Programmes [1]

Table 2.1.1: Alma pipeline summary

2.1.2 Galia Pipelines

PL3014 is the flexible 8" Production flowline from the Alma manifold to the GP1 tree, trenched and buried along the majority of its length. The single production well at Galia, GP1 is fitted with an ESP which is powered via a trenched and buried power cable, **PL3016**. The Galia production tree GP1 derives its power, hydraulic controls and chemicals via umbilical pipeline **PLU3015** which is trenched and buried between the Galia drill centre and the Alma manifold. The Galia pipeline lengths are detailed in Table 2.1.2.

Pipeline ID	Description, Size & Quantity
PL3014	Galia 8" GP1 production flowline, 5134m long
PLU3015	Galia production control umbilical pipeline, 5060m long
PL3016	Galia ESP power cable, 5050m long
	For details of pipeline stabilisation features please refer Decommissioning Programmes [1]

Table 2.1.2: Galia pipeline summary

[1] The six PL3006 production flowline jumpers range in length from between 40.5m and 80m
[2] The eight PLU3009 umbilical pipeline jumpers range in length from between 42m and 78m
[3] The six PL3011 power cable jumpers range I length between 68m and 83m

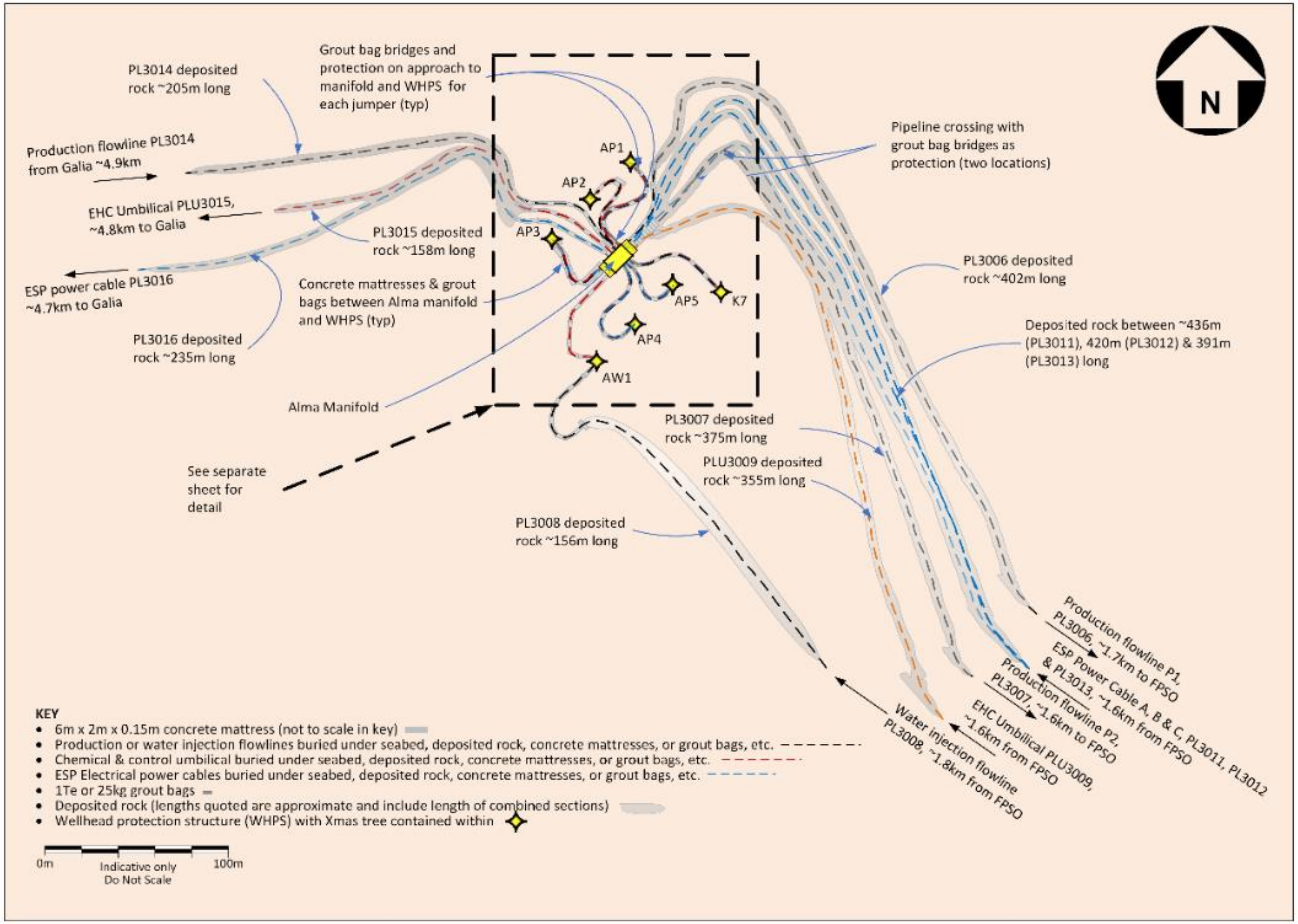

Figure 2.1.2: Alma Drill Centre Layout- Overview

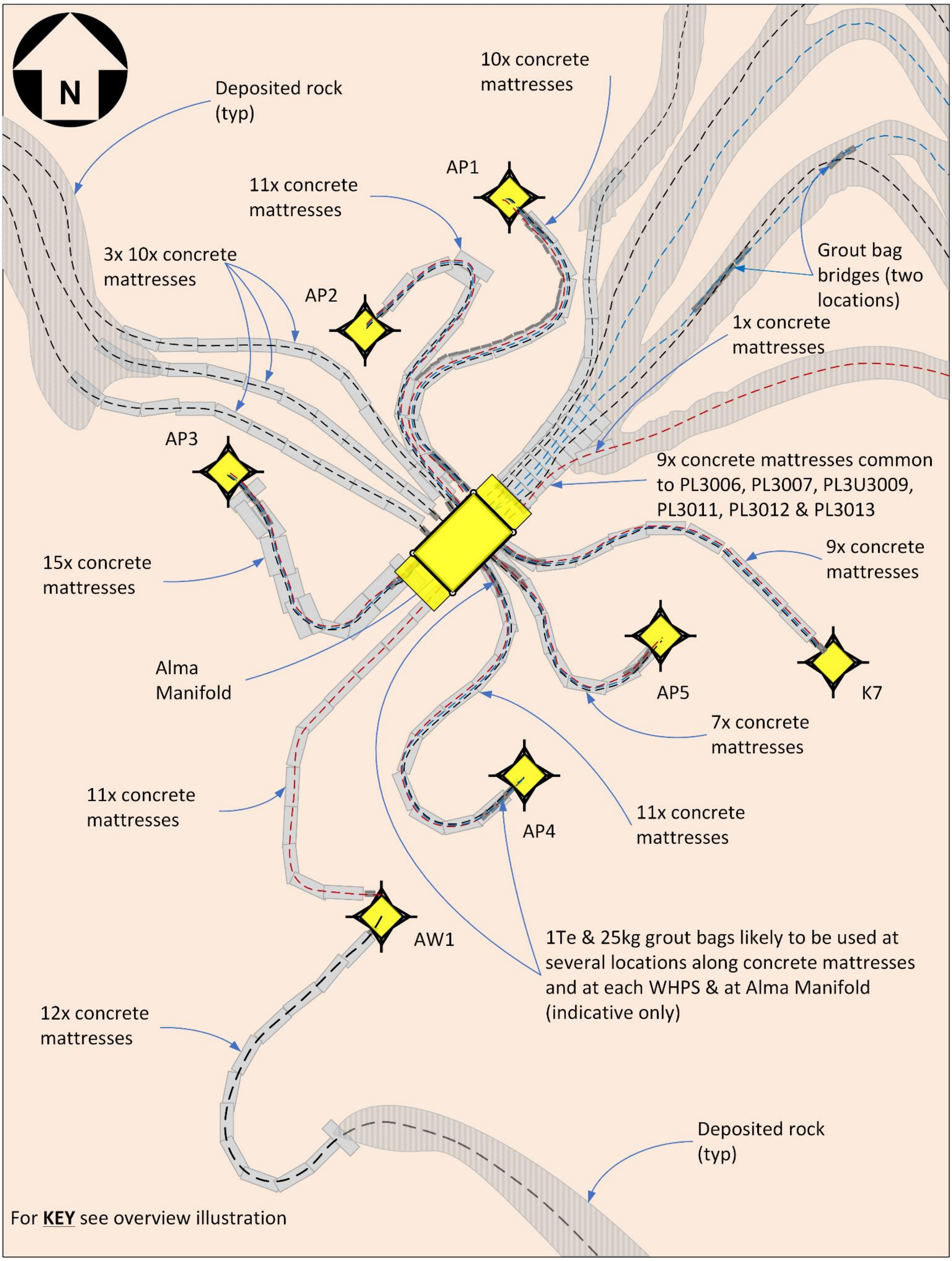

Figure 2.1.3: Alma Drill Centre Layout - Detail

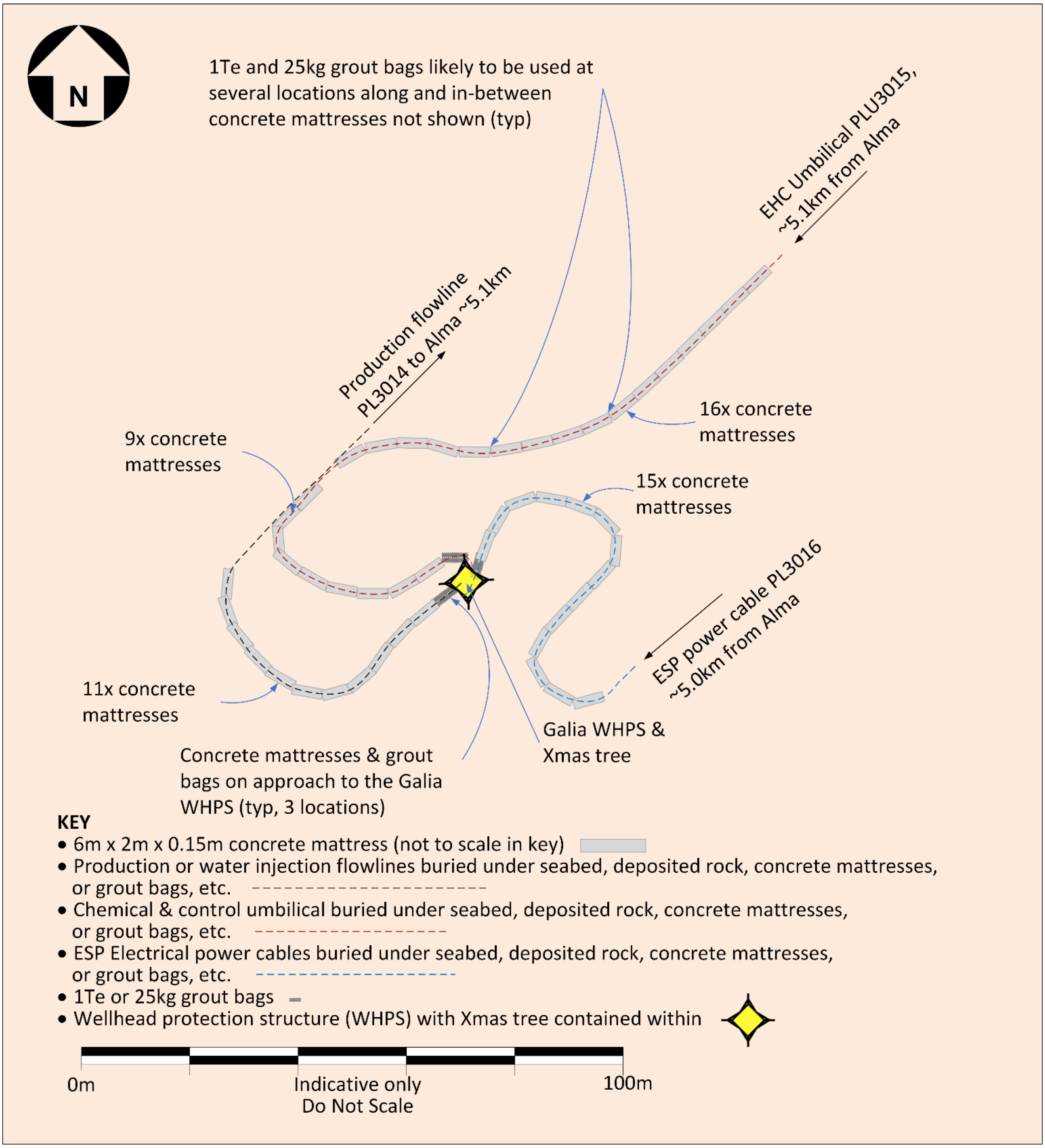

Figure 2.1.4: Galia Drill Centre Layout

2.1.3 Pipeline / Cable Construction Overview

The different pipeline constructions and relative sizes are indicated to a common scale in Figure 2.1.5 and Figure 2.1.6.

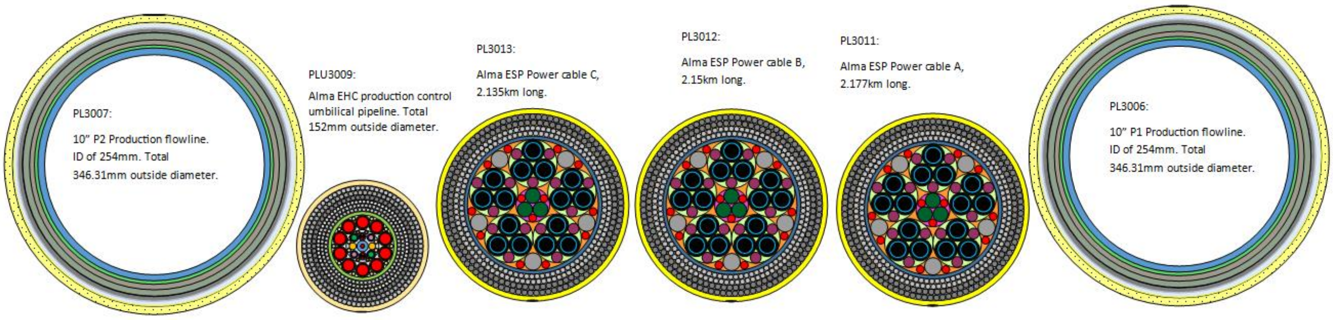

Figure 2.1.5 – Alma Flowline, Umbilical and Power Cable Cross Sections

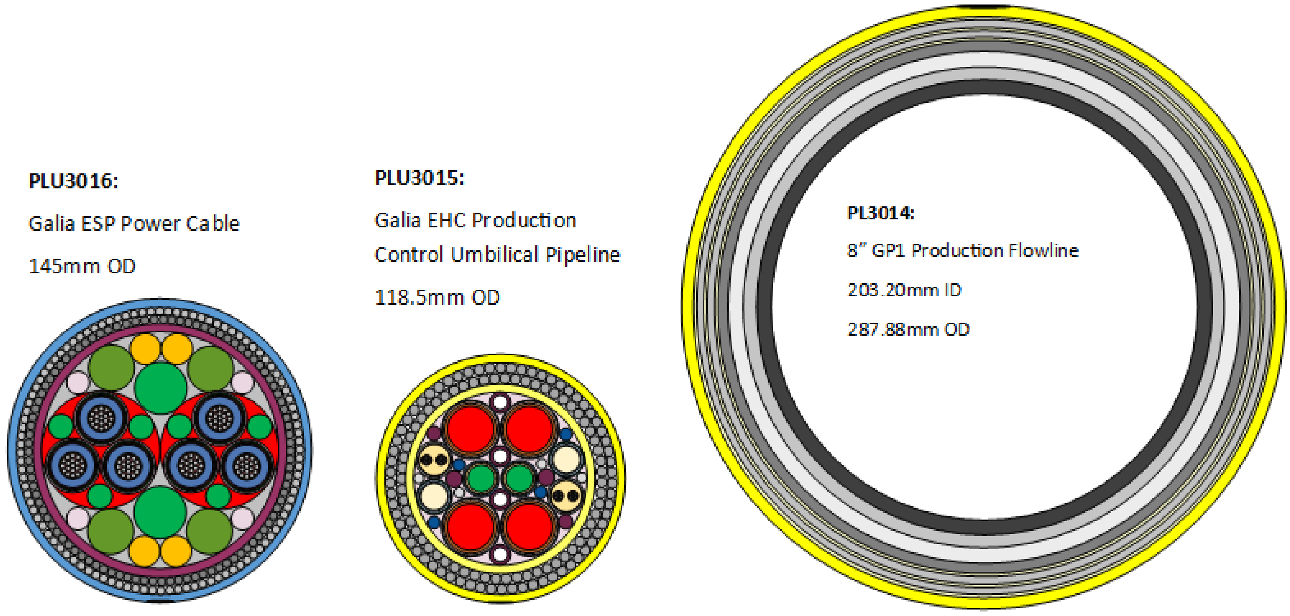

Figure 2.1.6: Galia Flowline, Umbilical and Power Cable Cross Sections

2.2 Purpose

As per the OPRED guidance notes [3] pipeline decommissioning options require to be comparatively assessed. Further, if the condition of the mattresses or grout bags precludes their safe or efficient removal, then any proposal to leave them in place must be supported by an appropriate comparative assessment of the options.

Following public, stakeholder and regulatory consultation, the Alma and Galia Decommissioning Programmes will be submitted in full compliance with the OPRED guidance notes [3]. The Decommissioning Programmes [1] explain the principles of the removal activities and are supported by an Environmental Appraisal [2] and this Comparative Assessment.

2.3 Environmental Setting

2.3.1 Overview

The seabed depth along the pipelines generally varies between LAT end depths as follows:

- 76.6m at the start of the flowline section (FPSO side) to 78.4m at Alma manifold north east face;

- 78.6m at Alma manifold north-west face to 75m at Galia drill centre.

The seabed within the Alma and Galia fields is uniform with occasional shell fragments. There are north north-east to south south-west orientated ripples in the east of the Alma development area, where mud in-fills troughs, and coarser sediments accumulate along the banks of the ripples. There are several sites of seabed depressions located across the Alma development area, ranging from 10 to 20 metres, up to 0.5 kilometres in length, and maximum gradient of 18º, which are likely to be associated with the decommissioning of the Argyll/Ardmore field. The sediment across the Galia development area can be described as featureless and generally homogeneous.

Commercial fishing activity within the vicinity of the project area is very low. Landings are predominantly demersal species. The most common gear types observed in the region were trawls, however, fishing effort in the project area has been undisclosed in recent years.

The flexible flowlines, umbilical pipelines and power cables at Alma and Galia were installed in 2012 and left to naturally backfill over time. The post installation survey shows Depth of Lowering (DOL) within the trenches to be generally around 1.5m. A pipeline survey was carried out in 2018 with the Depth of Cover (DOC) recorded, indicating that the trenches have only partially backfilled naturally since installation. The DOC varies over the lengths of the pipelines with approximately 35% of the total length of all trenched pipelines found to have a DOC less than 0.6m. The 2018 survey data indicated that exposures and buckled sections contribute to a total length of 146m which represents ~0.5% of the total length of the trenched and buried sections of the pipelines.

The pipeline burial profiles are presented in Section 4.

2.3.2 Deposited rock

While it is considered physically possible to remove deposited rock, the decommissioning philosophy in this document is consistent with the OPRED Guidance Notes [3], hence all deposited rock will be left *in situ*.

Material left in place will preserve the marine habitat that will have established over the time it has been on the seabed, and in this case its presence will not have a negative impact on the environment, nor impact on the safety of other users of the sea.

Methods that could be used to remove the rock include:

- Excavating the rock and disposing of the material at an approved offshore location;
- Excavating the rock and transporting the material to shore to be disposed of in an approved manner;
- lifting the rock using a grab vessel, depositing in a hopper barge and transporting it to shore for appropriate disposal.

All these proposed methods would impact on the seabed and associated communities, create sediment plumes, and require additional vessel use with the associated environmental impacts, safety risks, impacts on other users of the sea and additional costs.

2.3.3 Concrete mattresses

There are 194 concrete mattresses installed within the Alma and Galia fields, all of the same type (6m x 3m x 0.15m). The locations and condition of each of the concrete mattresses and proposals for decommissioning are detailed in the Decommissioning Programmes [1].

2.4 Assumptions, Limitations and gaps in Knowledge

The most significant assumptions, limitations and knowledge gaps relating to the comparative assessment are listed below. In addition, it should be noted that the presentation of the different categories of risks for comparison has required a degree of engineering judgement, which includes the following technical assumptions:

- Complete removal of the pipelines is considered achievable by reverse reeling since the trenches have been allowed to backfill naturally. This material could be displaced with little overall disturbance;
- Integrity of the pipelines is sufficient to allow recovery through buried sections and areas of rock placement;
- The mooring piles are not exposed and according to the original as-built information with the except for one mooring pile that is buried to 0.75m, the tops of the mooring piles are buried to at least 1.0m below seabed;
- Any spoil heaps arising from the excavation associated with decommissioning the mooring system would need to be mechanically backfilled;
- EnQuest is not aware of any fishing gear snagging reports. To our knowledge no exposures have been of such a magnitude that they have warranted being recorded as a snagging hazard via Kingfisher Information Services in FishSAFE (www.fishsafe.eu).

The following legacy assumptions have also been made:

- An environmental survey would be required on completion of decommissioning activities;
- Any pipeline being left *in situ* would be subject to at least three legacy burial surveys owing to relatively poor depth of cover for some of the pipelines;
- The mooring piles would be subject to at least three legacy burial surveys, although if the chains and piles were cut to -3m below seabed, no legacy surveys would be required;
- The seabed sediment type is such that any spoil heaps created during any decommissioning operations would not present significant snagging hazards, although any spoil heaps created during excavation activities around cut ends or around the mooring piles would be mechanically backfilled;
- In the long term, deposited rock would not present snagging hazards;
- The impact of the procurement of any new materials such as fabricated items or mining of new rock is ignored;
- Impact on commercial activities is inversely proportional to vessel activity;
- Societal benefits and vessel associated environmental impacts and risks are assumed to be proportional to vessel duration;
- Only a high-level comparison of what differentiates the costs is used.

3. THE MOORING PILES AND MOORING SYSTEM

3.1 Overview

The EnQuest Producer is moored using three clusters of three mooring lines in each. The angular spacing between each cluster of mooring lines is 120° and the spacing between adjacent mooring lines in each cluster is 3°.

Within each mooring line there are the following components as detailed in Figure 3.1.1;

Description	Component	Length
Top Chain	142mm stud link chain (255kg/link)	700m
Wire Rope	125mm sheathed spiral strand wire	1150m
Bottom Chain	142mm stud link chain	130m

Table 3.1.1: Mooring Line Composition

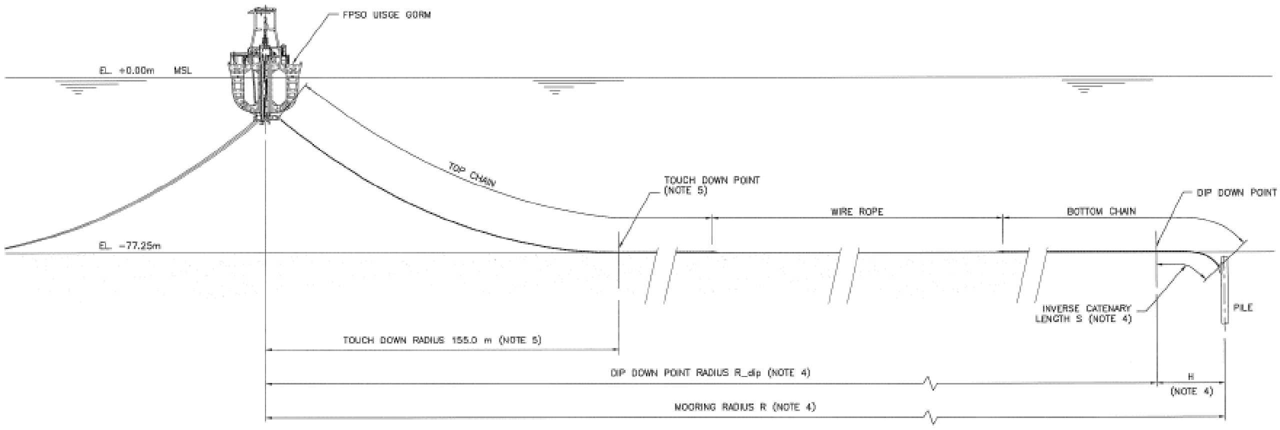

Figure 3.1.1: Mooring Line Layout

Each mooring chain is connected into a mooring pile, driven below the seabed to the depths shown in Table 3.1.2. Since hook up of the FPSO, no survey has been carried out of the bottom chain and mooring pile sections. The pile depths are determined from as-built installation records.

Description	Pile Length	Depth of Pile below seabed
Mooring Pile 01	32m	0.75m
Mooring Pile 02	32m	1m
Mooring Pile 03	32m	1m
Mooring Pile 04	40m	1m
Mooring Pile 05	40m	1m
Mooring Pile 06	40m	1.4m
Mooring Pile 07	34m	1m
Mooring Pile 08	34m	1m
Mooring Pile 09	34m	1m

Table 3.1.2: Mooring Pile Burial Depths

4. THE FLOWLINES, UMBILICAL PIPELINES AND POWER CABLES

4.1 Pipeline Crossings

There are no third party pipeline crossings within any of the Alma or Galia pipelines.

4.2 PL3006 Alma 8in/10in P1 production flowline

PL3006 is a flexible pipeline that is approximately 2203m long, made up of an 8in 355m dynamic riser and a 10in 1848m static flexible. The riser and flowline sections are connected via a flanged rigid hot tap tee section. It was laid in 2012 into an open trench and left to naturally backfill. A pipeline status survey conducted in 2018 shows that the flowline is buried with a reasonable depth of cover with some exposures. Refer Figure 4.2.1.

The first 115m of the flowline is unburied with no concrete mattress or deposited rock protection. The next 1305m of the flowline is trenched with the final section between the trench transition and the approach to the Alma manifold being buried by deposited rock. The final 41.5m to the Alma manifold is covered by 9 concrete mattresses dedicated to **PL3006** and an additional 9 concrete mattresses covering all the pipelines at the North East entrance to the Alma manifold.

Details of the exposures are included within Table 4.2-1.

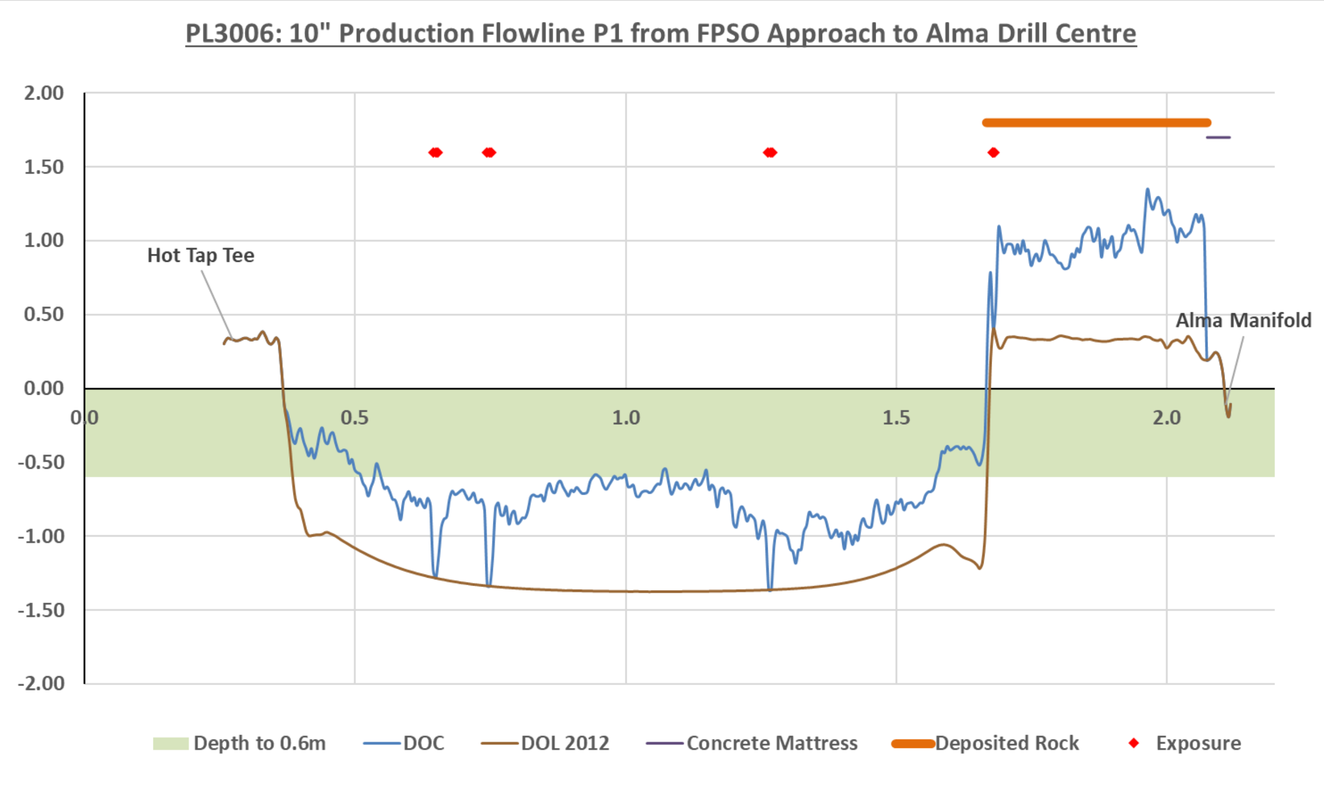

Figure 4.2.1: PL3006 Pipeline Burial Profile

KP	Exposure Type	Length (m)	Width (m)	Height (m)
0.65	90% exposure in trench	8.1	0	N/A
0.75	100% exposure in trench	7.6	0.1	N/A
1.26	75% exposure in trench	9.1	0	N/A
1.68	90% exposure in within rock	3.0	0	N/A

Table 4.2-1: PL3006 Exposure Details

4.3 PL3007 Alma 8in/10in P2 production flowline

PL3007 is a flexible pipeline that is approximately 2151m long, made up of a 8in 352m dynamic riser section and a 10in 1799m static flexible section. The riser and flowline sections are connected via a flanged rigid hot tap tee section. It was laid in 2012 into an open trench and left to naturally backfill. A pipeline status survey conducted in 2018 shows that the flowline is buried with relatively poor depth of cover in some areas. Refer Figure 4.3.1.

The first 130m of the flowline section is unburied with no mattress or deposited rock protection. The next 1291m of the flowline is trenched with the final section between the trench transition and the approach to the Alma manifold being buried with deposited rock. The final 19m to the Alma manifold is covered by 9 concrete mattresses covering all the pipelines at the North East entrance to the Alma manifold.

Details of the upheaval buckling are included within Table 4.3-1.

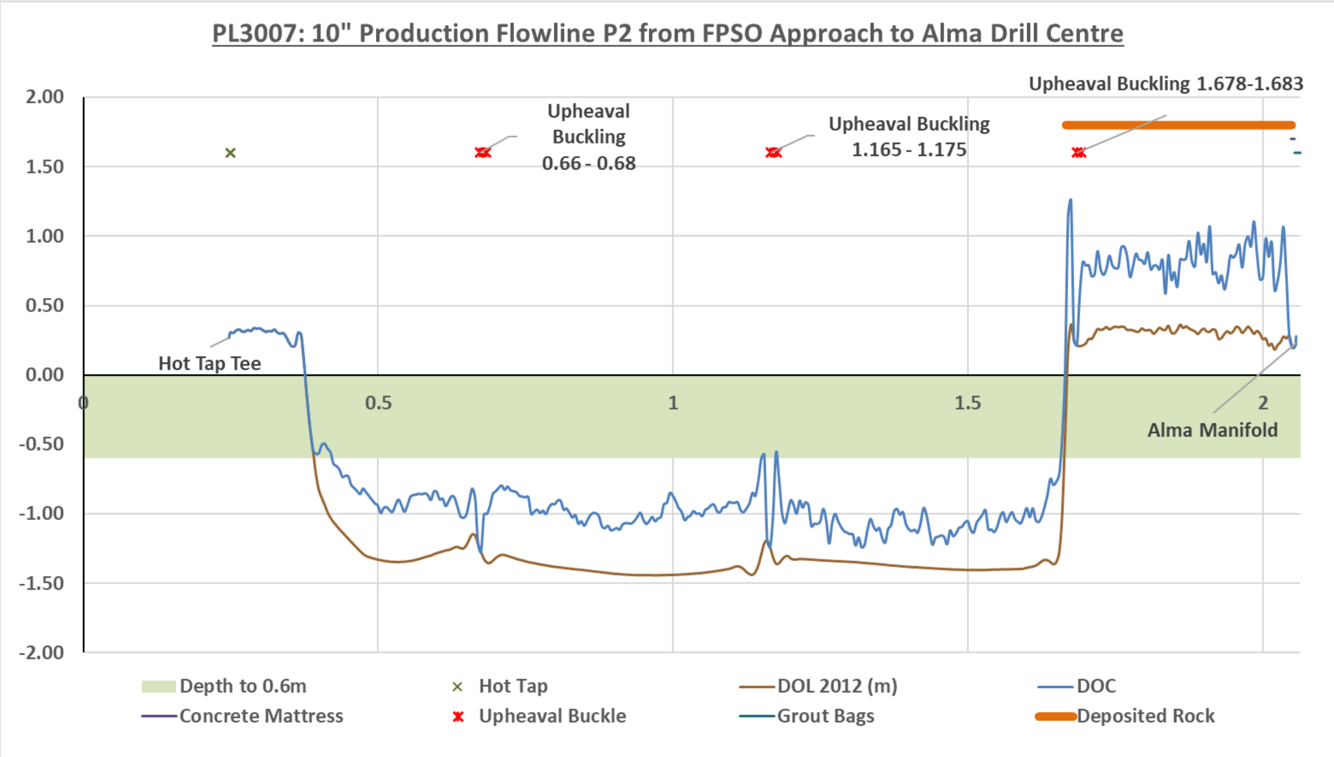

Figure 4.3.1: PL3007 Pipeline Burial Profile

KP	Exposure Type	Length (m)	Width (m)	Height (m)
0.67	Buckle	8.7	1.1	0.1
1.16	Buckle	8.3	1	0.1
1.67	Buckle	5.1	0.1	0.2

Table 4.3-1: PL3007 Upheaval Buckling Details

4.4 PL3008 Alma 8” water injection flowline

PL3008 is a flexible pipeline that is approximately 2454m long, made up of an 8” 343m dynamic riser section and a 8” 2111m static flexible section. The riser and flowline sections are connected via a flanged rigid hot tap tee section. It was laid in 2012 into an open trench and left to naturally backfill. A pipeline status survey conducted in 2018 shows that the flowline is buried with a variable depth of cover. Refer Figure 4.4.1.

The first 516m of the flowline section is unburied with dropped object protection using 8 concrete mattresses approximately 132m from the FPSO end of the flowline section. The next 1420m of the flowline is trenched with the final section between the trench transition and approach to the AW1 water injection well being covered by deposited rock. The final 52.5m to the Alma manifold is covered by 12 concrete mattresses.

Details of the exposures and upheaval buckling are included within Table 4.4-1.

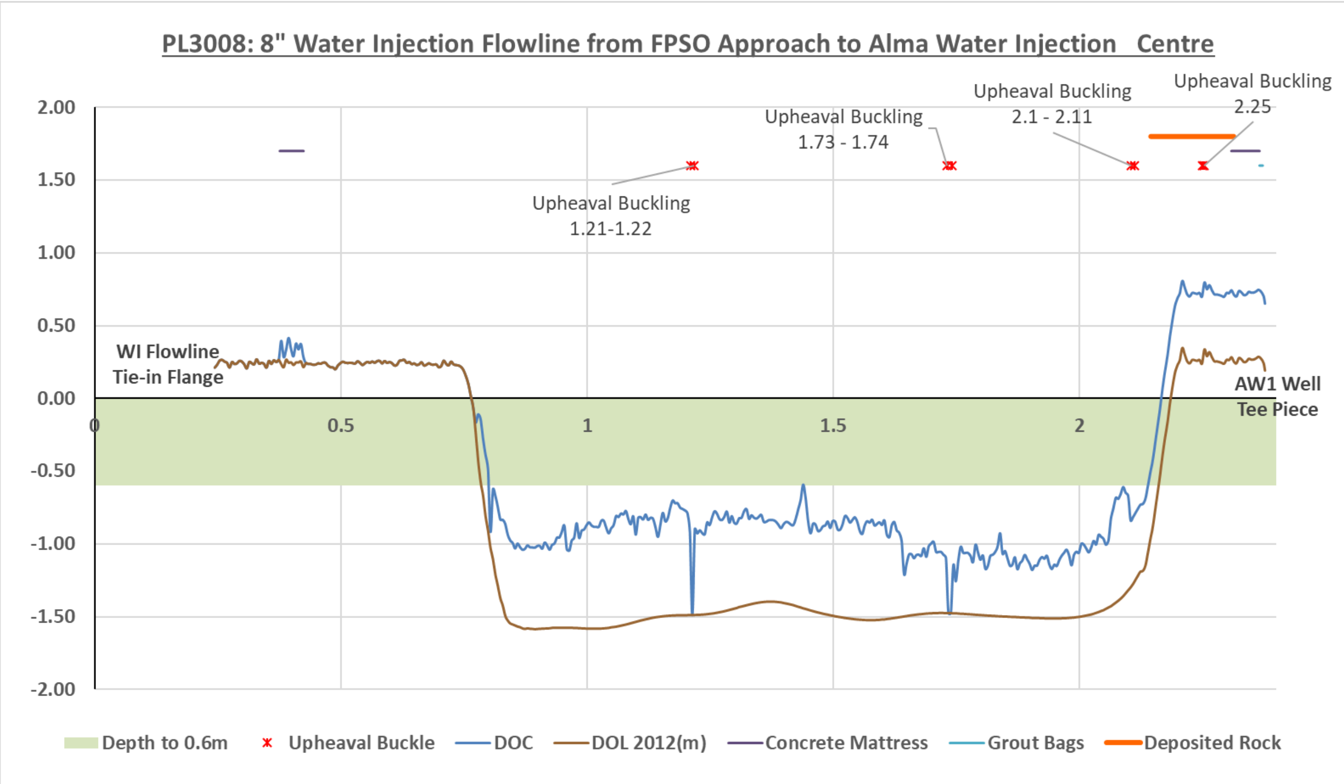

Figure 4.4.1: PL3008 Pipeline Burial Profile

KP	Exposure Type	Length (m)	Width (m)	Height (m)
1.21	Buckle	6.5	0.5	0.8
1.73	Buckle	9.1	1.5	0.2
2.10	Buckle	7.5	0.9	0.2
2.25	Buckle	2.9	0.1	0.2

Table 4.4-1: PL3008 Upheaval Buckling Details

4.5 PLU3009 Alma EHC production control umbilical

PLU3009 is an umbilical that is approximately 2138m long between the EnQuest Producer FPSO and the Alma manifold. It was laid in 2012 into an open trench and left to naturally backfill. A pipeline status survey conducted in 2018 shows that the umbilical is buried with good depth of cover. Refer Figure 4.5.1.

The first 262m of the flowline section between the touch down point and the trench is surface laid with no stabilisation or protection from concrete mattresses or deposited rock. The next 1295m of the umbilical is trenched with the final section between the trench transition and the approach to the Alma manifold being buried under deposited rock. The final 19m to the Alma manifold is covered by a single concrete mattress as well as 9 concrete mattresses covering all the pipelines at the North East entrance to the Alma manifold.

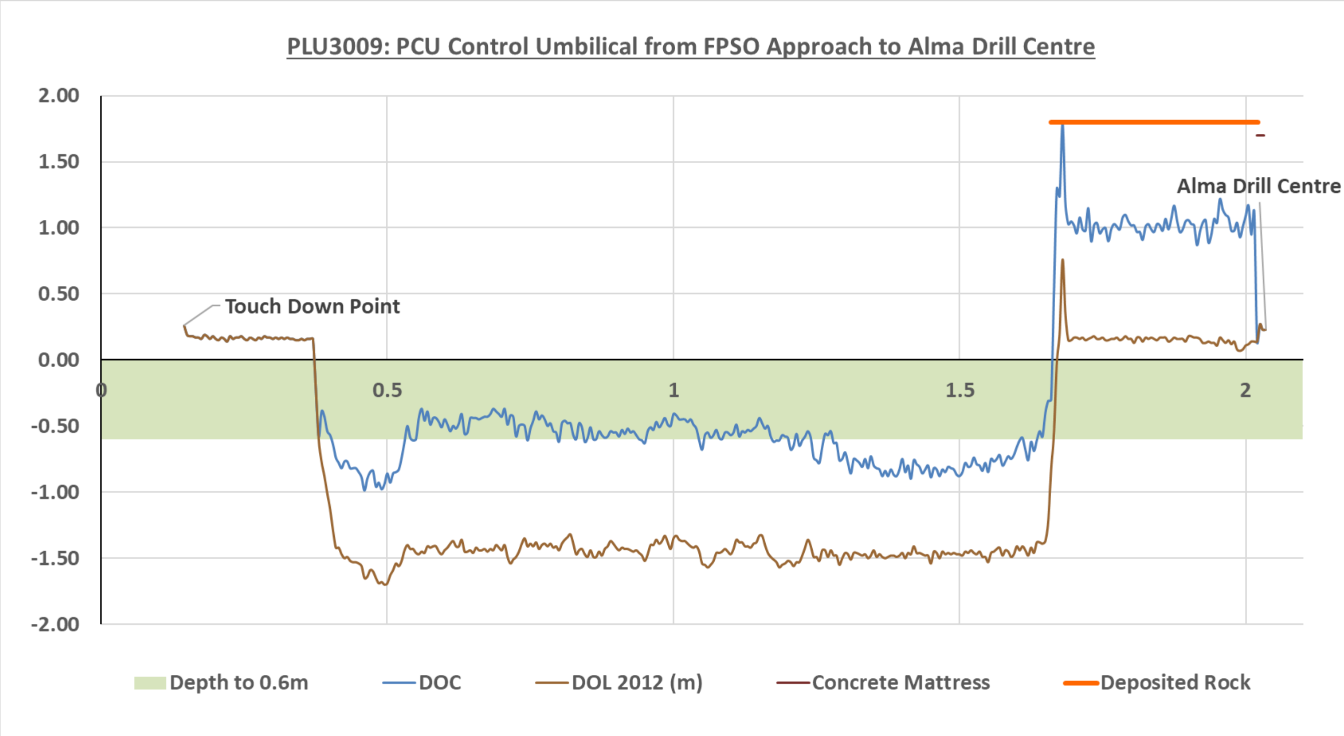

Figure 4.5.1: PLU3009 Pipeline Burial Profile

4.6 PL3011 Alma ESP power cable A

PL3011 is a power cable that is approximately 2177m long between the EnQuest Producer FPSO and the Alma manifold. It was laid in 2012 into an open trench and left to naturally backfill. A pipeline status survey being conducted in 2018 shows that the power cable is buried but with poor depth of cover. Refer Figure 4.6.1.

The first 265m of the power cable section between the touch down point and the trench is surface laid with no concrete mattress or deposited rock protection. The next 1280m of the power cable is trenched with the final section between the trench transition and the approach to the Alma manifold buried under deposited rock. The final 19m to the Alma manifold is covered by 9 concrete mattresses covering all the pipelines at the North East entrance to the Alma manifold.

Details of the exposure is included within Table 4.6.1.

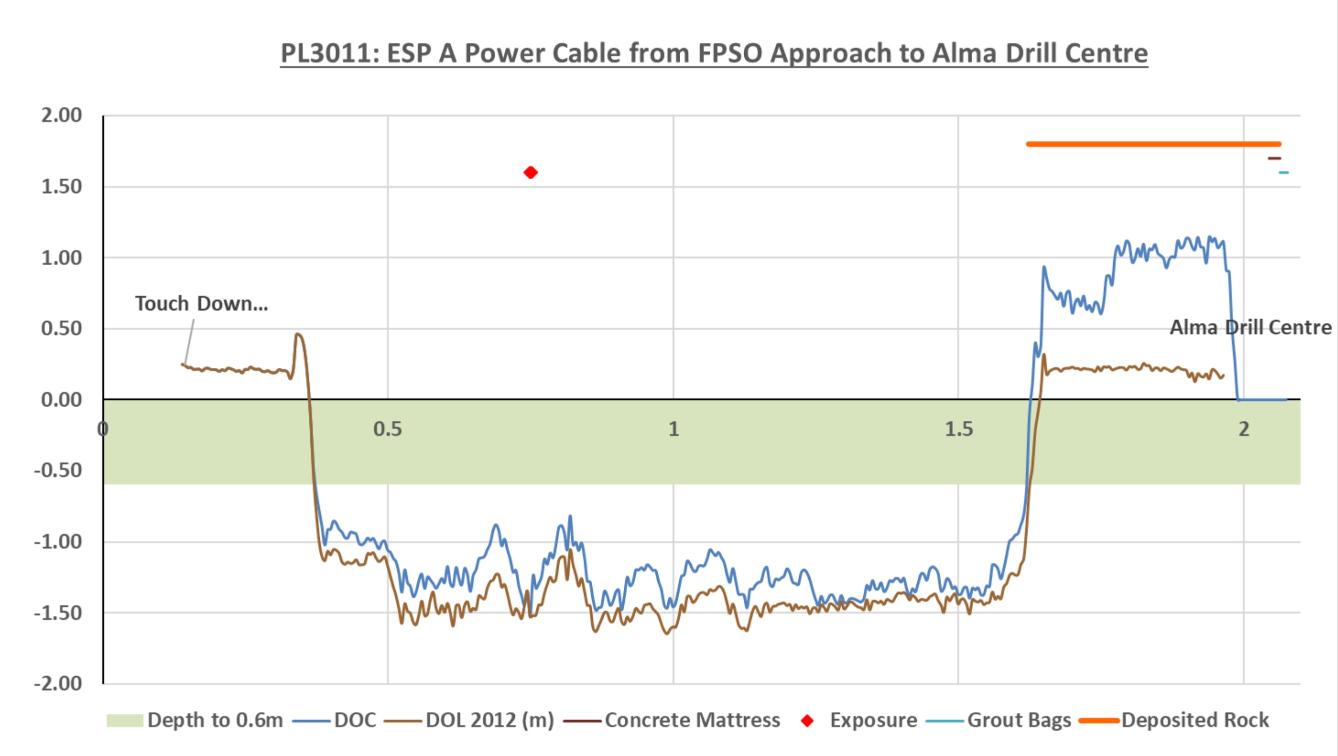

Figure 4.6.1: PL3011 Pipeline Burial Profile

KP	Exposure Type	Length (m)	Width (m)	Height (m)
0.75	50% exposure in trench	3.1	N/A	N/A

Table 4.6.1: PL3011 Exposure Details

4.7 PL3012 Alma ESP power cable B

PL3012 is a power cable that is approximately 2150m long between the EnQuest Producer FPSO and the Alma manifold. The power cable was laid in 2012 into an open trench and left to naturally backfill. A pipeline status survey being conducted in 2018 shows that the power cable is buried but with poor depth of cover. Refer Figure 4.7.1.

The first 263m of the power cable section is surface laid with no mattress or deposited rock protection. The next 1285m of the flowline is trenched with the final section between the trench transition and the approach to the Alma manifold buried under deposited rock. The final 19m to the Alma manifold is covered by 9 concrete mattresses covering all the pipelines at the North East entrance to the Alma manifold.

Details of the exposure is included within Table 4.7.1.

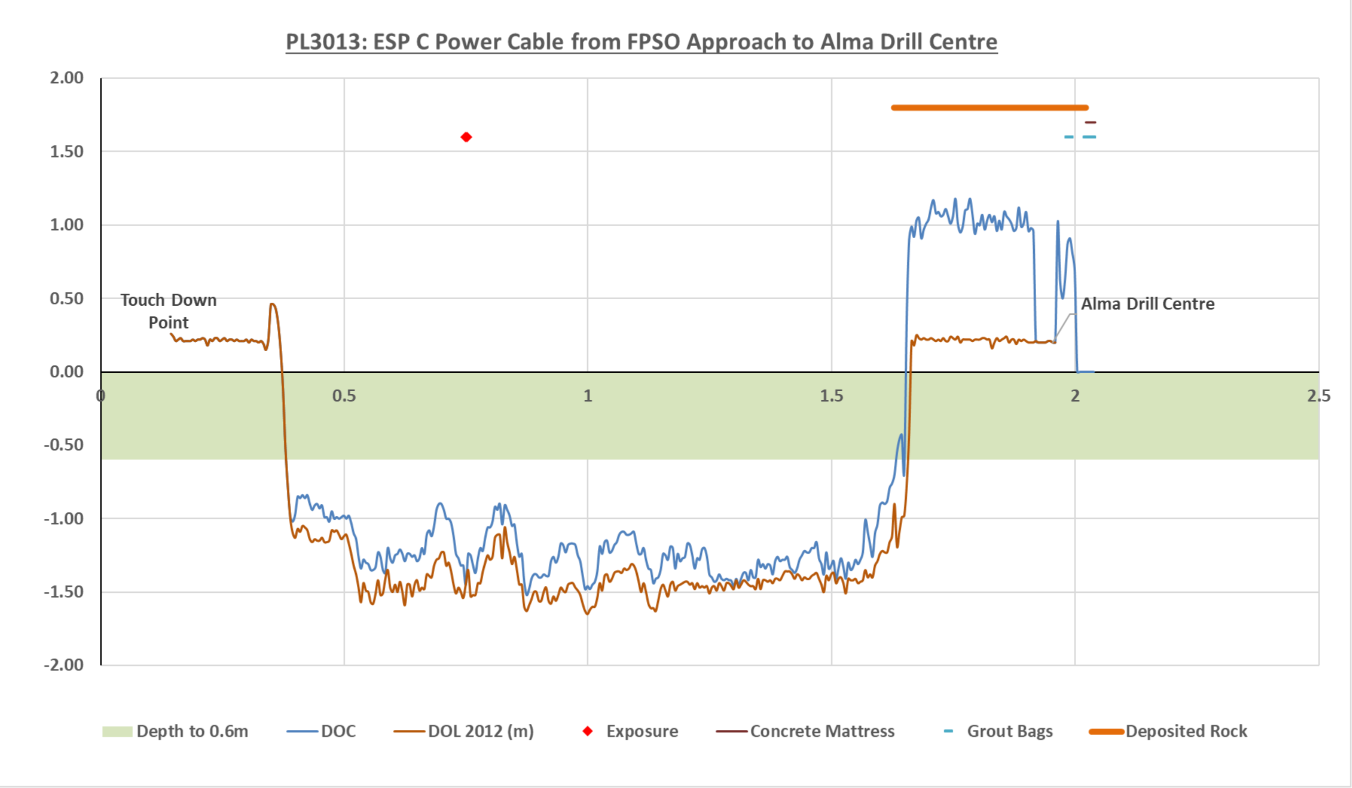

Figure 4.7.1: PL3012 Pipeline Burial Profile

KP	Exposure Type	Length (m)	Width (m)	Height (m)
0.75	50% exposure in trench	3.1	N/A	N/A

Table 4.7.1: PL3012 Exposure Details

4.8 PL3013 Alma ESP power cable C

PL3013 is a power cable that is approximately 2135m long between the EnQuest Producer FPSO and the Alma manifold. It was laid in 2012 into an open trench and left to naturally backfill. A pipeline status survey conducted in 2018 shows that the power cable is buried but with poor depth of cover. Refer to Figure 4.8.1.

The first 266m of the power cable section is surface laid with no concrete mattress or deposited rock protection. The next 1290m of the power cable is trenched with the final section between the trench transition and the approach to the Alma manifold buried under deposited rock. The final 19m to the Alma manifold is covered by 9 concrete mattresses covering all the pipelines at the North East entrance to the Alma manifold.

Details of the exposure is included within Table 4.8.1.

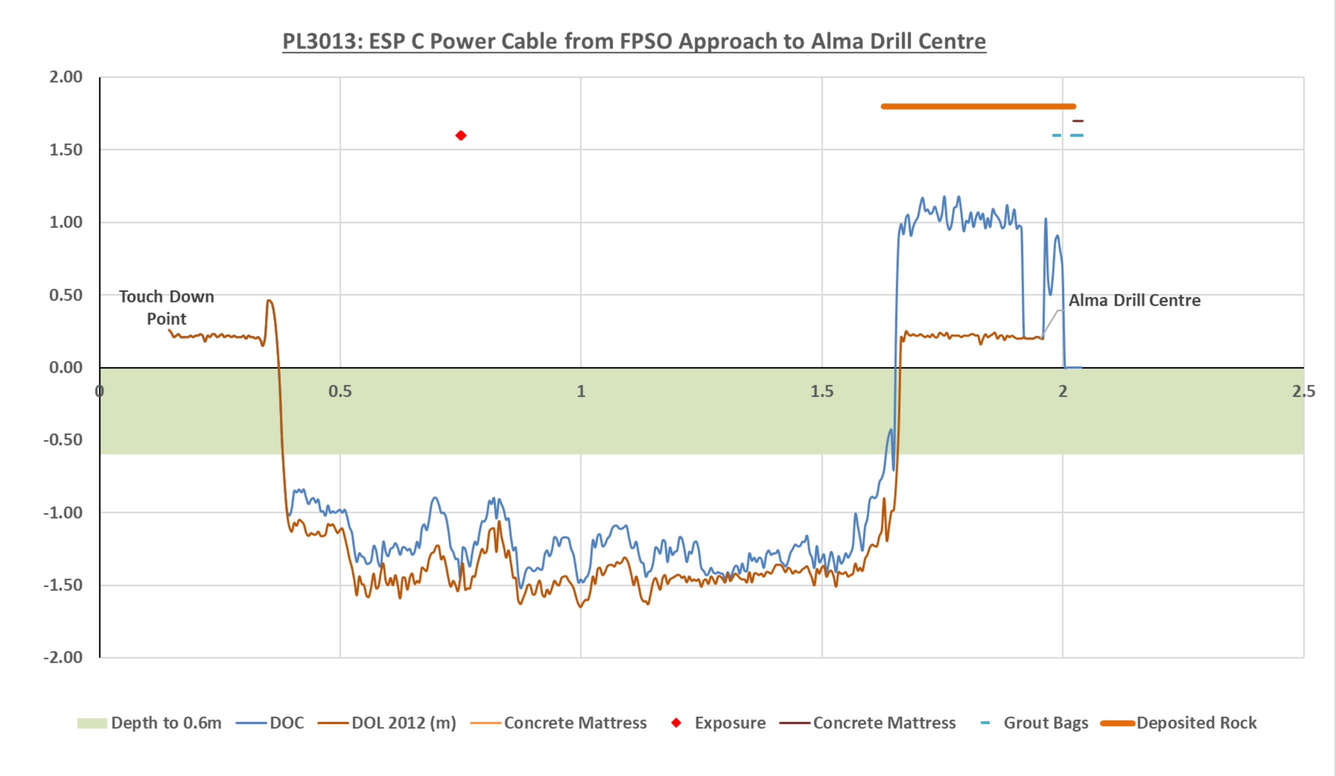

Figure 4.8.1: PL3013 Pipeline Burial Profile

KP	Exposure Type	Length (m)	Width (m)	Height (m)
0.75	50% exposure	3.1	N/A	N/A

Table 4.8.1: PL3013 Exposures

4.9 PL3014 Galia GP1 8” production flowline

PL3014 is a flexible flowline that is approximately 5134m long between the Alma manifold and the Galia GP1 tree. It was laid in 2012 into an open trench and left to naturally backfill. A pipeline status survey conducted in 2018 shows that the flowline is buried with good depth of cover. Refer Figure 4.9.1.

The first 250m of the flowline section between the Alma manifold and the trench is protected by 10 concrete mattresses and ~205m of deposited rock. The next 4884m of the flowline is trenched with the final section between the trench and the approach to the GP1 Xmas tree covered by 11 concrete mattresses.

Details of the exposures are included within Table 4.9-1.

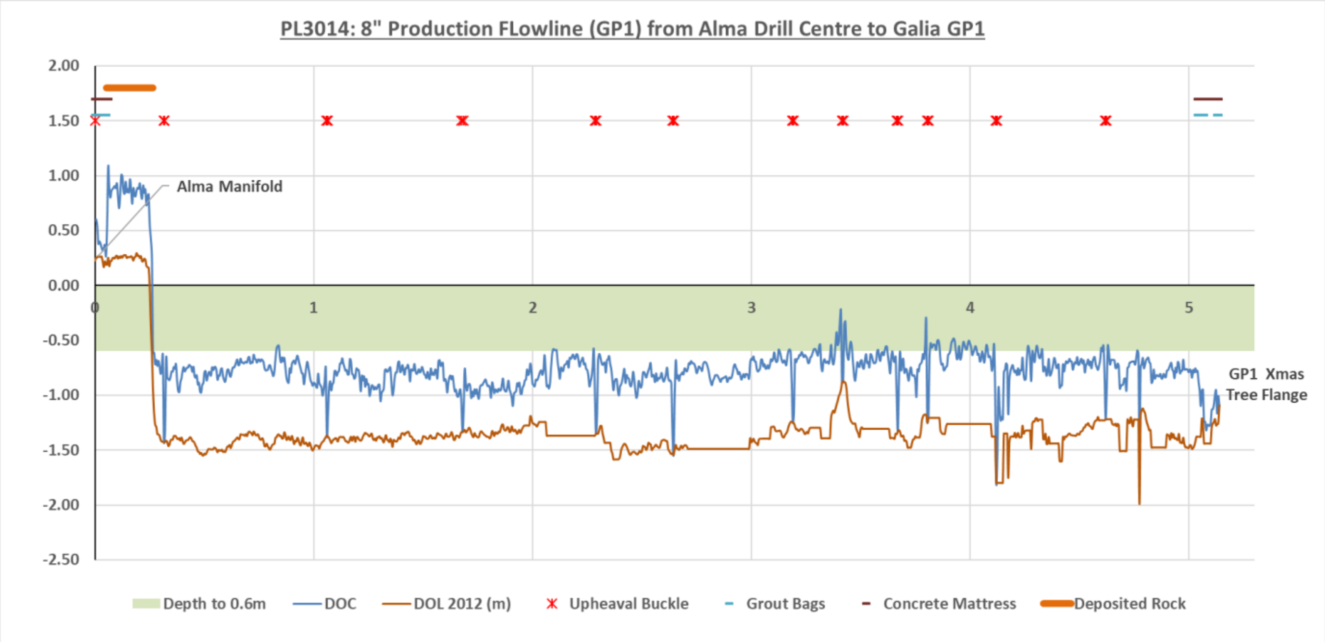

Figure 4.9.1: PL3014 Pipeline Burial Profile

KP	Exposure Type	Length (m)	Width (m)	Height (m)
0.31	Buckle	5.4	0.3	0.3
1.06	Buckle	5.0	0.7	0.1
1.67	Buckle	8.1	1.7	0.1
2.28	Buckle	6.1	1.2	0.2
2.64	Buckle	5.3	0	0.1
3.18	Buckle	7.0	1.1	0.1
3.41	Buckle	6.2	0.6	0.1
3.66	Buckle	5.5	0.5	0.1
3.8	Buckle	5.9	0.6	0.1
4.11	Buckle	5.9	0.7	0.1
4.62	Buckle	6.3	0.9	0.1

Table 4.9-1: PL3014 Upheaval Buckling Details

4.10 PLU3015 Galia EHC production control umbilical

PLU3015 is a control umbilical that is approximately 5060m long between the Alma manifold and the Galia GP1 tree. It was laid in 2012 into an open trench and left to naturally backfill. A pipeline status survey conducted in 2018 shows that the umbilical is buried with good depth of cover. Refer Figure 4.10.1.

The first 175m of the umbilical section between the Alma manifold and the trench is protected by 10 concrete mattresses and ~158m of deposited rock. The next 4825m of the flowline is trenched with the final section between the trench and the approach to the GP1 Xmas tree covered by 25 concrete mattresses.

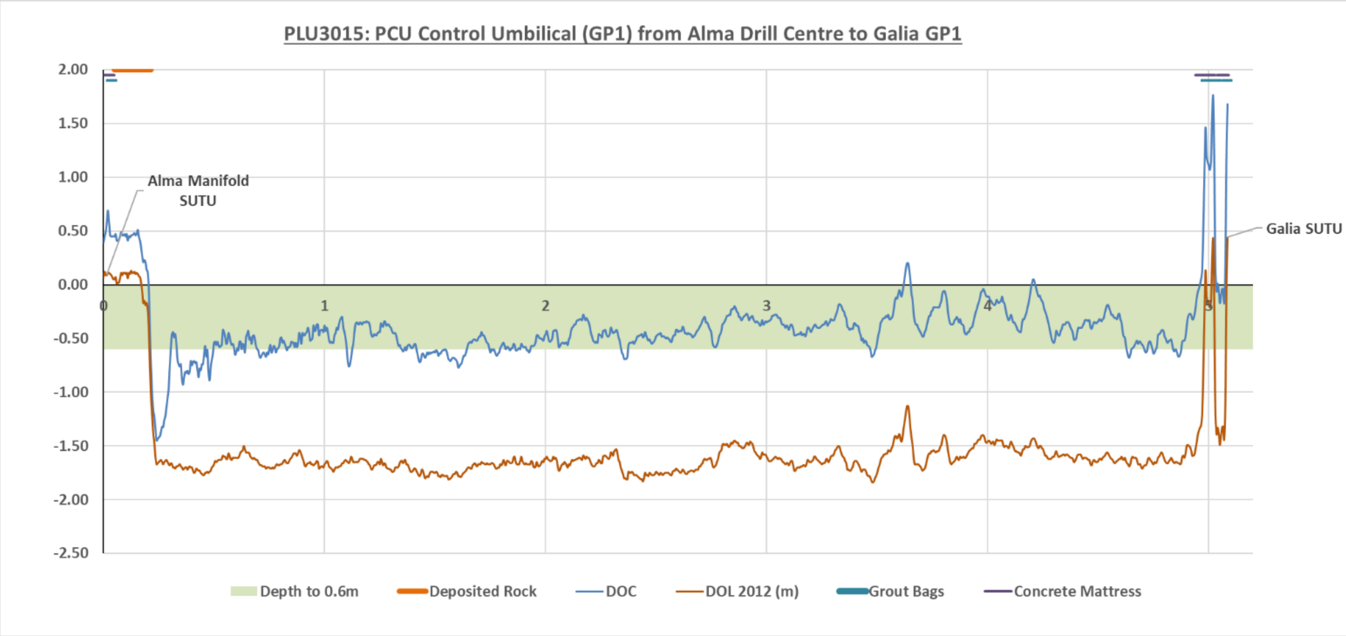

Figure 4.10.1: PLU3015 Pipeline Burial Profile

4.11 PL3016 Galia ESP power cable

PL3016 is a power cable that is approximately 5050m long between the Alma manifold and the Galia GP1 tree. It was laid in 2012 into an open trench and left to naturally backfill. A pipeline status survey conducted in 2018 shows that the power cable has good depth of cover. Refer Figure 4.11.1.

The first 275m of the power cable section between the Alma manifold and the trench is protected by 10 concrete mattresses and ~235m of deposited rock. The next 4690m of the flowline is trenched with the final section between the trench and the approach to the GP1 Xmas tree covered by 15 concrete mattresses.

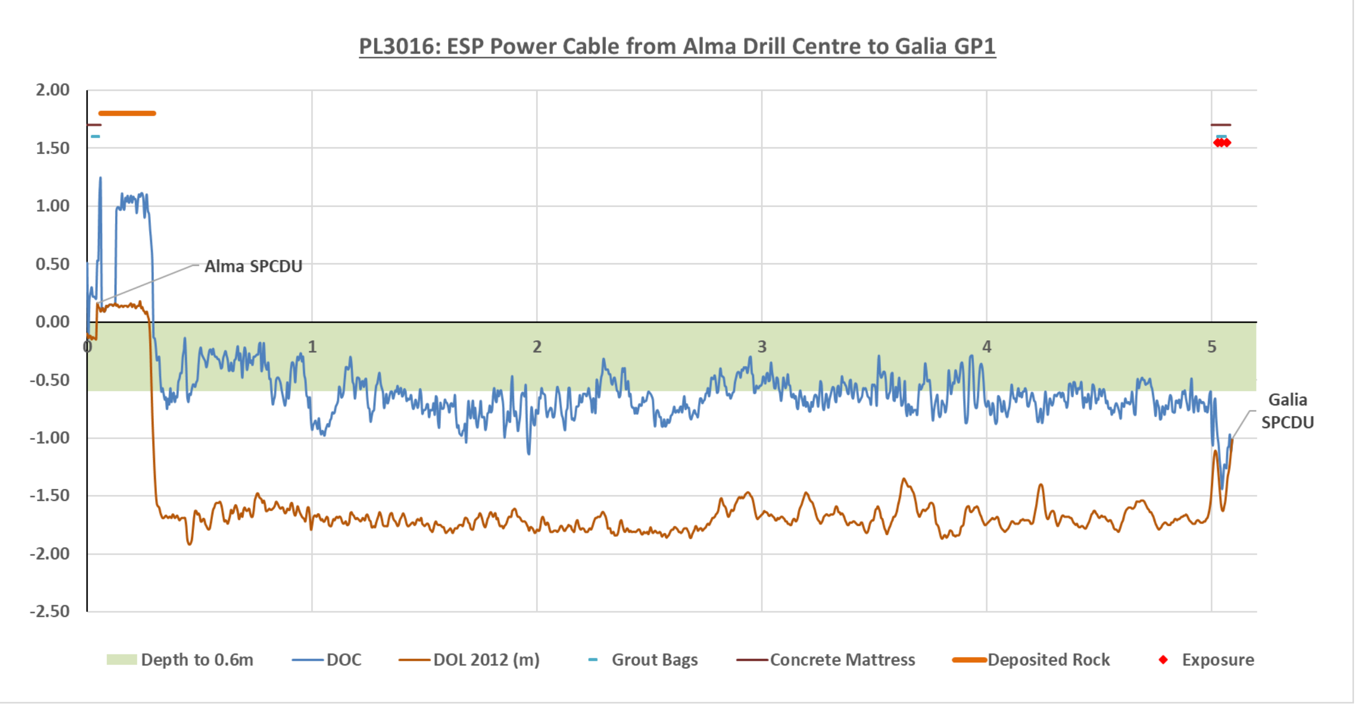

Figure 4.11.1: PL3016 Pipeline Burial Profile

5. DECOMMISSIONING OPTIONS

5.1 Mooring System Decommissioning

Although the mooring line lengths and mooring pile lengths vary slightly, the methodology for the different decommissioning options is the same and hence the 9 different mooring chains and mooring piles has been considered as part of the same assessment.

Three decommissioning options are considered for the mooring system:

- **Complete removal –** This involves the complete removal of the mooring system followed by remedial work for any excavated materials;
- **Partial removal –** This involves performing a cut of the mooring chain and mooring pile at 3m depth below seabed followed by remedial works for any excavated materials;
- **Leave *in situ*** – This involves leaving the cut end of the mooring chain and mooring piles *in situ* with remedial works being performed to ensure that the cut end of mooring chain is buried to 1m below seabed.

Since the decommissioning of the mooring chains between the FPSO and the dip down point is the same irrespective of which option is pursued, decommissioning of these particular mooring chain sections is not included within the assessment.

5.1.1 Options for decommissioning mooring system

ID[4]	Item	Option 1 Complete Removal	Option 2 Partial Removal	Option 3 Leave *in situ*
1	Top chain between FPSO spider and spiral strand wire rope section, 700m long.	Remove. C*ut below spider and recover mooring chain section to AHV. Return mooring chain section to shore for processing.*	Remove*. As Option 1.*	Remove*. As Option 1.*
2	Spiral strand wire rope section between top chain and bottom chain, 1150m long.	Remove. *Recover spiral strand wire rope to AHT. Return mooring chain section to shore for processing.*	Remove*. As Option 1.*	Remove*. As Option 1.*
3	Bottom chain between spiral strand wire rope and dip down point, cluster 1 (107.5m), cluster 2 (91m), cluster 3 (115.5m).	Remove. *Cut chain at dip down point and recover bottom chain section to AHV. Return section of mooring chain to shore for processing.*	Remove*. As Option 1.*	Remove*. As Option 1.*
4	Bottom chain between dip down point and the mooring pile, cluster 1 (22.5m), cluster 2 (39m), cluster 3 (14.5m).	Remove. *Excavate down to allow cut of mooring chain Recover this section to AHV and onwards to shore for processing.*	Remove cut chain section. *Excavate and cut bottom chain at 3m below seabed and recover cut section to vessel and onwards to shore for processing.*	Leave *in situ. Either excavation to 1m below seabed for cut or burial of remaining material in situ*.
5	Mooring Pile, cluster 1 (32m long), cluster 2 (40m long), cluster 3 (34m long).	Remove. *Excavate mooring pile and recover pile to CSV and onwards to shore for processing.*	Remove cut mooring pile. *Excavate and cut mooring pile at 3m below seabed and recover cut section to vessel. Return mooring pile section to shore for processing.*	Leave *in situ.*

Table 5.1.1: Mooring Line Decommissioning Options

[4] Items 1,2 and 3 are included for completeness, although the approach will be the same for all decommissioning options being considered

5.2 Pipeline Decommissioning

The flowlines, umbilical pipelines and power cables are all laid in separate trenches with the exception of Alma power cables, **PL3011**, **PL3012** and **PL3013** which are laid in a common trench. The options for decommissioning these pipelines are assessed together since many aspects of the assessment are common to both. Any aspect pertinent to an individual pipeline is explained in the narrative.

There is an implicit assumption that options for re-use of the pipelines have been exhausted prior to the facilities and infrastructure moving into the decommissioning phase and associated comparative assessment; therefore, this option has been excluded. The three decommissioning options considered are:

- **Complete removal** – This involves the complete removal of the pipelines by whatever means would be most practicable and acceptable from a technical perspective;
- **Partial removal –** This will involve removing exposed or potentially unstable sections of pipelines. Necessary remedial work will be carried out to make the remaining pipeline safe for leaving the remainder *in situ.* Please note, this option is only relevant for those pipelines that have known exposures, either because of upheaval buckling or because of poor depth of cover. There will likely be a need to verify their status via future surveys;
- **Leave *in situ* –** This involves leaving the pipeline(s) *in situ* with no remedial works but possibly verifying their status via future surveys.

The method for decommissioning of the risers or surface laid sections of pipelines and pipeline approaches is the same irrespective of which option is pursued. Therefore, decommissioning of these parts of the pipelines are not included in the assessment. All options include removal of features such as pipespools, surface laid pipelines, jumpers, concrete mattresses and grout bags in accordance with mandatory requirements.

Further details of the pipeline decommissioning options are described in sections 5.2.1 to 5.2.10. The activities detailed in these sections are expected to be undertaken using different vessel types. Vessel types might include an Anchor Handling Vessel (AHV), a Construction Support Vessel (CSV), a Dive Support Vessel (DSV), or a pipelay vessel, depending on the activities being undertaken.

Note: The infrastructure within the 500m zone associated with the FPSO will likely be cleared with decommissioning of the remaining infrastructure associated with Alma and Galia assets being carried out sometime in future.

5.2.1 Options For Decommissioning PL3006, 10in Production Flowline

ID[5]	Item	Option 1 Complete Removal	Option 2 Partial Removal	Option 3 Leave *in situ*
1	PL3006. 8in production riser between FPSO and 'hot-tap' tee (355m long), suspended in seawater using buoyancy modules.	Remove. *Cut at trench transition and recover flexible riser section to CSV/AHV. Return riser to shore for processing.*	Remove. *As Option 1.*	Remove. *As Option 1.*
2	The section of 10in flowline that is surface laid between the hot tap tee and trench transition but currently within the existing FPSO 500m zone (~115m long).	*Remove.* *Recover concrete mattresses near the Alma manifold.* *Recover entire production flowline to CSV/AHV using the reverse reel technique in a continuous process recovering the flowline initially from top of the seabed, and then from within the seabed sediment and from underneath the deposited rock.* *Return flowline sections and concrete mattresses to shore for processing.*	Remove. *As Option 1, using reverse reel or the 'cut and lift' method of recovery.*	Remove. *As Option 1, using reverse reel or the 'cut and lift' method of recovery'.*
3	The section of 10" flowline that is trenched and buried but with upheaval buckling exposures and then buried under deposited rock nearer the Alma manifold (~1305m long).		*Remove exposed or potentially unstable sections at KP0.65 (8.1m), KP0.75 (7.6m), KP1.26 (9.1m), and KP1.68 (3.0m) using the 'cut and lift' method of recovery and leave the remaining buried and stable sections in situ.* *Return cut sections of flowline to shore for processing.*	Leave *in situ.*
4	6in flowline jumpers. PL3006JAP1 (61.8m long), 'JAP2 (57.6m), JAP3 (44.7m), JAP4 (64m), JAP5 (40m), JAP6 (57m) between various wellheads and Alma production manifold, protected and stabilised using concrete mattresses and grout bags.	Remove. *Recover concrete mattress protection between Alma manifold and wellheads. Cut jumpers into sections as necessary and lift onto CSV. Return jumpers and associated concrete mattresses to shore for processing.*	Remove. *As Option 1.*	Remove. *As Option 1.*

<u>Table 5.2.1: PL3006 Decommissioning Options</u>

[5] Items 1,2 & 4 are included for completeness, although the approach will be the same for all decommissioning options being considered

5.2.2 Options For Decommissioning PL3007, 10in Production Flowline

ID[6]	Item	Option 1 Complete Removal	Option 2 Partial Removal	Option 3 Leave *in situ*
1	PL3007. 8in production riser between FPSO and 'hot-tap' tee (352m long), suspended in seawater using buoyancy modules.	Remove. *Cut at trench transition and recover flexible riser section to CSV/AHV. Return riser to shore for processing.*	Remove*. As Option 1.*	Remove*. As Option 1.*
2	The section of 10in flowline that is surface laid between the hot tap tee and trench transition but currently within the existing FPSO 500m zone (~130m long).	*Remove.* *Recover concrete mattresses near the Alma manifold.* *Recover entire production flowline to CSV/AHV using the reverse reel technique in a continuous process, recovering the flowline initially from top of the seabed, and then from within the seabed sediment and from underneath the deposited rock.* *Return flowline sections and concrete mattresses to shore for processing.*	Remove*. As Option 1, using reverse reel or the 'cut and lift' method of recovery.*	Remove*. As Option 1, using reverse reel or the 'cut and lift' method of recovery'.*
3	The section of 10" flowline that is trenched and buried but with several upheaval buckling exposures and then buried under deposited rock nearer the Alma manifold (~1291m long).		*Remove exposed or potentially unstable sections at KP0.67 (8.7m), KP1.16 (8.3m) and KP1.67 (5.1m) using the 'cut and lift' method of recovery and leave the remaining buried and stable sections in situ*. *Return cut sections of flowline to shore for processing.*	Leave *in situ.*

Table 5.2.2: PL3007 Decommissioning Options

[6]Item 1 is included for completeness, although the approach will be the same for all decommissioning options being considered

5.2.3 Options For Decommissioning PL3008, 8in Water Injection Flowline

<table>
<tr><th>ID[7]</th><th>Item</th><th>Option 1
Complete Removal</th><th>Option 2
Partial Removal</th><th>Option 3
Leave in situ</th></tr>
<tr><td>1</td><td>PL3008. 8” water injection riser between FPSO and WI flowline tie-in flange (343m long), suspended in seawater using buoyancy modules.</td><td>Remove. Cut at trench transition and recover flexible riser section to CSV/AHV. Return riser to shore for processing.</td><td>Remove. As Option 1.</td><td>Remove. As Option 1.</td></tr>
<tr><td>2</td><td>The section of 8in flowline that is surface laid between the hot-tap tee and trench transition but currently within the existing FPSO 500m zone (~516m long). Part of the flowline is overlain by eight concrete mattresses that serve as dropped object protection near the FPSO.</td><td rowspan="2">Remove.
Recover concrete mattresses near the FPSO (dropped object protection), and on approach to the Alma water injection Xmas tree.
Recover entire water injection flowline to CSV/AHV using the reverse reel technique in a continuous process, recovering the flowline initially from top of the seabed, and then from within the seabed sediment and from underneath the deposited rock.
Return flowline sections and concrete mattresses to shore for processing.</td><td>Remove. As Option 1, using reverse reel or the ‘cut and lift’ method of recovery.</td><td>Remove. As Option 1, using reverse reel or the ‘cut and lift’ method of recovery’.</td></tr>
<tr><td>3</td><td>The second section (~1420m) long between the trench transition and the Alma water injection wellhead AW1 is trenched and buried albeit having experienced upheaval buckling and has several exposures, and part is buried under deposited rock. The final section ~52m long is surface laid and overlain and protected by concrete mattresses and grout bags.</td><td>Remove exposed or potentially unstable sections at KP1.21 (6.5m), KP1.73 (9.1m), KP2.1 (7.5m), and KP2.25 (2.9m) using the ‘cut and lift’ method of recovery, leaving the remainder in situ.
Return cut sections of flowline to shore for processing.</td><td>Leave in situ.</td></tr>
</table>

Table 5.2.3: PL3008 Decommissioning Options

[7]Items 1 & 2 are included for completeness, although the approach will be the same for all decommissioning options being considered

5.2.4 Options For Decommissioning PLU3009, Umbilical Pipeline

ID[8]	Item	Option 1 Complete Removal	Option 2 Partial Removal	Option 3 Leave *in situ*
1	PLU3009. EHC umbilical pipeline between FPSO and 'touch down point' (346m long), suspended in seawater using buoyancy modules.	Remove. *Cut at trench transition and recover flexible riser section to CSV/AHV. Return riser to shore for processing.*	Remove. *As Option 1.*	Remove. *As Option 1.*
2	The surface laid section of umbilical between 'touch-down point' and trench transition point (~262m long)	Remove. *Recover concrete mattresses near the Alma manifold.* *Recover entire umbilical pipeline to CSV/AHV using the reverse reel technique in a continuous process, recovering the flowline initially from top of the seabed, and then from within the seabed sediment and from underneath the deposited rock.* *Return flowline sections and concrete mattresses to shore for processing.*	Remove. *As Option 1, using reverse reel or the 'cut and lift' method of recovery.*	Remove. *As Option 1, using reverse reel or the 'cut and lift' method of recovery'.*
3	The section of umbilical that is trenched and buried in the seabed but is also buried under deposited rock nearer the Alma manifold (~1295m long).		n/a	Leave *in situ*.
4	The section of umbilical between the end of the deposited rock trench transition and the Alma manifold (~19m long).		Remove. *As Option 1 but using the 'cut and lift' method of recovery.*	Remove. *As Option 1 but using the 'cut and lift' method of recovery.*
5	Umbilical jumpers PLU3009/JAP1 (78m long), 'JAP2 (72m), JAP3 (60m), JAP4 (79m), JAP5 (56m), JAP6 (72m) between various wellheads and Alma production manifold, protected and stabilised using concrete mattresses and grout bags.	Remove. *Recover concrete mattress protection between Alma manifold and wellheads. Cut jumpers into sections as necessary and lift onto CSV. Return jumper sections and mattresses to shore for processing.*	Remove. *As Option 1.*	Remove. *As Option 1.*

Table 5.2.4: PLU3009 Decommissioning Options

[8] Items 1, 2, 4 & 5 are included for completeness, although the approach will be the same for all decommissioning options being considered

5.2.5 Options For Decommissioning PL3011, ESP Power Cable A

<table>
<tr><th>ID[9]</th><th>Item</th><th>Option 1
Complete Removal</th><th>Option 2
Partial Removal</th><th>Option 3
Leave in situ</th></tr>
<tr><td>1</td><td>PL3011. Power cable between FPSO and ‘touch down point’, (346m long) suspended in seawater using buoyancy modules.</td><td>Remove. Cut at trench transition and recover flexible riser section to CSV/AHV. Return riser to shore for processing.</td><td>Remove. As Option 1.</td><td>Remove. As Option 1.</td></tr>
<tr><td>2</td><td>The section of power cable between ‘touch-down point’ and trench transition point (~265m long).</td><td rowspan="3">Remove.
Recover concrete mattresses near the Alma manifold.
Recover entire power cable to CSV/AHV using the reverse reel technique in a continuous process, recovering the flowline initially from top of the seabed, and then from within the seabed sediment and from underneath the deposited rock.
Return sections of power cable and concrete mattresses to shore for processing.</td><td>Remove. As Option 1, using reverse reel or the ‘cut and lift’ method of recovery.</td><td>Remove. As Option 1, using reverse reel or the ‘cut and lift’ method of recovery.</td></tr>
<tr><td>3</td><td>The section of power cable that is trenched and buried in the seabed but is also buried under deposited rock nearer the Alma manifold (~1280m long).</td><td>Remove poorly buried or potentially unstable section at KP0.75 (3.1m), using the ‘cut and lift’ method of recovery, leaving the remainder in situ.
Return cut sections of flowline to shore for processing.</td><td>Leave in situ.</td></tr>
<tr><td>4</td><td>The section of power cable between the end of the deposited rock trench transition and the Alma manifold (~19m long).</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td></tr>
<tr><td>5</td><td>Power cable jumpers. PL3011JAP1 (2x75m long), ‘JAP2 (2x74m), ‘JAP3 (2x68m), ‘JAP4 (2x83m), ‘JAP5 (2x59m), ‘JAP6 (2x76m long) between Alma manifold and various wellheads, protected and stabilised by concrete mattresses and grout bags on the approaches.</td><td>Remove. Recover concrete mattress protection between Alma manifold and wellheads.
Cut jumpers into sections as necessary and lift onto CSV.
Return jumper sections and concrete mattresses to shore for processing.</td><td>Remove. As Option 1.</td><td>Remove. As Option 1.</td></tr>
</table>

Table 5.2.5: PL3011 Decommissioning Options

[9] Items 1, 2, 4 & 5 are included for completeness, although the approach will be the same for all decommissioning options being considered

5.2.6 Options For Decommissioning PL3012, ESP Power Cable B

<table>
<tr><th>ID[10]</th><th>Item</th><th>Option 1
Complete Removal</th><th>Option 2
Partial Removal</th><th>Option 3
Leave in situ</th></tr>
<tr><td>1</td><td>Power cable between FPSO and ‘touch down point’ (346m long), suspended in seawater using buoyancy modules.</td><td>Remove. Cut at trench transition and recover flexible riser section to CSV/AHV. Return riser to shore for processing.</td><td>Remove. As Option 1.</td><td>Remove. As Option 1.</td></tr>
<tr><td>2</td><td>The section of power cable between ‘touch-down point’ and trench transition point (~265m long).</td><td rowspan="3">Remove.
Recover concrete mattresses near the Alma manifold.
Recover entire power cable to CSV/AHV using the reverse technique in a continuous process, recovering the power cable initially from top of the seabed, and then from within the seabed sediment and from underneath the deposited rock.
Return sections of power cable and concrete mattresses to shore for processing.</td><td>Remove. As Option 1, using reverse reel or the ‘cut and lift’ method of recovery.</td><td>Remove. As Option 1, using reverse reel or the ‘cut and lift’ method of recovery.</td></tr>
<tr><td>3</td><td>The section of power cable that is trenched and buried in the seabed but is also buried under deposited rock nearer the Alma manifold (~1285m long).</td><td>Remove poorly buried or potentially unstable section at KP0.75 (3.1m), using the ‘cut and lift’ method of recovery, leaving the remainder in situ.
Return cut sections of flowline to shore for processing.</td><td>Leave in situ.</td></tr>
<tr><td>4</td><td>The section of power cable between the end of the deposited rock trench transition and the Alma manifold (~19m long), protected and stabilised by concrete mattresses and grout bags.</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td></tr>
</table>

Table 5.2.6: PL3012 Decommissioning Options

[10] Item 1,2 & 4 is included for completeness, although the approach will be the same for all decommissioning options being considered

5.2.7 Options For Decommissioning PL3013, ESP Power Cable C

<table>
<tr><th>ID[11]</th><th>Item</th><th>Option 1
Complete Removal</th><th>Option 2
Partial Removal</th><th>Option 3
Leave in situ</th></tr>
<tr><td>1</td><td>Power cable between FPSO and ‘touch down point’ (346m long), suspended in seawater using buoyancy modules.</td><td>Remove. Cut at trench transition and recover flexible riser section to CSV/AHV. Return riser to shore for processing.</td><td>Remove. As Option 1.</td><td>Remove. As Option 1.</td></tr>
<tr><td>2</td><td>The short section of power cable between ‘touch-down point’ and trench transition point (~266m long).</td><td rowspan="3">Remove.
Recover concrete mattresses near the Alma manifold.
Recover entire power cable to CSV/AHV using the reverse reel technique in a continuous process, recovering the power cable initially from top of the seabed, and then from within the seabed sediment and from underneath the deposited rock.
Return sections of power cable and concrete mattresses to shore for processing.</td><td>Remove. As Option 1, using reverse reel or the ‘cut and lift’ method of recovery.</td><td>Remove. As Option 1, using reverse reel or the ‘cut and lift’ method of recovery.</td></tr>
<tr><td>3</td><td>The section of power cable that is trenched and buried in the seabed but is also buried under deposited rock nearer the Alma manifold (~1290m long).</td><td>Remove poorly buried or potentially unstable section at KP0.75 (3.1m), using the ‘cut and lift’ method of recovery, leaving the remainder in situ.
Return cut sections of flowline to shore for processing.</td><td>Leave in situ.</td></tr>
<tr><td>4</td><td>The section of power cable between the end of the deposited rock trench transition and the Alma manifold (~19m long), protected and stabilised by concrete mattresses and grout bags.</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td></tr>
</table>

<u>Table 5.2.7: PL3013 Decommissioning Options</u>

[11]Item 1, 2 & 4 are included for completeness, although the approach will be the same for all decommissioning options being considered

5.2.8 Options For Decommissioning PL3014, 8in Production Flowline

<table>
<tr><th>ID[12]</th><th>Item</th><th>Option 1
Complete Removal</th><th>Option 2
Partial Removal</th><th>Option 3
Leave in situ</th></tr>
<tr><td>1</td><td>The 8in production flowline between Alma manifold and the trench transition or deposited rock is overlain protected by concrete mattresses and grout bags. Total length of this section ~65m.</td><td rowspan="3">Remove.
Recover concrete mattresses at Alma manifold and GP1 approach.
Recover entire flowline section to CSV/AHV using the reverse reel technique in a continuous process, pulling flowline through deposited rock and buried section.
Return flowline section and concrete mattresses to shore for processing.</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td></tr>
<tr><td>2</td><td>The 8in production flowline that is trenched and buried (total ~4884m long), mostly in the seabed, but partly buried under deposited rock (~205m long). The flowline has experienced upheaval buckling and therefore several parts are exposed.</td><td>Remove poorly buried or potentially unstable sections at KP0.31 (5.4m), KP1.06 (5.0m), KP1.67 (8.1m), KP2.28 (6.1m), KP2.64 (5.3m), KP3.18 (7.0m), KP3.41 (6.2m), KP3.66 (5.5m), KP3.8 (5.9m), KP4.11 (5.9m), KP4.62 (6.3m) using the ‘cut and lift’ method of recovery, leaving the remainder in situ;
Return cut sections of flowline to shore for processing.</td><td>Leave in situ.</td></tr>
<tr><td>3</td><td>The surface laid section between the trench transition and the Galia production wellhead GP1 (~65m long) that is overlain and protected by concrete mattresses and grout bags.</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td></tr>
</table>

Table 5.2.8: PL3014 Decommissioning Options

[12] Item 1, & 3 are included for completeness, although the approach will be the same for all decommissioning options being considered

5.2.9 Options For Decommissioning PLU3015, EHC Production Control Umbilical

<table>
<tr><th>ID[13]</th><th>Item</th><th>Option 1
Complete Removal</th><th>Option 2
Partial Removal</th><th>Option 3
Leave in situ</th></tr>
<tr><td>1</td><td>The EHC production control umbilical between Alma manifold and the trench transition or deposited rock is overlain protected by concrete mattresses and grout bags. Total length of this section ~175m.</td><td rowspan="3">Remove.
Recover concrete mattresses at Alma manifold and GP1 approach.
Recover entire flowline section to CSV/AHV using the reverse reel technique in a continuous process, pulling flowline through deposited rock and buried section.
Return flowline section and concrete mattresses to shore for processing.</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td></tr>
<tr><td>2</td><td>The umbilical that is trenched and buried (total ~4825m long), mostly in the seabed, but partly buried under deposited rock (~158m long).</td><td>n/a</td><td>Leave in situ.</td></tr>
<tr><td>3</td><td>The surface laid section between the trench transition and Galia GP1 (~150m long) that is overlain and protected by concrete mattresses and grout bags.</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td><td>Remove. As Option 1 but using the ‘cut and lift’ method of recovery.</td></tr>
<tr><td>4</td><td>PLU3015 EHC production control umbilical jumper between the Galia SUTU and the Galia GP1 Xmas tree, 8m long.</td><td>Remove. Cut jumpers into sections as necessary and lift onto CSV. Return jumper sections to shore for processing.</td><td>Remove. As Option 1.</td><td>Remove. As Option 1.</td></tr>
</table>

Table 5.2.9: PLU3015 Decommissioning Options

[13] Items 1, 3 & 4 are included for completeness, although the approach will be the same for all decommissioning options being considered

5.2.10 Options For Decommissioning PL3016, ESP Power Cable

ID[14]	Item	Option 1 Complete Removal	Option 2 Partial Removal	Option 3 Leave *in situ*
1	The ESP power cable between Alma manifold and the trench transition or deposited rock is overlain protected by concrete mattresses and grout bags. Total length of this section ~275m.	Remove. *Recover concrete mattresses at Alma manifold and GP1 approach.* *Recover entire flowline section to CSV/AHV using the reverse reel technique in a continuous process, pulling flowline through deposited rock and buried section.* *Return flowline section and concrete mattresses to shore for processing.*	Remove. *As Option 1 but probably using the 'cut and lift' method of recovery.*	Remove. *As Option 1 but probably using the 'cut and lift' method of recovery.*
2	The ESP power cable that is trenched and buried (total ~4690m long), mostly in the seabed, but partly buried under deposited rock (~235m long).		n/a	Leave *in situ*.
3	The surface laid section between the trench transition and Galia GP1 (~90m long) that is overlain and protected by concrete mattresses and grout bags.		Remove. *As Option 1 but probably using the 'cut and lift' method of recovery.*	Remove. *As Option 1 but probably using the 'cut and lift' method of recovery.*
4	PL3016 ESP power cable jumpers 01 and 02 between the Galia GP1 Xmas tree and the Galia SPCDU SP01 & SP02 protected and stabilised using concrete mattresses and grout bags, 8m long;	Remove. *Cut jumpers into sections as necessary and lift onto CSV. Return jumper sections to shore for processing.*	Remove. *As Option 1.*	Remove. *As Option 1.*
5	PL3016 ESP power cable jumpers 01 and 02 between the Alma manifold SPCDU and the Galia SPCDU protected and stabilised using concrete mattresses and grout bags, 20m long.	Remove. *Cut jumpers into sections as necessary and lift onto CSV. Return jumper sections to shore for processing.*	Remove. *As Option 1.*	Remove. *As Option 1.*

Table 5.2.10: PL3016 Decommissioning Options

[14] Items 1,3, 4 & 5 are included for completeness, although the approach will be the same for all decommissioning options being considered

6. COMPARATIVE ASSESSMENT

6.1 Method

Most of the comparative assessment is qualitative, carried out at a level enough to differentiate between the options. However, in some cases, such as cost, it is necessary to examine the differences in more detail and quantitatively to provide clarity. The comparative assessment considers the following generic evaluation criteria and specific sub-criteria in line with OPRED guidance notes [3]. These elements are considered for short-term work as the assets are decommissioned as well as over the longer-term as 'legacy' impacts and risks.

- Technical:
    - Risk of major project failure;
    - Technological challenge;
    - Technical challenge (legacy).
- Health & Safety:
    - Health & Safety risk to offshore project personnel;
    - Health & Safety risk to other users of the sea;
    - Health & Safety risk to onshore project personnel;
    - Residual Risk to other Users of the Sea.
- Environment:
    - Environmental impacts of operations during offshore works;
    - Environmental impacts from energy, emissions and resource consumption;
    - Environmental impacts due to legacy aspects that would need to be undertaken over the longer-term.
- Societal:
    - Commercial impact on fisheries;
    - Socio-economic impact on communities and amenities;
    - Legacy impact on society.
- Cost:
    - Cost (short term);
    - Cost (legacy).

Environmental impacts include consideration of such impacts on the atmosphere, seabed, special area of conservation, the water column and waste in the short-term due to project related activities and over the long term due to legacy activities offshore.

No scores have been determined however risk matrices have been created to determine if the planned and unplanned impacts would be for example broadly acceptable, possibly acceptable, unlikely to be acceptable or not acceptable. Cells coloured red indicate high risk, high impact and less desirable outcomes. Green coloured cells indicate less risk, less impact and more desirable outcomes. Cells coloured orange sit in-between red and green and may or may not be less, or more, desirable. High costs also attract a 'less desirable outcome' but cost differences are compared relative to each other. A relatively high cost therefore would be coloured red whereas a relatively low cost would be coloured green. It should be noted that societal score looked at beneficial outcomes as well as detrimental outcomes.

The following paragraphs describe the philosophy and processes followed for the Comparative Assessment using generic, high level evaluation sub-criteria. The results of the assessment are summarised in Sections 6.3.8 and 6.2.8.

It is proposed to decommission the approaches and surface laid sections in the FPSO 500m zone for each pipeline in the same way irrespective of the decommissioning option chosen. Therefore the approaches are not included in this assessment. However, for completeness they are included in the decommissioning option tables included in section 5.

6.1.1 Technical Assessment

The technical aspect of the assessment is concerned with the risk of major project failure. Technical feasibility confirms whether the method being assessed is physically possible given the technical issues to be addressed.

Definition: A technical evaluation is simply the application of a measure to express the complexity of a job, which can be expected to proceed without major consequence, or failure, if it is adequately planned and executed.

6.1.2 Health & Safety Assessment

Definition: An assessment of the potential health and safety risk to people directly or indirectly involved in the programme of work offshore and onshore, or who may be exposed to risk as the work is carried out. Health and safety risk is assessed using three specific sub-criteria.

Sub-criteria:

1. The health and safety risk for project personnel who would be engaged in carrying out decommissioning activities offshore are presented in Table 6.1.1:

Example Description of Hazard	Who is at risk?
Loss of dynamic positioning leading to uncontrolled movement of vessel and pipeline(s), hydrocarbon release, dropped objects	Diving personnel underwater
Limited experience surrounding the process for recovering trenched and buried pipelines. Pipeline parting or buckling during reverse reeling operations; uncontrolled movement of pipelines and associated reeling and recovery equipment	Vessel based personnel
Sudden movements during pipeline recovery works leading to dropped objects or swinging loads	Diving personnel, vessel-based personnel, vessel-based assets (e.g. Remotely Operated Vehicles)
Collision between vessels and offshore structures due to mix of shipping lane traffic, product transport vessels, supply and maintenance barges and boats, drifting boats	Offshore personnel and assets
Residual hazardous materials such as methanol, chemicals from umbilical cores, wax deposits, hydrocarbons or NORM from within pipelines released to the local marine environment	Divers and vessel-based personnel

Table 6.1.1: Description of offshore hazards

2. The residual risks to marine users on successful completion of the assessed decommissioning option are presented in Table 6.1.2:

Example Description of Hazard	Who is at risk?
Exposed pipeline or umbilical sections leading to snagging risk	Other users of the sea, predominantly fishing vessels

Table 6.1.2: Description of residual hazards to mariners

3. The safety risks for project personnel who would be engaged in carrying out decommissioning activities onshore are presented in Table 6.1.3:

Example Description of Hazard	Who is at risk?
Residual hazardous materials such as methanol, chemicals from umbilical cores, wax deposits, hydrocarbons or NORM from within pipelines released to the local onshore environment	Hazardous or toxic substances affecting onshore personnel
Onshore cutting – sharp edges and repetitive operations when dismantling pipelines	Onshore personnel
Unplanned sudden movements during pipeline dismantling works leading to dropped objects or swinging loads	Onshore personnel

Table 6.1.3: Description of onshore hazards

Assessment of sub-criteria:

The difference in potential safety risks between the options is sufficiently large that a Hazard Identification (HAZID) was not deemed to be required at this stage. A HAZID workshop will be carried out when the selected option is developed in more detail. For the purposes of the comparative assessment in lieu of a HAZID a high-level review of the differences was undertaken and correlated to the duration of activities that would be required.

As many of the hazards are common between the complete removal and the partial removal options, only those hazards giving rise to difference between the options were assessed. Examples of this are:

- Where a hazard exists for one option but not the other (e.g. risks relating to pipeline failure during reverse reel lay recovery);
- Where the hazard exists for both options but is different in magnitude (e.g. risks relating to dropped objects if whole pipeline is recovered to shore (to be cut into transportable pieces).

6.1.3 Environmental Assessment

The comparative assessment uses three sub-criteria for the assessment of environmental impacts. These are described below.

Definition: An assessment of the significance of the risks/impacts to the environmental receptors because of activities or the legacy aspects. Environmental impact is assessed using the following specific sub-criteria.

Sub-criteria:

1. Environmental impacts of operations during offshore works;
    - Discharge to sea;
    - Effect on seabed;
    - Seabed disturbance;
    - Unplanned leaks and spills;
    - Effect of Noise (air and subsea).
2. Environmental impacts from energy, emissions and resource consumption;
    - Emissions to atmosphere;
    - Fuel usage;
    - Energy usage;
    - Resource consumption.
3. Environmental impacts due to legacy aspects that would need to be undertaken over the longer-term
    - Discharge to sea;
    - Effect on seabed;

- Seabed disturbance;
- Unplanned leaks and spills;
- Effect of Noise (air and subsea);
- Emissions to atmosphere;
- Fuel usage;
- Energy usage.

Assessment of sub-criteria:

The environmental assessment considers the impacts of the decommissioning options. The findings were summarised in an environmental management worksheet and these formed the input to the comparative assessment. Environmental impacts include consideration of such impacts on the atmosphere (energy and emissions), seabed (area impacted and material mobilised into water column), the water column (vessel discharges and effect of material lifted in the water column) and waste (fate and quantity of material) in the short-term due to project related activities and over the longer–term due to legacy activities offshore.

Only the *differentiators* between decommissioning options were included in the overall assessment.

The sub-criteria are qualitative and assessed per the EnQuest Environmental Impact Assessment matrix. Based on experience we can conclude that energy use and the associated emissions to air are unlikely to significantly contribute to greenhouse gas emissions or global warming impacts.

A full assessment of the environmental impacts of the selected decommissioning option can be found in the Environmental Appraisal [2].

Sub-criteria definitions:

1. Environmental impacts of operations during offshore works

The severity of environmental risks associated with unplanned events or the impact to the marine and terrestrial environments from planned operational events.

2. Environmental impacts from energy, emissions and resource consumption

The severity of environmental risks associated with use of a finite energy resource (vessel fuel, energy) during planned operational events or the impact to the environment from a finite resource (steel, plastic etc.) not being recovered for recycling or re-use.

3. Environmental impacts due to legacy aspects

The severity of environmental risks associated with unplanned legacy events or the impact to the marine and terrestrial environments from planned legacy activities.

Note that the emissions to air and energy requirements are *representative,* although not the same, of the fuel and energy input data used for waste handling activities.

The environmental assessment was developed by identifying the interactions with the environment for the activities required for each of the options. Activities that were not differentiators were screened out. Those remaining activities with associated interactions with the environment were assessed for consequence and duration to ascertain the potential level of significance of the environmental impact. The interactions with the environment were grouped into the four comparative assessment sub-criteria but the assessment remained qualitative.

6.1.4 Societal Assessment

Definition: An assessment of the significance of the impacts on societal activities, including offshore and onshore activities associated with the complete programme of work for each option and the associated legacy impact. This includes all the “direct” societal effects (e.g. employment on vessels undertaking the work) as well as “indirect” societal effects (e.g. employment associated with services in the locality to onshore work scope, accommodation, etc.).

Sub-criteria:

1. Commercial impact on fisheries;
2. Socio-economic impact on communities and amenities.

Assessment of sub-criteria:

A qualitative assessment has been undertaken to differentiate between options from a societal perspective. This was undertaken through review of relevant data, discussion and textual descriptions.

6.1.5 Cost Assessment

Only the incremental costs of the main offshore decommissioning activities are compared, with owners' costs such as engineering, management, insurance, procurement and logistical costs contributing to the difference as a percentage of the offshore work. To simplify the assessment, we have concentrated on the different vessel types that would be required for a specific activity and how long the vessel would be required for. Although different for different activities, common elements such as mobilisation costs and decommissioning of pipeline ends are not included on the assumption that they would be decommissioned in much the same way irrespective of which option was being pursued.

For this assessment, complete removal represents the full scope and other options are compared to this.

We compare the difference in cost for like-for-like activities in the short-term as well as for legacy related activities in the longer-term. From a legacy perspective, all decommissioning options would involve carrying out an environmental survey at the end of the decommissioning activities so this would not differentiate the costs over the longer-term. Legacy survey costs, however, will be different depending on the option. We would expect that no legacy surveys would be required for the complete removal option.

This shows the difference in incremental cost as being comparable to the other evaluation criteria (i.e. safety, environmental, technical and societal) and it allows an understanding of the *significance* of the difference.

In the assessment tables that follow we indicate the acceptability or otherwise of the costs. We do, however, recognise that the cost of an option would only be *acceptable* if the other aspects of the comparative assessment show that this would be preferred.

If the incremental difference in cost for one option is assessed to be an order to magnitude greater than the other options being considered it is assessed as being 'tolerable & non-preferred'; a two orders-of-magnitude difference is assessed as 'intolerable & non-preferred'.

6.2 Mooring System Comparative Assessment

6.2.1 Technical Assessment

The FPSO is moored in location using three clusters of three mooring lines connected to mooring piles 84in diameter. The piles in each of the three pile clusters are 32m long, 40m long and 34m long respectively. Each of the mooring lines comprises an upper and lower chain connect with wire rope. The upper and lower chains are 700m and 130m long respective, and the wire is 130m long. The lower mooring chains rest on or are buried in the seabed from the dip down point to the padeyes on the mooring piles. The padeyes on the mooring piles are buried several metres below the seabed.

The mooring piles are not exposed and according to the original as-built information except for one mooring pile that is buried to 0.75m, the tops of the mooring piles are buried to at least 1.0m below seabed.

To completely remove the mooring piles would be extremely technically challenging; significant excavation work would be required in order to gain access to the mooring piles. In addition, the loads required to remove the mooring piles from the seabed would be unknown and require detailed engineering with potential for needing specialist and bespoke equipment. The expectation is that any spoil heaps arising from any excavation activities would need to be mechanically backfilled.

For the partial removal option, significant excavation would be required in order to reach the point where the mooring chain is 3m below the seabed. The end of the mooring chain forms an inverse catenary between the dip down point and the padeye on the mooring piles. Due to the inverse catenary, the location at which the chain is 3m below the seabed is unknown and hence as a result, there is potential for extended excavation requirement.

To leave the chain *in situ* presents very little technical risk and only involves local excavation to the cut location mooring chain ends to 1m below seabed. An alternative would be to bury the end of the mooring chain locally.

Sub-Criterion	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
Technical feasibility	**Short-term:** As opposed to purpose-designed suction piles, driven piles were designed to remain in the seabed. There is no track record of completely removing driven piles from seabed in the North Sea. Extensive excavation would be required to enable access for recovering the piles. Any spoil heaps arising from the excavation activities would need to be backfilled. A crane vessel would be needed to recover the mooring piles. It is arguable whether this could be achieved technically, especially from seabed substrata such as clay	**Short-term:** The location of the mooring chain at least 3m below the seabed would take time to determine with the possibility that excavation works extends to a much larger area than planned. Severance of piles to ~3m has been achieved in the North Sea so we know this is technically feasible	**Short-term:** Local excavation and burial work is undertaken very regularly so we know this is feasible
	Legacy: No status surveys would be required in future	**Legacy:** Reduced need for status surveys in future, although may be required. We know that status surveys are feasible and are carried out frequently in the North Sea. Little to differentiate partial removal and leave *in situ* options.	

Table 6.2.1: Mooring System Technical Assessment

Summary of technical assessment

As opposed to purpose-designed suction piles, driven piles were designed to remain in the seabed. There is no track record of completely removing driven piles from seabed in the North Sea. Extensive excavation would be required to enable access for recovering the piles. A crane vessel would be needed to recover the piles. This exercise needs to be repeated nine times, once for each of the mooring piles. It is arguable whether this would technically feasible, especially from seabed substrata such as clay.

The padeyes to which the mooring chains are connected are buried more than 3m below the seabed and tracking devices become less accurate with depth. This means that there is the possibility that the position of the mooring chain is not located accurately within the seabed, leading to a larger volume of seabed material being excavated than would otherwise be necessary. This needs to be carried out nine times, once for each of the mooring piles and lower mooring chains. However, partial removal is technically feasible albeit with uncertainties.

Of the three options considered, the leave *in situ* option was assessed as being the preferred option since the proposed method is a common approach for FPSOs in the North Sea. Technically we know this is achievable.

The leave *in situ* and partial removal options may require future surveys to be conducted to confirm the burial status of the mooring pile and chain but technically we know that future surveys are achievable.

6.2.2 Health & Safety Assessment

Health and Safety Risk to Offshore Project Personnel

All hazards were assessed as broadly acceptable. The key differences between the decommissioning options are as follows.

- Risk to personnel on the vessel from recovered sections of mooring pile and mooring chain will be greater for complete removal than for partial removal or leave *in situ* due to the larger volume of material recovered;
- Increased risk to all activities due to adverse weather is greater for complete removal than for partial removal or leave *in situ* as the time the vessel would be in the field is greater, irrespective of the removal method adopted;
- Risk associated with legacy survey activities that is, the risks associated with vessels being used is greater for leave *in situ*. At least three legacy surveys would be required to confirm the burial status of the sections of mooring system being left *in situ*.

Health and Safety Operational Risk to Other Users of the Sea

There remains the possibility of interaction with other mariners while decommissioning works are being carried out in the field and this potentially would increase with the number of vessels, the location of the work and the frequency of marine traffic. Decommissioning activities involve vessels working in the field, and over the longer term will be related to the amount of surveys and any pipeline remedial works that may be required in future. By way of example, vessel durations associated with the complete removal option will be greater than for the partial removal and leave *in situ*.

Safety Risk to Onshore Project Personnel

All hazards associated with onshore project activities were assessed as broadly acceptable. The key differences between the options are as follows:

- Risks associated with cutting the mooring chains and mooring piles which may result in injury, are greater for complete removal due to the higher quantity of material returned to shore compared with the partial removal and leave *in situ* options;
- Risks associated with lifting and handling large sections of mooring chain and mooring piles are also greater for complete removal, due to larger quantity of material being returned to shore;

Residual Risk to Other Users of the Sea

The greatest risk relating to marine users is likely to be concerned with snagging of fishing gear on mooring chains, mooring piles and spoil mounds left on the seabed from removal activities. Due to limited survey data, the current condition and hence snagging risk of the mooring piles in unknown.

From this it can be reasoned that decommissioning activities that minimise the disturbance to the seabed will reduce the likelihood of creating new snag hazards and avoid leaving open trenches. Both complete removal and partial removal will leave the seabed free of snagging hazards, while leave *in situ* will present the same risks as there is currently. Significant excavation will be required in order to completely remove or partially remove the mooring system. Although these options will create spoil mounds it is possible to backfill the excavations to reduce the snagging hazard.

Once any spoil heaps associated with the excavations had been backfilled, the risk of snagging fishing gear and the risk of snagging equipment were assessed as broadly acceptable. The key differences between the options are:

- There would be a risk of snagging fishing gear on the mooring chain and mooring pile in future for the leave *in situ* option in the unlikely event that the burial status changes, but this would be eliminated for complete removal and partial removal options;
- As the leave *in situ* option would involve leaving a significant portion of the mooring pile and mooring chain *in situ*, legacy surveys would be required. The legacy surveys have risks associated with the

use of vessels that are not required for the complete removal option, but the work can be considered routine. Legacy related survey vessels would also be in the field for significantly less time than vessels involved in the complete removal and partial removal activities.

Sub-Criterion	**Option 1 Complete Removal**	**Option 2 Partial Removal**	**Option 3 Leave *in situ***
Health & Safety risk to offshore project personnel	More offshore work than leave *in-situ* and partial removal*.* Use of vessel crane for recovery of large mooring piles	More offshore work than leave *in-situ* but less than complete recovery. Recovery of cut mooring pile sections and cut mooring chain sections to vessel deck.	Standard excavation operations. No recovery of cut mooring pile sections to deck
Health & Safety risk to other users of the sea	Duration of vessels in field would be longer than leave *in-situ* option and partial removal option	Duration of vessels in field would be longer than leave *in-situ* option but less than complete removal option	Shortest offshore duration
Health & Safety risk to onshore project personnel	Numerous vessel mobilisations required. Large quantities of material recovered onshore. Significantly more onshore cutting, lifting and handling associated with disposal of mooring chain and mooring piles	Single vessel mobilisation. Less material handing involved than the completely remove option	Minimal recovery of materials from the field so less material handling than for either option 1 or option 2. Single vessel mobilisation

Table 6.2.2: Mooring System Health & Safety Assessment – Short-term

Sub-Criterion	**Option 1 Complete Removal**	**Option 2 Partial Removal**	**Option 3 Leave *in situ***
Health & Safety risk to offshore project personnel	No future works would be required	Status surveys would be required in future. There is little to differentiate the requirement for future surveys between option 2 and option 3	
Health & Safety risk to other users of the sea	Potential snagging risks completely removed; no legacy activities would be required	Status surveys would be required in future. As a result, there would be a collision risk, albeit small. There is little to differentiate the requirement for future surveys between option 2 and option 3	
Health & Safety risk to onshore project personnel	No future works would be required	Status surveys would be required in future, therefore there would be a requirement to mobilise survey vessels and equipment	

Table 6.2.3: Mooring System Health & Safety Assessment – Legacy

Summary of Health and Safety Assessment

Many of the hazards described above are common to all decommissioning options. Based on the differences, in the short-term the leave *in situ* options give rise to lower risks to project personnel for the following reasons:

- Less offshore work;

- Less onshore handling.

The residual risk to other users of the sea is greatest for leave *in situ.* However, this is still deemed broadly acceptable since all but one of the mooring piles are driven to a depth 1m or greater below the seabed. One top of pile was installed to 0.75m below seabed. Although the partial and complete removal options remove all material within the seabed to a minimum depth of 3m, a significant amount of excavation work is required to access the mooring chains and mooring piles and therefore this will potentially present a snagging hazard in itself in the mounds are not rectified appropriately.

6.2.3 Environmental Impact of Operational Aspects

The environmental impact of operational activities is primarily a function of vessel duration in the field and largely independent of the specific vessel activity. The impact of this on liquid discharges to sea, noise, emissions to air and energy requirements, water column, seabed, waste, etc. are summarised in Table 6.2.4.

The seabed disturbance for the complete removal option is considered 'intolerable or high' and is an option not to be pursued where there are viable alternatives. This is because the volume of seabed material needing to be excavated would be several orders of magnitude larger than the partial removal option. The volume of excavated material for the partial removal option would be an order of magnitude larger than would be required for leave *in situ*.

Operational Environmental factors impacted	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
Atmosphere (energy & emissions)	Emissions and use of energy greatest for this option. No energy and emissions needed to create new material to replace any that may be left *in situ*	Emissions and energy use for this option is less than complete removal but more than the leave *in situ* option. Energy and emissions required to create new material which is left *in situ*	Emissions and use of energy is least for this option. Savings offset slightly by emissions and energy used to create replacement material
Seabed disturbance; area affected	Significant seabed disturbance due to extensive excavation of entire piles; the volume of seabed material excavated would be several orders of magnitude larger than the alternative options	Area of seabed disturbed would fall in between the complete removal and leave *in situ* options. Volume of seabed material excavated would be an order of magnitude greater than for the leave *in situ* option	Least seabed disturbance due to least excavation works
Water column disturbance: • liquid discharges to sea • liquid discharges to surface water • noise	Discharges and releases to the water column are related to the duration of activities which is greater than the leave *in situ* and partial removal options.	Discharges and release would be less than generated for complete removal but more than leave *in situ* option.	Potential discharges and releases are less for the leave *in situ* option compared to the other options.
Waste creation and use of resources such as landfill. Recycling and replacement of materials	No material left in seabed; all material fully recovered and available for reuse or recycling	Slightly more material recovered for reuse and recycling than for leave *in situ*	Leave in situ would mean than more material would be left *in situ* and therefore not recovered for reuse or recycling

Table 6.2.4: Mooring System Operational Environmental Impacts

6.2.4 Environmental impact of legacy aspects

Operational Environmental factors impacted	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
Atmosphere (energy & emissions)	No surveys would be required	We assume that no legacy surveys would be required for this option, but this would need to be agreed with OPRED	We assume that at least three legacy surveys would be required
Seabed disturbance; area affected	No surveys would be required	Status surveys are not usually intrusive	Status surveys are not usually intrusive. Therefore, we would not expect any seabed disturbance arising from legacy surveys should they be required
Water column disturbance: • liquid discharges to sea • liquid discharges to surface water noise	No surveys would be required	Degradation of material over decades if not hundreds of years. Marginally less material left in situ. Little to differential the partial removal and leave in situ decommissioning options	Degradation of material over decades, if not hundreds of years
Waste creation and use of resources such as landfill. Recycling and replacement of materials	No materials would be recovered in future, and no replacement materials would be required. There is little to differentiate the options from a legacy perspective		

Table 6.2.5: Mooring System Legacy Environmental Impacts

6.2.5 Summary of environmental assessment

The environmental impact of operational activities such as emissions and energy use are primarily a function of vessel duration in the field, and largely independent of pipeline or cable type. Seabed disturbances will be greater the more material is removed from the seabed. If more material is recovered, more is available for recycling or could be used to create energy. Conversely if more material is left behind, more new material would need to be manufactured to replace it.

In the overall context however, emissions and energy used for any of these decommissioning activities are small compared to overall energy use and emissions in the oil and gas industry and so cannot on their own be used to justify one option over another. Likewise, any disturbance to the seabed would be small compared to the area of the UKCS.

The key differentiator here is the requirement to excavate the piles to ensure that they can be fully recovered without any technical uncertainties. There will be trade-offs between the amount of material needing excavation to ensure successful and incident free recovery of the piles, so this assessment can be considered ‘worst case’. However, the assessment demonstrates that if viable for other reasons, an alternative decommissioning solution should be sought. In this case from an environmental perspective the preferred solution from an operational perspective would be the leave *in situ* option. The excavation requirements for this solution are relatively small and will not affect legacy considerations over the longer term (Table 6.2.5).

6.2.6 Societal Assessment

Please refer section 6.3.6 as we believe that the societal impacts of operational activities for the pipelines and the mooring systems are broadly similar. Therefore, we propose not to repeat the discussion here.

6.2.7 Cost Assessment

Detailed cost estimates have not been prepared, but a cost analysis based on vessel type and duration has been prepared. To enable a comparison the leave *in situ* option assumes that three future surveys will be required as part of liability commitments.

Assuming that the leave in situ option would involve carrying out a minimum of three legacy surveys, the incremental cost difference – that is, accounting for the cost of only those activities that would be different for each option, the partial removal and complete removal options would be £1.44MM and £5.37MM more expensive to implement than leave *in situ*. The incremental difference in cost is such that there is not an order of magnitude difference between the options.

Sub-Criterion	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
Operational cost	The cost of complete removal is the most expensive option and carries a high risk that excavation time and hence overall cost could increase	The cost of partial removal of the mooring piles and mooring chains to 3m would be significantly more expensive than the leave *in situ* option but considerably less expensive than the complete removal option.	The cost of leave *in situ* would be the least expensive of all the options
Legacy cost	Once the mooring system has been completely removed and the spoil heaps arising from the excavations have been backfilled, we would expect that legacy surveys will not be required	We would expect that no legacy surveys would be required	Future burial surveys would be required. The premise is that three legacy surveys would be required

Table 6.2.6: Mooring System Cost Assessment

6.2.8 Overall Summary of Assessment

The results of the comparative assessment for the mooring piles and mooring system is summarised in Table 6.2.7. When assessing the different decommissioning options against technical, health and safety, environmental, societal and cost risk, the leave *in situ* option was assessed as being the most preferred option.

The risks associated with the complete removal option was assessed as being unacceptably high due to the risk of major project failure. This is because of the excessive excavation, unknown recovery loads and the lack of track record of recovering similar mooring piles. To a lesser extent the partial removal option also carries a high risk technically due to the uncertainty around the location of the mooring chains at 3m below seabed and the extensive excavation requirement.

When assessing the options against health and safety risk, the main differences were attributed to vessel durations and onshore handling. The leave *in situ* option required significantly less vessel duration and material handling than partial and complete removal and hence is the preferred option.

The offshore durations and hence the environmental impacts from energy usage, emissions to air and discharges to the water column are less for leave *in situ* than partial removal and complete removal. When the additional emissions generated through manufacture of new material required to replace any mooring chain and mooring pile sections remaining on the seabed is considered, there is little to differentiate the different options. The main differentiator when assessing the environmental impact is the seabed disturbance. The complete removal and partial removal options involve significant excavation and seabed excavation to gain access to the mooring chain and mooring piles in comparison to the leave *in situ* option.

When looking at societal impacts, the complete removal option is preferred over the short term due to continuation of employment opportunities associated with vessel activities and waste management jobs associated with re-use and recycling of the recovered mooring chain and mooring piles. Over the longer term however, the leave *in situ* option is favourable due to the potential requirement for future surveys.

The incremental cost of complete removal and partial removal options are higher than leave *in situ* by £5.37 MM and £1.44 MM respectively, dominated by vessel time.

Recognising that there is a trade-off between the amount of excavation versus technical feasibility, the results of the comparative assessment showed the risks and impacts of complete removal of the mooring piles to be unacceptably high from an environmental perspective and non-preferred from a technical perspective. This is primarily due to the risk of major project failure through excessive dredging and unknown loads required to recover the mooring piles. Furthermore, there is no known experience in recovering driven mooring piles either within EnQuest or within the industry. To a lesser extent the partial removal option also carries a higher technical risk due to the uncertainty around the locating of the mooring chains at 3m below seabed and the potential need for more extensive dredging to locate the mooring chain. The leave *in situ* option carries little technical risk and would be significantly most cost effective than complete and partial options and is the recommended option.

Aspect	Sub-criterion	Short-term or Legacy?	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
Technical	Technical feasibility	Short-term			
		Legacy			
Health and Safety	Safety risk to offshore personnel	Short-term			
		Legacy			
	Safety risk to mariners	Short-term			
		Legacy			
	Safety risk to onshore project personnel	Short-term			
		Legacy			
Environmental	Atmosphere (energy & emissions)	Short-term			
		Legacy			
	Seabed disturbance, area affected	Short-term			
		Legacy			
	Water column disturbance	Short-term			
		Legacy			
	Waste creation	Short-term			
		Legacy			
Social	Commercial fisheries	Short-term			

Aspect	Sub-criterion	Short-term or Legacy?	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
		Legacy			
	Employment	Short-term			
		Legacy			
	Communities	Short-term			
		Legacy			
Cost		Short-term			
		Legacy			

Table 6.2.7: Mooring System Summary of Comparative Assessment

6.3 Pipelines Comparative Assessment

Although the various pipeline and cable constructions differ, the approach to decommissioning their trenched sections will fundamentally be the same. Therefore, the comparative assessments have been combined, noting any differences that may arise. The 'partial removal' option is only applicable to pipelines **PL3006, PL3007, PL3008, PL3011, PL3012, PL3013** and **PL3014**. The production and water injection flowlines **PL3006**, **PL3007**, **PL3008**, and **PL3014**. These pipelines have all experienced upheaval buckling and are likely to require remedial works. The power cables PL3011, PL3012, PL3013 all have relatively poor depth of cover, and as a result have experienced some degree of exposure and these may also require remedial works. Details of the specific exposures are explained in Section 4.

6.3.1 Technical Assessment

For the complete removal option, the flowline, umbilical or power cable would need to be retrieved through the deposited rock and the trench in which is has been buried by natural backfill. It has been assumed that the deposited rock and backfill sediment will be loose enough to allow the flowline, umbilical and power cables to be retrieved to a vessel reel without any significant excavation work. The complete removal option will be subject to integrity checks and may require the removal of material using specialist equipment such as a mass flow excavator.

Operations that involve removal of relatively short lengths of pipe in discrete areas are well-established activities with little technical uncertainty. This option has been widely used for removing a short pipeline in its entirety, or for removing discrete lengths. It is usually the recommended removal option for short sections of pipe when it is impractical or prohibitively expensive to mobilise major equipment for removal.

Please note that dealing with the pipeline approaches will be common for all decommissioning options and so is not used to differentiate the options.

Sub-Criterion	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
Technical feasibility	**Short-term:** Integrity of pipelines is not currently known although it is unlikely that their integrity will have been impaired sufficiently to prevent recovery. Reverse reeling has been carried out previously but limited track record of pulling pipelines through rock. In a contingency scenario mass flow excavators have been used to excavate seabed material.	**Short-term:** Removing sections of pipe using the 'cut and lift' method for short sections has been carried out in the North Sea, so we know this is achievable. Searching and excavation can be problematic and time consuming, but such activities have been done before.	**Short-term:** Pipelines have been left *in situ* before and we know this is achievable.
	Legacy: No pipeline surveys required.	**Legacy:** Pipeline surveys have been undertaken in the past, so this is achievable for continuous steel pipelines with no complications. However, composite flowlines, umbilical pipelines and power cables can become more difficult to locate with increasing trench depth and depth of cover.	**Legacy:** Pipeline surveys have been undertaken in the past, so this is achievable for continuous steel pipelines with no complications. However, composite flowlines, umbilical pipelines and power cables can become more difficult to locate with increasing trench depth and depth of cover. Remedial work will likely be required for exposed sections of pipe.

Table 6.3.1: Pipelines Technical Assessment

Summary of technical assessment

Three options were considered for the buried flowlines, umbilical's and power cables. Theoretically, given the right conditions all three options can be considered technically feasible.

The leave *in situ* option presents the lowest technical risk in the short-term because no intrusive work would be required. Over the longer term, although pipeline surveys are carried out quite regularly, composite flowlines, umbilical pipelines and power cables can present more of a challenge; they become more difficult to locate with increasing trench depth and depth of cover. However, the depths of cover associated with these pipelines is not excessive, and so pipeline surveys should be possible to achieve.

The 'cut and lift' method is viable for short lengths of pipeline, but the excavation requirement can be particularly time-consuming when dealing with intermittent lengths of pipe. It is still technically feasible.

The reverse reel method of removal has been used for recovering small composite pipelines in the North Sea. The flexibility of these pipelines compared to steel would suggest that they could be pulled through shallow naturally deposited backfill, although an engineering assessment would be required to confirm this. The structure of the wall of a flexible flowline means it doesn't experience the same deformation cycles as the rigid pipeline during the reeling and unreeling process. Multiple reeling and unreeling cycles should not, therefore, compromise the integrity of a flexible flowline.

We believe that all the decommissioning options are technically feasible. Although there are more technical uncertainties associated with the complete removal option there is little to choose between this and partial removal from a technical perspective. Both are broadly acceptable.

6.3.2 Health & Safety Assessment

Health and Safety Risk to Offshore Project Personnel

All hazards associated with the handling of a large quantity of pipe or associated with a heavy object (pipeline) onshore were assessed as 'broadly acceptable but non-preferred' on the basis that operations of this type have been done before, and that they would be controlled by procedure. The key differences between the options are as follows:

- Risk to personnel on the vessel from hydrocarbon or hazardous substance releases from recovered pipelines will be greater for complete removal than for partial removal or leave *in situ* due to the larger volume of material recovered;
- Exposure to potentially NORM contaminated materials increases with the volume of material recovered;
- The risk to personnel and assets is greater for complete removal option compared to partial removal option or leave *in situ* where only a small part of the overall pipeline would be removed;
- Increased risk to all activities due to adverse weather is greater for complete removal than for partial removal or leave *in situ* as the time the vessel would be in the field is greater, irrespective of the removal method adopted;
- Risk associated with legacy survey activities that is, the risks associated with vessels being used is greater for partial removal and leave *in situ*. At least three legacy surveys would be required to confirm the status of any pipelines or sections thereof left *in situ*.

For context it is worth noting that it is likely that in adopting the partial removal and leave *in situ* decommissioning options that more 'cut and lift' activities would be required for lengths of surface laid pipelines that would be too short to be removed using the reverse reeling method of recovery.

Health and Safety Operational Risk to Other Users of the Sea

There remains the possibility of interaction with other mariners while decommissioning works are being carried out in the field and this potentially would increase with the number of vessels, the location of the work and the frequency of marine traffic. Decommissioning activities involve vessels working in the field, and over the longer term will be related to the amount of surveys and any pipeline remedial works that may be required in future. By way of example, vessel durations associated with the complete removal option will be greater than for the partial removal and leave *in situ*.

Safety Risk to Onshore Project Personnel

All hazards associated with the handling of many pipe lengths or associated with a heavy object (pipeline) on or near the vessel during reverse reeling were assessed as 'tolerable and non-preferred' for the complete removal option. The key differences between the options are as follows:

- More heavy equipment including pipeline reels would need to be mobilised for the complete removal option;
- Risks associated with cutting the pipeline and exposure of any residues with a potential to result in injury, are greater for complete removal due to the higher quantity of material returned to shore compared with the partial removal and leave *in situ* options;
- Risks associated with lifting and handling pipeline sections are also greater for complete removal, due to larger quantity of material being returned to shore;
- Risks associated with unravelling the composite pipelines or separating the pipelines into their individual components - resulting in injury - are greater for complete removal due to the quantity of material returned to shore compared with the leave *in situ* and partial removal options;
- Risks associated with dealing onshore with any residues within either the flowlines or umbilical pipelines would be greater for complete removal;
- Exposure to potentially NORM contaminated materials increases with the volume of material

recovered;

Residual Risk to Other Users of the Sea

The greatest risk relating to marine users is likely to be concerned with snagging of fishing gear on subsea infrastructure and spoil mounds left on the seabed. Data relating to pipeline burial status are shown in Section 4. The data shows that there are several pipeline buckles and exposures that have been identified as snagging hazards for trawl gear.

From this it can be reasoned that decommissioning activities that minimise the disturbance to the seabed will reduce the likelihood of creating new snag hazards and avoid leaving an open trench. Both complete removal and partial removal will leave the seabed free of snagging hazards, while leave *in situ* will present risks that will remain as they are now. Although the complete removal option has the potential to leave spoil heaps that could present snagging hazards, any disturbance would be confined to within the trench, thereby minimising the impact of recovery operations.

The risk of snagging fishing gear and the risk of snagging equipment were assessed as broadly acceptable once potential snagging hazards such as exposed sections of pipe have been remediated. The key differences between the options are:

- There would be a risk of snagging fishing gear on the pipeline in future for partial removal or leave *in situ* should the burial status change, but this would be eliminated for complete removal;
- As the partial removal and leave *in situ* options leave a significant portion of the pipeline *in situ*, legacy pipeline status surveys would be required for these options. Legacy surveys have risks associated with the use of vessels that are not required following complete removal, but the work can be considered routine. Legacy related survey vessels would also be in the field for significantly less time than vessels involved in the complete removal and partial removal activities.

Sub-Criterion	**Option 1 Complete Removal**	**Option 2 Partial Removal**	**Option 3 Leave *in situ***
Health & Safety risk to offshore project personnel	More vessel transits, mobilisations and demobilisations, offshore work and more handling on the vessel than either partial removal or leave *in situ*	'Cut and lift' of more than 25 exposed sections of pipe would lead to more offshore work and more material handling on the vessel than leave *in situ*	Negligible offshore work compared with partial or complete removal
Health & Safety risk to other users of the sea	Duration of vessels in the field is longer than for leave *in situ*. The removal method means that that the vessel is attached to the pipeline and can't move out of the way quickly. The risk to mariners in the short term is aligned with the duration the activities that are undertaken in the field	Duration of vessels in the field is longer than for leave *in situ*. The removal method means that that the vessel is not attached to the pipeline segments as they are being removed it can move out of the way if required. The risk to mariners in the short term is aligned with the duration the activities that are undertaken in the field	The duration of any vessels in the field would be shorter than for either complete or partial removal
Health & Safety risk to onshore project personnel	Numerous vessel mobilisations required with large pieces of equipment such as pipeline reels. Large quantities of material recovered onshore. Significantly more stripping of material, onshore cutting, lifting and handling associated with disposal of the pipelines.	Fewer vessel mobilisations required, smaller quantities of material to be handled onshore that for the complete removal option	Fewer vessel mobilisations required, smaller quantities of material to be handled onshore that for the complete removal option

Table 6.3.2: Pipelines Health & Safety Assessment – Short-term

<table>
<tr><th>Sub-Criterion</th><th>Option 1
Complete Removal</th><th>Option 2
Partial Removal</th><th>Option 3
Leave in situ</th></tr>
<tr><td>Health & Safety risk to offshore project personnel</td><td>No future works would be required</td><td>Pipeline surveys and potential remedial works would be required.</td><td>Pipeline surveys and remedial works will likely be required for sections posing snagging risk.</td></tr>
<tr><td rowspan="3">Health & Safety risk to other users of the sea</td><td rowspan="3">Potential snagging risks completely removed; no legacy activities would be required</td><td rowspan="2">Pipelines surveys would still be required over the medium and longer term, leading to potential collision risks offshore. However, the risks of collision are low. For those pipelines whose exposures have been removed, potential snagging risks could arise at or near the cut pipeline ends</td><td>Pipelines surveys would still be required over the medium and longer term, leading to potential collision risks offshore. However, the risks of collision are low. Unacceptable snagging risks would meantime remain for the four pipelines (PL3006, PL3007, PL3008 & PL3014) that have experienced upheaval buckling. Pipeline survey vessels would still need to be mobilised. Remedial works would also be required that may result in new stabilisation materials being required or requiring materials to be brought back to shore for processing</td></tr>
<tr><td>Pipelines surveys would still be required over the medium and longer term, leading to potential collision risks offshore. However, the risks of collision are low. Potential snagging risks would meantime remain for the three pipelines (PL3011, PL3012 & PL3013) that have exposures arising due to poor depth of cover. Pipeline survey vessels would still need to be mobilised. Remedial works would also be required that may result in new stabilisation materials being required or requiring materials to be brought back to shore for processing</td></tr>
<tr><td>Pipelines surveys would still be required over the medium and longer term, leading to potential collision risks offshore. However, the risks of collision are low. For the pipelines that have not experienced upheaval buckling there is little to differentiate the partial removal and leave in situ options</td><td>Pipelines surveys would still be required over the medium and longer term, leading to potential collision risks offshore. However, the risks of collision are low. For the pipelines that have not experienced upheaval buckling there is little to differentiate the partial removal and leave in situ options</td></tr>
<tr><td>Health & Safety risk to onshore project personnel</td><td>No onshore work required</td><td colspan="2">Although snagging risks had meantime been removed, pipeline survey vessels would still need to be mobilised. Remedial works may also be required that may result in new stabilisation materials being required or requiring materials to be brought back to shore for processing</td></tr>
</table>

Table 6.3.3: Pipelines Health & Safety Assessment – Legacy

Summary of health & safety assessment

Many of the hazards described above are common to all decommissioning options. The complete removal option would require more material handling – for example, pipeline reels and pipeline removal equipment in preparation of the offshore work than for either the partial removal or leave *in situ* options. Further, complete removal would result in the recovery of more material to shore, that would then need to be stripped into composite components. However, these are activities that have been conducted previously in the North Sea. Based on the differences, in the short-term the partial removal and leave *in situ* options give rise to lower risks to project personnel for the following reasons:

- Less offshore work;
- Less onshore handling.

Despite having a slightly higher risk than partial removal and leave *in situ,* the complete removal option is broadly acceptable; recovery of flexible pipelines through buried sections has been carried out previously within the North Sea.

By completely removing the pipelines the risk of snagging is removed in perpetuity. Therefore, the complete removal option would result in lower residual risks to mariners and other users of the sea.

6.3.3 Environmental impact of operational aspects

The duration of vessels that would be required in the field for complete removal and partial removal was comparable, albeit complete removal is likely to be slightly longer in duration.

The impact of this on liquid discharges to sea, noise, emissions to air and energy requirements, water column, seabed, waste, etc. are summarised in Table 6.3.4.

Operational Environmental factors impacted	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
Atmosphere (energy & emissions)	Emissions and use of energy greatest for this option but no offset would be generated because of the energy and emissions needed to create new material to replace any that may be left *in situ*	Emissions and energy use for this option fall in-between complete removal and leave *in situ* although there would be little to differentiate complete removal and partial removal options	Least amount of energy used, and least emissions generated in the short-term, although this is counteracted by the energy and emissions required to create new material
Seabed disturbance; area affected	The amount of seabed disturbed is directly related to the length of pipeline being removed. The area affected would be largest for this option	This area of seabed disturbed would fall in-between the complete removal and leave *in situ* options	The least area of seabed would be disturbed with this option
Water column disturbance: • liquid discharges to sea • liquid discharges to surface water • noise	Discharges and releases to the water column are related to the duration of activities being undertaken and will therefore be greatest for the complete removal	Discharges and release would be less than generated for complete removal but slightly more than leave *in situ*	Discharges and releases would be least for this option, particularly in the short-term

Operational Environmental factors impacted	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
Waste creation and use of resources such as landfill. Recycling and replacement of materials	This option would result in the largest mass of material being returned to shore. No material would be lost as no material would be left *in situ.* Experience has shown that most of the material recovered could be recycled or used to create energy	This option sits in-between option 1 and option 3 and would sit closer to option 3 than option 1. Experience has shown that most of the material recovered could be recycled or used to create energy	No material would be returned to shore for recycling and so the material would be lost, and new manufactured material would be needed to replace the loss

Table 6.3.4: Pipelines – Operational Environmental Impacts

6.3.4 Environmental impact of legacy aspects

On completion of decommissioning activities, a final environmental survey would be carried out, and this would be common for all options and is not a differentiator. For longer-term legacy related activities, a differentiator between options would be the number of pipeline burial surveys that would be required as well as any possible remedial works.

The environmental impact of legacy activities associated with future requirements of ensuring that the pipeline(s) remains buried and stable are assessed in much the same way as operational activities. The impacts of legacy related activities can be expected to be significantly less than those brought about by operational activities during decommissioning work.

Operational Environmental factors impacted	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
Atmosphere (energy & emissions)	No pipeline surveys would be required	We anticipate that future survey requirements would be about the same for either option 2 or option 3, although option 3 would likely need more remedial work than option 2	We anticipate that future survey requirements would be about the same for either option 2 or option 3, although if we assume that no remedial work is done to remove sections of pipelines that are exposed during decommissioning activities, they would require remedial work following pipeline surveys

Operational Environmental factors impacted	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
Seabed disturbance; area affected	No composite materials would be left to deteriorate in the seabed. No pipeline surveys would be required, but in any event such surveys would not normally result in disturbance to the seabed	Degradation of composite materials such as plastics can be expected to take decades and more. Overtime, the local marine environment would be exposed to the materials as they degrade *in situ*. Pipeline surveys would not normally result in disturbance to the seabed. Remedial work might be required as a result of the surveys	Degradation of composite materials such as plastics can be expected to take decades and more. Overtime the local marine environment would be exposed to the materials as they degrade *in situ*. Pipeline surveys would not normally result in disturbance to the seabed. Remedial work would likely be required as a result of the surveys
Water column disturbance: • liquid discharges to sea • liquid discharges to surface water • noise	No pipeline burial surveys required	We anticipate that future survey requirements would be about the same for either option 2 or option 3, although option 3 would likely need more remedial work than option 2	We anticipate that future survey requirements would be about the same for either option 2 or option 3, although if we assume that no remedial work is done to remove sections of pipelines that are exposed during decommissioning works, they would require remedial work following pipeline surveys
Waste creation and use of resources such as landfill. Recycling and replacement of materials	Experience has shown that most of the material recovered could be recycled or used to create energy. As quantities recovered from any remedial works would be small for the partial removal and leave in situ options, there is little to differentiate any of the options from a legacy and waste perspective		

Table 6.3.5: Pipelines – Legacy Environmental Impacts

6.3.5 Summary of environmental assessment

The environmental impact of operational activities such as emissions and energy use are primarily a function of vessel duration in the field, and largely independent of pipeline or cable type. Seabed disturbances will be greater the more material is removed from the seabed. If more material is recovered, more is available for recycling or could be used to create energy. Conversely if more material is left behind, more new material would need to be manufactured to replace it.

In the overall context however, emissions and energy used for any of these decommissioning activities are small compared to overall energy use and emissions in the oil and gas industry and so cannot on their own be used to justify one option over another. Likewise, any disturbance to the seabed would be small compared to the area of the UKCS.

From Table 6.3.5, while there will be different impacts arising from each of the options, the overall impact of the 'complete removal' option would result in more energy use and emissions, a larger impact in the water column and more disturbance to the seabed. Conversely the leave *in situ* option would result in the least energy use and emissions, seabed impact, etc. In reality there is little to differentiate the three options.

Degradation of composite materials left *in situ* would take decades and more to degrade. Overtime the local marine environment would be exposed to these materials as they degrade.

Legacy survey requirements for leave *in situ* and partial removal would be greater than for complete removal and these would mostly impact the atmosphere and water column. However, if no remedial work is carried out to the exposed parts of the pipelines during decommissioning, legacy pipeline surveys will be required and would likely result in a requirement to carry out remedial works. Such remedial works can take several forms, including excavation, installation of additional material such as grout bags. However, in real terms there will be little to distinguish between the options.

Although, in the short term the amount of emissions to air and energy discharges is greatest for the complete removal option, this would offset by the fact that no pipeline surveys and no pipeline remedial works would be required in future, and that material would be recovered for recycling or re-use. Complete removal was assessed to be the marginally preferred option. However, all three options were deemed broadly acceptable from an environmental perspective.

6.3.6 Societal Assessment

The assessment of the other criteria (safety, environment, cost and technical) considers the level of detrimental effect whereas the assessment of impacts on employment considers the level of benefit, a positive effect. Vessel durations are used as an indicator of magnitude of the *continuation* of employment rather than creating new employment. We can discuss short-term effects due to decommissioning operations – 'project' activities - and longer-term impacts due to legacy related activities.

The societal issues around the pipelines are discussed below.

Commercial activities

Commercial fishing activity within the vicinity of the Alma-Galia is very low with no data for most of the year and undisclosed data in June 2019. Aggregated ICES data for fishing effort in hours with bottom trawls and dredges for 2009-2016 showed the effort for these types of fishing was low enough not to register [2]. Therefore, the potential effects could be loss of fishing revenue due to exclusion from fishing grounds, disturbance of the seabed or loss or damage of fishing equipment. However, the impact of decommissioning activities on fishing activity can be expected to be small.

While the vessels are present in the field and activities are being undertaken, the area will not be accessible for fishing. Therefore, the magnitude of the impact on commercial activities is related to the vessel duration. In the short-term, irrespective of which pipeline is being decommissioned, the complete removal activities will incur activities with longer vessel durations. Conversely, the leave *in situ* option would require the least vessel activity. Where available the partial removal option will incur longer vessel durations that are slightly less than the complete removal option but more than for leave *in situ*.

Decommissioning activities common to all decommissioning options such as dealing with the pipeline ends or removing surface laid pipelines, are not considered here as they do not differentiate the options.

Partial removal leaves much of the infrastructure *in situ* and, the leave *in situ* option would leave most of the infrastructure in the seabed resulting in less offshore activities, so there would be less of an impact on any commercial fishing activities. As explained earlier, fishing activity in the area is low [2] and hence although the complete removal option can be expected to have a greater impact on fishing activities through disturbance to seabed and duration of vessels in field, it is not a key differentiator between the options.

While all decommissioning options would require an environmental survey to be completed, only the partial removal; and leave *in situ* options would require pipeline surveys and stability assessments in future. The degree to which these will be required will be governed by the results of each survey, and if it can be demonstrated that the pipeline remains stable and pose no snagging risk such surveys may no longer be required. This would be assessed on a case by case basis.

While any such surveys are being undertaken, fishing activity may be disrupted for a short time, but the impact can be expected to be minimal. Typically, one post-decommissioning environmental survey would be required, and for each decommissioning option where material is left within the seabed, we have assumed that three legacy pipeline surveys would be required. The exact magnitude of the impact will be dependent on the type, frequency and duration of the surveys required.

Employment

The complete removal option has greater vessel duration and waste management requirements and therefore impacts more positively on employment than partial removal and leave *in situ*. The effect on employment will be the continuation of existing jobs for construction and survey vessels appointed to carry out the decommissioning activities as well as port authority and waste management contractors.

Communities

Vessels would be in the field for a relatively short duration, both within and outside the 500m safety zones. Shipping will be notified and continue alternative routes and hence the disruption to commercial vessels is minimal.

The port and the disposal site for recovered materials have yet to be established. However, they will be existing sites which are used for oil and gas activities and hold the required licenses and permits for waste management. The communities around the port and the waste disposal sites are therefore expected to be adapted to the types of activities required and the decommissioning activities will be an extension of the existing situation. Therefore, the effect on communities is not considered a differentiator between options.

The results of the societal assessments for the pipelines are presented in Table 6.3.6.

Sub-Criterion	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
Short-term: Commercial activities	Impact of decommissioning vessel traffic on local commercial activities such as fishing would be greatest for complete removal	Impact of decommissioning vessel traffic on local commercial activities such as fishing would be slightly less than complete removal but more than leave *in situ* option	Impact of decommissioning vessel traffic on local commercial activities such as fishing would be the least for leave *in situ* removal
Legacy: Commercial activities	An environmental survey would be required but this is the same for all options. No legacy pipeline surveys would be required	Impact of survey vessel traffic on local commercial activities such as fishing would be slightly more than for complete removal and less than for leave *in situ*	Impact of survey vessel traffic on local commercial activities such as fishing would be slightly more with the leave *in situ* option but there is little to differentiate option 2 and option 3
Short-term: Employment	Decommissioning activities would contribute greatest to continuity of employment for complete removal	Decommissioning activities would contribute to continuity of employment less than for complete removal and more that for leave *in situ* option	Decommissioning activities would contribute the least to continuity of employment for leave *in situ*
Legacy: Employment	Once the pipeline(s) had been completely removed, the opportunity for continuation of employment would be minimal once the environmental survey had been completed	Once the pipeline had been partially removed the opportunity for continuation of employment would be associated with survey work would be like the leave *in situ* option. Some jobs would be associated with the manufacture of new material to replace that which is left *in situ*	Should the pipeline(s) be left *in situ* surveys would need to be carried out as would be required for option 2 and Some jobs would be associated with the manufacture of new material to replace that which is left *in situ*, otherwise there is little to differentiate options 2 & 3.
Short-term: Communities	Decommissioning activities would contribute greatest to continuity of work in ports and disposal sites for complete removal	Decommissioning activities would contribute to continuity of work in ports and disposal sites less than for complete removal and more that for leave *in situ* option	Decommissioning activities would contribute the least to continuity of work in ports and disposal sites for leave *in situ*
Legacy: Communities	Once the pipeline(s) had been removed there would be few opportunities for continuity of work in ports and disposal sites	Once the pipeline(s) had been partially removed there would be few opportunities for continuity of work in ports and disposal sites other than associated with survey related and possible remedial work	Once the pipeline(s) had been left *in situ* there would be few opportunities for continuity of work in ports and disposal sites other than associated with survey related and possible remedial work. There is little to differentiate options 2 & 3

Table 6.3.6: Pipelines Societal Assessment

Summary of societal assessment

Vessel durations were used as an indicator of magnitude of the *continuation* of employment rather than creating new employment. Short-term effects due to decommissioning operations were considered –

‘project’ activities - and long-term impacts due to legacy related activities. The potential disruption to commercial activities resulting from the presence of vessels specifically to carry out the decommissioning work has also been considered.

Disruption to commercial activities would be least when the decommissioning effort in the field is minimised, and this is the case for leave *in situ*, whereas complete removal could potentially result in the most disruption to commercial activities with partial removal being in-between.

Conversely, legacy related disruption on commercial activities in the area would be greatest for leave *in situ* and partial removal options due to the requirement for future surveys and potential remedial works. Complete removal would cause the least disruption to commercial activities in future as there would be no infrastructure left to inspect.

Employment opportunities would be greatest for the complete removal option owing to the larger amount of vessel time and onshore dismantling and recycling works. Such opportunities would be least for the leave *in situ* option but slightly greater for the partial removal option.

Conversely, legacy related employment opportunities would be least for complete removal and greatest for leave *in situ*, with opportunities associated with partial removal being like leave *in situ*. This is because the leave *in situ* and partial removal options would require legacy activities to be carried out, at least for the foreseeable future.

6.3.7 Cost Assessment

Detailed cost estimates have not been prepared. The incremental cost difference assessment is calculated taking account different vessel types for each decommissioning option for just the trenched and buried sections of the pipelines. To enable a comparison of the leave *in situ* option and partial removal option assumes that three future surveys will be required as part of liability commitments. The costing assessment does not include costs for removing stabilisation features or unburied sections of pipeline since this is a common requirement for all options.

The costs associated with the leave *in situ* option are estimated to be around £0.84MM. The partial removal option applies to pipelines with known exposures and is estimated to cost around 6 times the leave *in situ* option at £5.4MM. The partial removal option has the highest incremental cost. The incremental increase in cost for complete removal versus leave *in situ* is estimated at a cost of £4.9MM. The incremental difference in cost between complete removal and partial removal including the requirement for legacy surveys would be £0.5 MM. Due to the relatively small difference in incremental costs between the complete and partial removal options, both options are considered 'Broadly Acceptable' although extent of legacy burial surveys required would remain an uncertainty.

The difference in cost described here assumes that the same method of removal –re-reeling - would be used for recovering the short lengths of pipelines on the approaches to the Alma manifold, the water injection well and the Galia drill centre for all decommissioning options. However, the reverse reel method of removal would be impractical for such short lengths of pipeline, and the 'cut and lift' method would likely be used instead. Using the 'cut and lift' method of removing pipelines would be relatively inefficient, resulting in an incremental increase in costs associated with 'leave in situ' and partial removal and this would likely nullify the incremental difference in cost between the partial and complete removal options

Sub-Criterion	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
Operational cost	The cost of complete removal is slightly less expensive than the partial removal option but significantly more expensive than the leave *in situ* option.	The cost of partial removal of exposed sections is slightly more expensive than the full removal option but significantly more expensive than the leave *in situ* option.	The cost of leave *in situ* would be the least expensive of all the options
Legacy cost	Once the pipeline has been completely removed, it is not envisaged that pipeline surveys will be required.	Future surveys will be required with the possibility that remedial works would be required as a result. However, there is little to differentiate leave *in situ* and partial removal costs over the long-term.	Future surveys will be required with the likelihood that remedial works would be required as a result. However, there is little to differentiate leave *in situ* and partial removal costs over the long term.

Table 6.3.7: Pipelines Cost Assessment

6.3.8 Overall Summary of Assessment

The results the assessment are summarised in Table 6.3.8 and show the short-term risks and impacts of all pipeline decommissioning options to be broadly acceptable. The four flowlines **PL3006**, **PL3007**, **PL3008** and **PL3014** each exhibit multiple exposures and spans that have resulted from upheaval buckling. Each of the three Alma power cables (**PL3011**, **PL3012** and **PL3013**) also suffer from a short exposure along their length and these could also pose a snagging hazard for fishing activity over the longer-term. Just the two umbilical pipelines (**PLU3009** and **PLU3015**) and the Galia power cable (**PL3016**) have no exposures along the trenched and buried sections of their length.

In the short-term the complete removal option presents more risk and uncertainty from a technical and safety perspective and would result in more material handling both offshore and onshore. Complete removal would also result in more energy use and emissions, and more impact to the water column and seabed. A benefit would be that having been recovered, more materials would be available for reuse and recycling than either partial removal or leave *in situ* options. No materials would be left to degrade in the seabed.

Overall, for all the pipelines the leave *in situ* option has been assessed as having the lowest short-term safety risk, lowest environmental impact and risk, lowest technical uncertainty and lowest cost. However, over the longer-term, legacy pipeline surveys would be required to monitor the status of pipelines and the requirement could extend should remedial works be required. Further, the leaving the four buckled pipelines as they are would present an unacceptable high risk of snagging to other users of the sea. Leaving the three pipelines with lesser exposures and relatively poor depth of cover will mean that the pipelines will need to be monitored with the possibility of remedial works sometime in future. For these reasons, the leave *in situ* decommissioning option is non-preferred, at least for those pipelines that have experienced upheaval buckling and those that exhibit poor depth of cover and exposures.

We believe that all the decommissioning options are technically feasible. Although there are more technical uncertainties associated with the complete removal option using reverse reeling there is little to choose between this and partial removal from a technical perspective. Both are broadly acceptable.

The ‘cut and lift’ method is viable for short lengths of pipeline, although the excavation requirement can be particularly time-consuming and inefficient when dealing with intermittent lengths of pipe associated with the partial removal option. It is still technically feasible.

It is perhaps worth noting that should either the partial removal or leave *in situ* option be pursued it is likely that ‘cut and lift’ operations would be used on the approaches and surface laid pipelines. This is because in many cases the pipeline lengths being recovered would be too short to justify use of a pipeline reel.

The environmental impact of operational activities such as emissions and energy use are primarily a function of vessel duration in the field, and largely independent of pipeline or cable type. Seabed disturbances will be greater the more material is removed from the seabed. If more material is recovered, more is available for recycling or could be used to create energy. Conversely if more material is left behind, more new material would need to be manufactured to replace it.

In the overall context however, emissions and energy used for any of these decommissioning activities are small compared to overall energy use and emissions in the oil and gas industry and so cannot on their own be used to justify one option over another. Likewise, any disturbance to the seabed would be small compared to the area of the UKCS. Therefore, there is little to differentiate the options from a short-term environmental perspective.

Over the longer-term, degradation of composite materials left *in situ* would take decades and more to degrade. Overtime the local marine environment would be exposed to these degraded materials as they disperse into the seabed and into the water column. For this reason, the leave *in situ* option would be non-preferred from an environmental perspective over the longer-term.

When considering societal aspects such as employment, all the options can be considered to contribute to an extension of employment rather than create new jobs or new companies. The same applies whether considering the short-term or longer-term opportunities.

Finally, although the cost of partial removal is slightly higher, there is little to differentiate the partial and complete removal options from a cost perspective when we consider the benefits of the complete removal option over the longer-term and the uncertainty concerning future pipeline surveys and potential requirement for remedial works. Complete removal via reverse reel should prove more cost effective when dealing with the approaches and surface laid sections of the pipelines in the same campaign.

Aspect	Sub-criterion	Short-term or Legacy	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
Technical	Technical feasibility	Short-term			
		Legacy			
Health and Safety	Safety risk to offshore personnel	Short-term			
		Legacy			
	Safety risk to mariners	Short-term			
		Legacy			PL3006, PL3007, PL3008, PL3014 PL3011, PL3012, PL3013 Others
	Safety risk to onshore project personnel	Short-term			
		Legacy			
Environmental	Atmosphere (energy & emissions)	Short-term			
		Legacy			
	Seabed disturbance, area affected	Short-term			
		Legacy			
	Water column disturbance	Short-term			
		Legacy			
	Waste creation	Short-term			
		Legacy			
Societal	Commercial fisheries	Short-term			
		Legacy			
	Employment	Short-term			
		Legacy			
	Communities	Short-term			
		Legacy			
Cost		Short-term			
		Legacy			

Table 6.3.8: Pipelines Summary of Comparative Assessment

7. CONCLUSIONS

Comparative assessment was undertaken with a focus on the decommissioning options for the various buried pipelines, umbilical's and power cables as well as the mooring piles and associated mooring chains.

The assessments considered five criteria in both the short-term for decommissioning activities and the longer term for any 'legacy' related activities. The criteria were: technical feasibility, safety related risks, environmental impact, societal effects, and cost.

Since the decommissioning of the pipeline and umbilical approaches is the same irrespective of which option is pursued, decommissioning of these is not included in the assessment. Therefore, any differences are incremental to the activities associated with dealing with the pipeline approaches.

Similarly, the decommissioning of the mooring chains between the FPSO and the dip down point is the same irrespective of which option is pursued and thus, decommissioning of these particular mooring chain sections is not included within the assessment.

7.1 Conclusion of Comparative Assessment for Mooring System

The EnQuest Producer is moored using three clusters of three mooring lines in each. Each mooring line is anchored using a mooring pile, driven below the seabed. Three decommissioning options were compared for the mooring system – complete removal, partial removal and leave *in situ.* Complete removal would involve significant excavation of the mooring pile(s), internally and externally to allow recovery of the large steel mooring pile(s) and associated section of mooring chain. Partial removal would involve excavation of the mooring chain(s) and mooring pile(s) to allow a cut at 3m below seabed before recovery of the mooring chain and part of the mooring pile respectively. The leave *in situ* option would involve cut of the mooring chain at the dip down point and either excavation of the mooring chain to 1m below seabed or burial of the mooring chain end to ensure the cut end is 1m below seabed.

The results for the mooring piles and mooring system comparative assessment are summarised Table 6.2.7. General trends include the following;

- Leave *in situ* is the preferred option, although complete and partial removal improve legacy aspects;
- From a technical perspective complete removal can be considered 'broadly acceptable but non-preferred' if it can be assumed that each of the piles could be fully excavated. However, the volume of excavation is such that it would be 'high and intolerable' if alternative and viable decommissioning options are available. However, technical risks and uncertainties would increase should the volume of excavated material be reduced such that part of the mooring pile(s) remain buried in the seabed;
- The excavation involved in complete removal is significant and the volume of excavated material would be several orders of magnitude larger than would be required for the leave *in situ* option;
- The excavation involved in complete removal is significant and the volume of excavated material would be an order of magnitude larger than would be required for the leave *in situ* option;
- Although a detailed cost estimates have not been prepared, a cost analysis based on vessel type and duration has been prepared. The results of which suggest that the cost of complete removal and partial removal options are estimated greater than leave *in situ* option, inclusive of legacy survey costs. However, the incremental difference in cost is such that there is not an order of magnitude difference between the options.

In conclusion, based on the comparative assessment 'leave *in situ*' is the recommended option for decommissioning the FPSO mooring system.

7.2 Conclusion of Comparative Assessment for Pipelines

The Alma and Galia are all trenched and buried in the seabed and under deposited rock along parts of their length. Several of these pipelines have known exposures due to upheaval buckling (**PL3006**, **PL3007**, **PL3008**, **PL3014**) and several pipelines (**PL3011**, **PL3012** and **PL3013**) suffer from exposures due to poor depth of cover. Only the two umbilical pipelines **PLU3009** and **PLU3015** and Galia ESP (**PL3016**) power cable have been found to be buried without exposures.

Three decommissioning options were compared for the seven of the ten pipelines – complete removal, partial removal and leave *in situ*. Complete removal would involve recovering the pipelines through seabed sediment and short lengths of deposited rock. Partial removal would involve several exposed lengths of pipeline being removed. The leave *in situ* option would involve leaving the pipelines 'as is' without remediation and monitoring of its burial status over the foreseeable future.

The results for the buried pipelines comparative assessment are summarised in Table 6.3.8. General trends include the following;

- Despite the technical uncertainties, complete removal would be the preferred option, as it would completely remove the snagging hazards and the residual uncertainties associated with legacy surveys and remedial works;
- Experience has shown that the partial removal can be time consuming to achieve as more interventions would be required to remove relatively short sections of pipeline. The residual uncertainties associated with legacy surveys and potential remedial works would remain;
- Leave *in situ* – that is, leaving the pipelines without remediation of exposures that have arisen as a result of historical upheaval buckling - provides an unacceptably high risk to residual users of the sea. On this basis, remedial works would likely be required as part of the decommissioning activities, equating to the partial removal option;
- Complete removal would is presents a marginal benefit to society over the short-term due to continuation of employment for offshore vessel work and onshore waste management associated with re-use and recycling of the recovered pipelines;
- Finally, assuming that leave *in situ* without remedial works can be discounted there is little to differentiate the complete removal and partial removal options from a cost perspective, with partial removal being slightly more expensive. When taking account of the full pipeline decommissioning scope, should partial removal be adopted, more 'cut and lift' activities would be required for lengths of surface laid pipelines that would be too short to be removed using the reverse reeling method of recovery. This would increase the overall cost of the partial removal option in relation to complete removal, although we do not quantify the increase in cost in this report.

The assessment results in a preference for completely removing the pipelines and removing the uncertainty associated with legacy surveys and remedial works. This approach appears to concur with the decommissioning of other FPSOs and associated infrastructure in the North Sea.

8. REFERENCES

[1] EnQuest (2019) Decommissioning Programmes, M3523-PDi-ALG-EG-000-REP-0005;

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