Comparative Assessment

Alba Floating Storage Unit Mooring System

Document Control

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<u>Figures and tables</u>

Table of Abbreviations

Acronym	Description
~	Approximately, circa
AHV	Anchor Handling Vessel
ALARP	As Low As Reasonably Practicable
Angle of repose	The angle of repose, or critical angle of repose, of a granular material is the steepest angle of descent or dip relative to the horizontal plane on which the material can be piled without slumping. At this angle, the material on the slope face is on the verge of sliding
ANP	Alba Northern Platform
AXS	Alba Extreme South
CA	Comparative Assessment
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CNS	Central North Sea
CSV	Construction Support Vessel
Ø	Outside diameter (anchor piles)
dia.	Diameter
DP	Decommissioning Programme
EUNIS	European Nature Information System
FPV	Fall Pipe Vessel (rock dumper)
FSU	Floating Storage Unit
GMG	Global Marine Group (Statutory Consultee), formerly Global Marine Systems
in	Inch (25.4mm)
ICES	International Council for the Exploration of the Sea
kg	Kilogramme
MFE	Mass Flow Excavator
NCMPA	Nature Conservation Marine Protected Area
NFFO	National Federation of Fishermen's Organisations (Statutory Consultee)
NIFPO	Northern Ireland Fish Producer's Organisation (Statutory Consultee)
m	Metre (1,000mm)
MFE	Mass Flow Excavator
ML	Mooring Line
mm	Millimetre
MPA	Marine Protection Area
O/A	Overall
OPRED	Offshore Petroleum Regulator for Environment and Decommissioning
PLL	Potential Loss of Life. The PLL metric estimates the number of fatalities that could arise from a hazardous event. It combines event frequencies, consequences, and population data to provide an understanding of the potential human impact. It is calculated as the probability of a fatality (per year) from a hazard or as the probability of a fatality during the execution of a scope of work.
ROV	Remotely Operated Vehicle
SADIE	South Area Drilling and Injection Equipment
SAC	Special Area of Conservation
SFF	Scottish Fishermen's Federation (Statutory Consultee)
SNS	Southern North Sea
Te	Metric Tonne (1,000 kg)
UKCS	United Kingdom Continental Shelf
UNO	Unless Noted Otherwise
WT	Wall thickness
x	Number of

Comparative Assessment colour scheme

The colour scheme used in the comparative assessment summary tables (refer Appendix A) is presented in Table 1.1.1 below. The intention is that the colour scheme shows - at a glance, which option performs best for the specific aspect being assessed.

<table>
<tr><th colspan="3">Table 1.1.1: Comparative Assessment colour scheme</th></tr>
<tr><th colspan="2">Assessment[1]</th><th>Description</th></tr>
<tr><td>On balance this is the best option</td><td>Broadly Acceptable / Low & most preferred</td><td>The performance of this option the best overall and ‘broadly acceptable’.
This is the best option.
For cost this is the cheapest option.</td></tr>
<tr><td rowspan="2">↑</td><td>Broadly Acceptable / Low & less preferred</td><td>The performance of this option is marginally worse than the best option or slightly more expensive than the cheapest cost.</td></tr>
<tr><td>Tolerable / Medium Non-preferred</td><td>Risks are tolerable and managed to ALARP. Implement controls and measures to reduce risks to ALARP; requires identification, documentation, and approval by responsible leader.
For cost, an item highlighted orange means that the cost would be more than twice the cost of the cheapest option.</td></tr>
<tr><td>On balance this is the worst option</td><td>Intolerable / High not acceptable</td><td>Impacts are intolerable. Implement controls and measures to reduce the risks to ALARP (at least to medium); requires identification, documentation, implementation, and approval by responsible leader.
For cost, an item highlighted red means that the cost would an order of magnitude (i.e. 10x) higher than the cheapest option.</td></tr>
</table>

[1] The options are compared in absolute terms. For a preferred option the “Broadly Acceptable / Low & most preferred” shade of green is used. If both / all options are deemed acceptable, a choice of one of the two shades of green are used to provide further differentiation. The colour orange is used in the comparative assessment summary tables to show that the impact would be significantly higher and non-preferred of the options.

1. EXECUTIVE SUMMARY

1.1 Overview

A comparative assessment of the severance of the mooring lines is a key consideration within the Alba Floating Storage Unit (FSU) Decommissioning Programmes (DPs) that are submitted to the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED).

The mooring system for the Alba FSU comprises twelve mooring lines, each of which is connected to an anchor pile. The mooring lines comprise a combination of cables, chains, link-plates and shackles. Each is a nominal 678.8 m long and secured to a padeye mounted on an anchor pile 19 m below the seabed.

1.2 Alba FSU mooring system

The mooring system that serves the Alba FSU is summarised in Table 1.2.1 below.

Table 1.2.1: Mooring system details

Description	No.	Size / Dimensions, Mass (Te) of each component	Comments / Status
Anchor pile(s)	12	1.524mØ32-38mmWT, 37m long, 50.8 Te Overall mass of the piles is 12x50.8 = 609.6 Te	As-built' data records that each pile was driven to a depth such that the top of pile is at least 10 m below seabed.
Mooring lines	12	152mm studlink chain each with a nom. length 17.6m, 277 Te	The quoted length of chain excludes a 152mm Y-link (0.73m long) that connects the 152mm chain to the 149mm sheathed rope. Refer Figure 2.3.1.
		149mm sheathed wire rope each with a nom. length 100m, 112.9 Te	The quoted length of 140mm stud link chain excludes a 140mm Y-link (0.68 m long) that connects the 149mm sheathed wire rope to the 140mm stud link chain. Refer Figure 2.3.1
		Combined 140mm & 133mm stud link chain each with a nom. length 290.6m and 34.2m respectively, 1,965 Te	
		133mm stud link chain each with a nom. length 234.5m, 1,210 Te	The length of chain quoted for the 133mm stud link chain is final section of the mooring line that connects to a padeye on the anchor pile positioned 19m below seabed. It is estimated that ~80 m of mooring chain is buried at it approaches the padeye. Refer Figure 2.3.1, Figure 2.3.2 and Figure 2.3.3.

The cumulative length of the mooring line is 8,145.8 m. The mass of each mooring line – excluding the anchor piles, is 297.1 Te. The overall mass of the mooring lines as 12 x 297.1 = ~3,565 Te.

1.3 Decommissioning options

- **Complete removal** – This would involve the complete removal of the mooring lines (along with the anchor piles) by whatever means most practicable and acceptable from a technical perspective.
- **Partial removal to seabed with subsequent burial to 1 m below the seabed** – This would involve tensioning the mooring line to the point where the chain section enters the seabed and cutting it. Thereafter, the chain would be buried to a depth of at least 1 m below the seabed using a Mass Flow Excavator (MFE). No remedial work involving rock would be required.
- **Partial removal to 3 m below seabed** – This would involve excavating each mooring chain locally to 3.5 m below seabed to enable access to cut the chain. Use rock to backfill excavation.
- **Leave *in situ*** – This would involve leaving the entire mooring system *in situ*.

A cut at seabed and subsequent burial of the cut end to at least 1 m below the seabed is an appropriate compromise given the soil conditions.

The OPRED oil and gas decommissioning guidance notes [4] state:

"…any piles should be severed below the natural seabed level at such a depth to ensure that any remains are unlikely to become uncovered. Operators should aim to achieve a cut depth of 3m below the natural seabed

level, however consideration will be given to the prevailing seabed conditions and currents and this should be detailed in the decommissioning programme and discussed with the relevant decommissioning team."

The anchor piles are buried to more than 3 m below the seabed. They would not present a snag hazard if left *in situ*, and the benefits of removal would be outweighed by the effort required to remove them. For the mooring lines, the leave *in situ* option is not a consideration as it would not satisfy mandatory requirement for a clear seabed, and therefore the option has been discounted. Therefore, only the two 'partial removal' options for the mooring lines are considered in this Comparative Assessment. The anchor piles are not included in the assessment.

1.4 Method

The assessment is qualitative and considers five criteria for both the short-term decommissioning activities and the longer-term 'legacy' related activities. The criteria were: technical feasibility with three sub-criteria, safety related risks with three sub-criteria, environmental with five sub-criteria, societal effects with three sub-criteria and cost.

1.5 Conclusions

There is a significant difference between the partial removal options from a technical and environmental perspective. The volume of excavation and requirement for backfill material is significantly greater for the cutting of the chain at -3 m option; no rock would be required for the -1 m cut at seabed and burial option. Much more vessel time and energy would be required for the -3 m option compared to the -1 m cut at seabed and burial option. For the -3 m option, the mechanical remediation of such material may not be practical and natural redistribution of this excavated sediment would not be expected due to the sediment type (typically mud) and relatively weak currents in the area (i.e. compared to the southern North Sea where sediment is typically sand and is a high energy system with seabed sediment movement). Disturbance to the seabed for the -1 m cut at seabed and burial option would be significantly lower and no berms of material would be created or left behind.

From a health and safety perspective there is little to differentiate the options. The decommissioning works for both options would be conducted using remotely operated equipment. For the -3 m option a potential snagging risk could remain from any excavated material remaining on the seabed. Following completion of the decommissioning works, no snagging risk would arise from the severed mooring chains below the seabed for either option.

There is a ~3% difference[2], relative to the entire mooring system between the options in material being brought to shore for recycling, so there would be little to choose from a waste perspective.

There is little to choose between the options from a commercial and employment perspective. Any associated work would be extension of existing workloads rather than a creation of new and sustainable employment.

Finally, the incremental cost would be more than an order of magnitude (10x) greater for severing the mooring lines at -3 m rather than cutting them where they enter the seabed and burying them to -1 m. Future burial surveys for the -1 m option would be conducted as part of a wider survey campaign and so would not be significant from a cost perspective.

1.6 Recommendations

Bury the severed mooring chain end to 1 m below the seabed using mass flow excavation slurrify the local seabed on the basis that no snagging risk would remain, and environmental impact would be minimised. Proposals for monitoring and remediation of any potentially exposed sections of the cut chain ends will be explained in the decommissioning Close Out Report following a completion of decommissioning activities and a

[2] 98 Te vs. 3,565 Te overall. The -3 m option would result in the recovery of slightly more material than the -1 m option

post-decommissioning survey.

2. INTRODUCTION

2.1 Overview

A comparative assessment of the severance of the mooring lines is a key consideration within the Alba FSU DPs being submitted to OPRED.

The Alba field lies about 210 km north-east of Aberdeen, Scotland, in the UK Central North Sea, in water depths of ~138 m. First oil was achieved in January 1994.

The field facilities include a fixed steel platform, the Alba Northern Platform (ANP), and a Floating Storage Unit, the first to be purpose-built for the UK sector of the North Sea. The field was further developed in 2001 through the addition of the Alba Extreme South (AXS) subsea production centre supported by the Sadie water injection drill centre.

Alba crude oil is offloaded from the stern of the FSU to a shuttle tanker before being transported to refineries in northwest Europe. Alba gas is used for ANP fuel and the ANP is also connected by a 4 km long gas pipeline to the Britannia platform.

The mooring system comprises 12x mooring lines comprising cables, chains, link-plates and shackles, each a nominal 678.8 m long and each secured to a padeye 19 m below the seabed. Each padeye is connected to a 60 in x 37 m long pile, the top of which is buried more than 10 m below the seabed.

There are no windfarms in the locality, and the facility is not located within any protected areas.

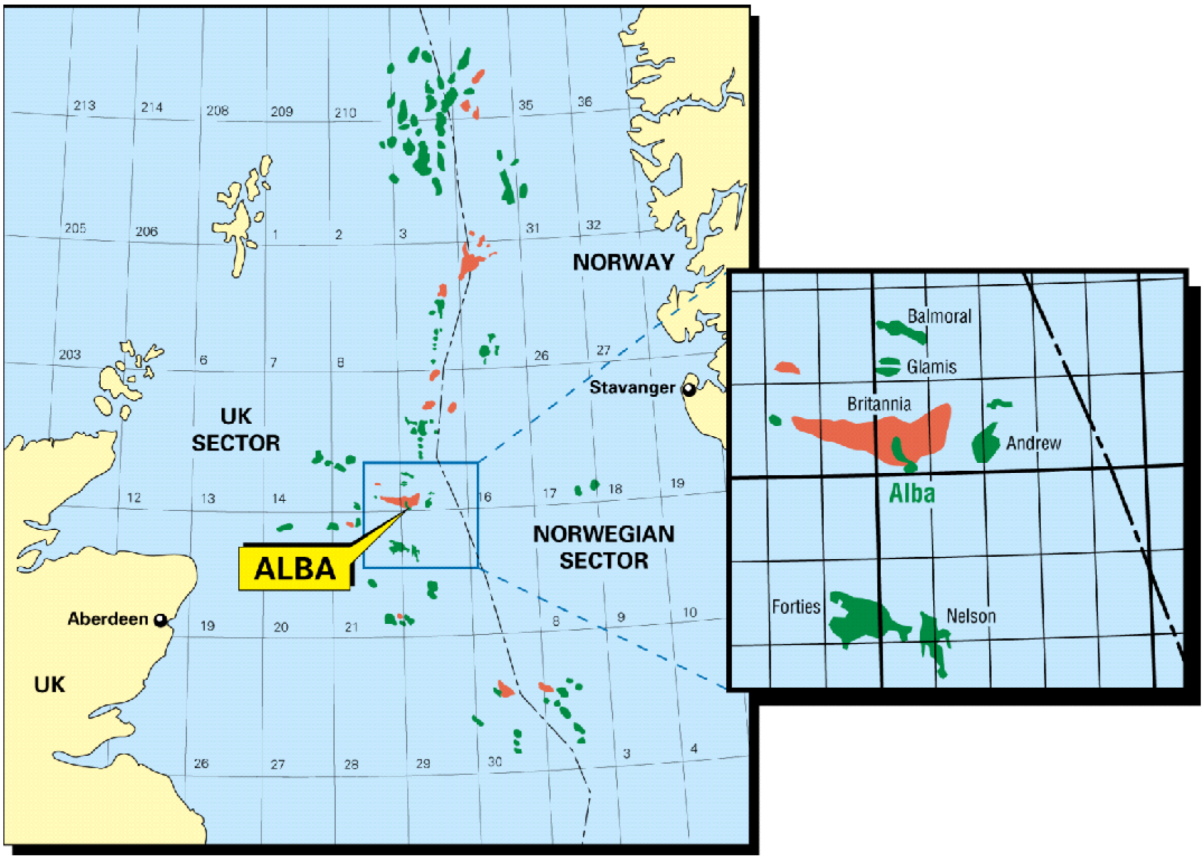

Figure 2.1.1: Location of Alba installations and infrastructure in UKCS

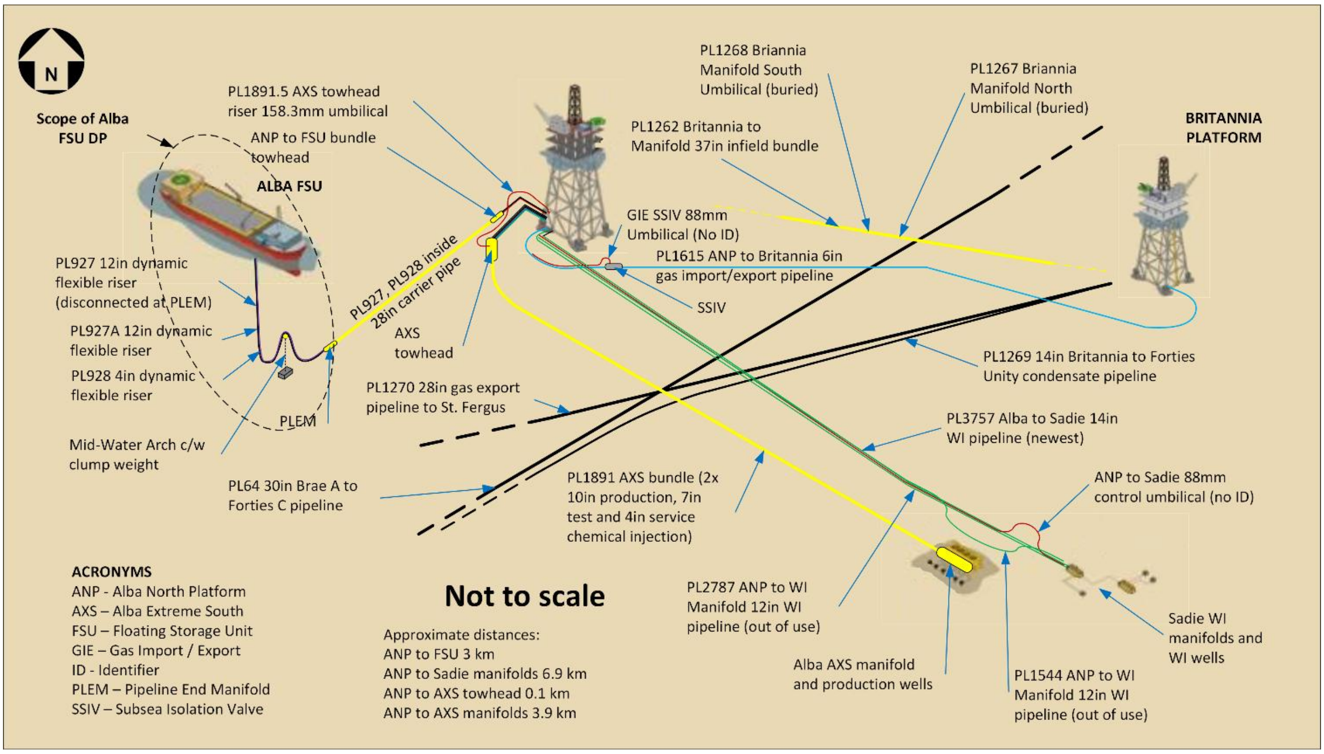

Figure 2.1.2: Alba field installations and infrastructure (not to scale)

2.2 Overview of environmental setting

An overview of the environmental setting is presented below. More details and references may be found in the DP [1].

The seabed in the area is relatively flat, with a few inflexions where the profile crosses existing pipelines. Seabed features include occasional boulders and, seabed depressions, traces of installed infrastructure such as pipelines and various seabed scars from trawling and anchoring. Sediment types across the Alba area range from mud to very fine sands typical of the fine-grained sediments of the Fladen Ground. The EUNIS classification for the Alba area is Atlantic Offshore Circalittoral Mud. From previous surveys the proportion of silt/clay in the sediments is moderate to high, although this varies between surveys. The proportion of silt/clay in the sediments is moderate to high, although with variation between surveys, ranging between 23.55% and 72.08% [1]; 21.41-80.62% [2] and 66.27-75.28% [4].

The top 30 cm of sediment in the Alba area, including at the FSU will be relatively soft, having been bioturbated by deeply burrowing species such as *Nephrops*.

The Alba field is located in ICES rectangle 45F1, Cefas' reference block F1/45. Spawning areas: Cod (Jan-April) Mackerel (adjacent to spawning area (May-July/Aug)), Norway Pout (March-May), *Nephrops* (Jan-Dec). Nursery areas: anglerfish, cod, European hake, herring, ling, spotted ray, spurdog and whiting. Mackerel (adjacent to nursery area), Haddock, Norway Pout, Blue Whiting, Sandeel (*A. marinus*), (adjacent to nursery area), *Nephrops* (adjacent to nursery area). Reference to "adjacent to" is qualified in that the spawning or nursery areas could be listed as being within 45F1 but may not necessarily lie over the infrastructure; these features are dynamic.

Alba is located within an area where the feature 'submarine structures made by leaking gases' associated with pockmarks are known to occur. Survey data indicate that a number of pockmarks have been recorded in the wider Alba field area, however carbonate structures have not been recorded at Alba. None of the Alba infrastructure is located within a designated area, the nearest is the Scanner Pockmark Special Area of Conservation (SAC), located ~24 km to the north.

The two closest Nature Conservation Marine Protected Areas (NCMPAs) are the Norwegian Boundary Sediment Plain NCMPA (34 km to the east), designated for the presence of *Arctica islandica* aggregations, including sands and gravels as their supporting habitat and the East of Gannet and Montrose Fields NCMPA (65 km to the south), designated for the presence of *Arctica islandica* aggregations and the presence of offshore deep-sea muds.

The SADIE pipeline route habitat assessment identified the OSPAR threatened and declining habitat 'Seapens and burrowing megafauna communities' in circalittoral fine mud' based on the presence of high densities for faunal burrows and seapens (*Virgularia mirabilis* and *Pennatula phosphorea*) observed in seabed video footage. This habitat is widespread within the Fladen Ground and has been recorded in surveys conducted in the wider area including stations from the South East Fladen Ground proposed NCMPA survey ~8 km to the north-west of the Alba field. From the presence of sea pens and evidence of bioturbation, the previous survey reports concluded the presence of the "sea pens and burrowing megafauna communities" habitat is likely; this habitat is therefore expected to be present across the Alba field area, including the FSU location.

No Annex I habitats have been observed in any of the previous surveys.

The faunal composition of the Alba area described during the 1991 (ANP) baseline survey (closest survey locations to FSU ~1.1 km) was characterised by the polychaetes *Levinsenia gracilis*, *Heteromastus filiformis* and *Paramphinome jeffreysii*, the bivalves of the *Thyasira* species complex also regularly occurred in the top five ranked species.

The macrofaunal community found during the 2000 survey at stations at 500 m from ANP, were dominated by the indicator species *P. jeffreysii* and *Thyasira. sarsi*, consistent with the 1991 survey.

Faunal assemblages from the 2005 survey, of stations to the north of ANP indicated that *P. jeffreysii* and *T. sarsi* dominated the stations 200-500 m from ANP. *P. jeffreysii* was present in lower numbers (but still ranked within the three most abundant species) at stations 800 m, 1,200 m, 2,500 m from ANP and absent from the station 5,000 m north, while *T. sarsi* was present in low numbers at the station 800 m north of ANP and absent from other stations.

Several species of infauna commonly associated with the habitat 'Seapens and burrowing megafauna in circalittoral fine mud' were present including *Thyasira equalis*, the third most abundant species overall, was present at all stations, *Nephtys hystricis*, the fourth most abundant species overall, was present at all stations with the exception of the closest to ANP (200 m distant) and *Terebellides stroemi* was present in very low numbers at all stations beyond 500 m from ANP. The seapen *Virgularia mirabilis* was recorded in low numbers from stations 800 m from ANP, while individual *Pennatula phosphorea* were recorded in samples at 800 m, 2,500 m and 5,000 m from ANP.

The SADIE pipeline route habitat assessment identified (at Station 1) faunal burrows, seapens (*Virgularia mirabilis* and *Pennatula phosphorea*), unidentified fish, starfish (*Astropecten irregularis*), burrowing anemone (*Cerianthus lloydii*) and hermit crab (*Paguroidea*); the faunal assemblage present was typical of the sediment present.

The Alba field is located in ICES rectangle 45F1. Although pelagic fishing activities used to be more prominent, since 2017 the demersal and shellfish activities have been prevalent. In 2022, demersal fishing activity in the area accounted for 0.37% of the UK total landings – a slight decrease on 2021 landings, while shellfish accounted for 1.09%, which was a slight increase on 2021 data.

Alba is in the north of the central North Sea oil and gas development area with several oil and gas fields but no windfarms nearby.

2.3 Alba FSU mooring lines

The nominal length of each mooring line is 678.8 m giving an overall length of 8,145.8 m. The mass of each mooring line is 297.1 Te, giving the overall mass of the mooring lines as 12x297.1 = 3,565 Te. Schematics of the mooring lines are presented in Figure 2.3.1, Figure 2.3.2, and Figure 2.3.3 below.

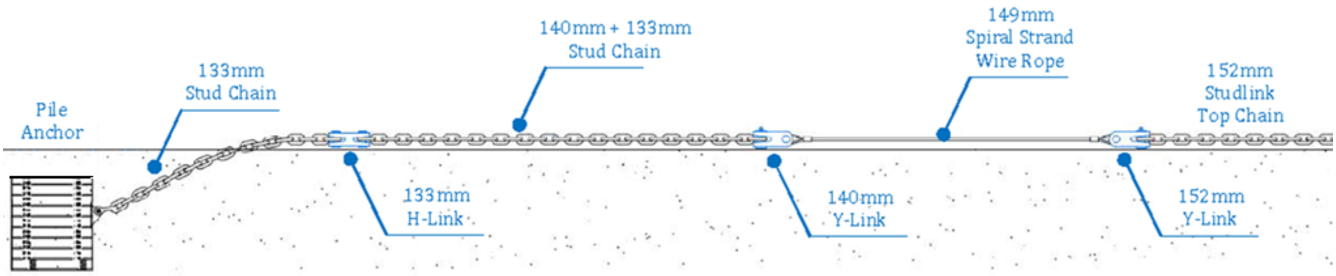

Figure 2.3.1: Alba FSU – typical mooring arrangement(s)

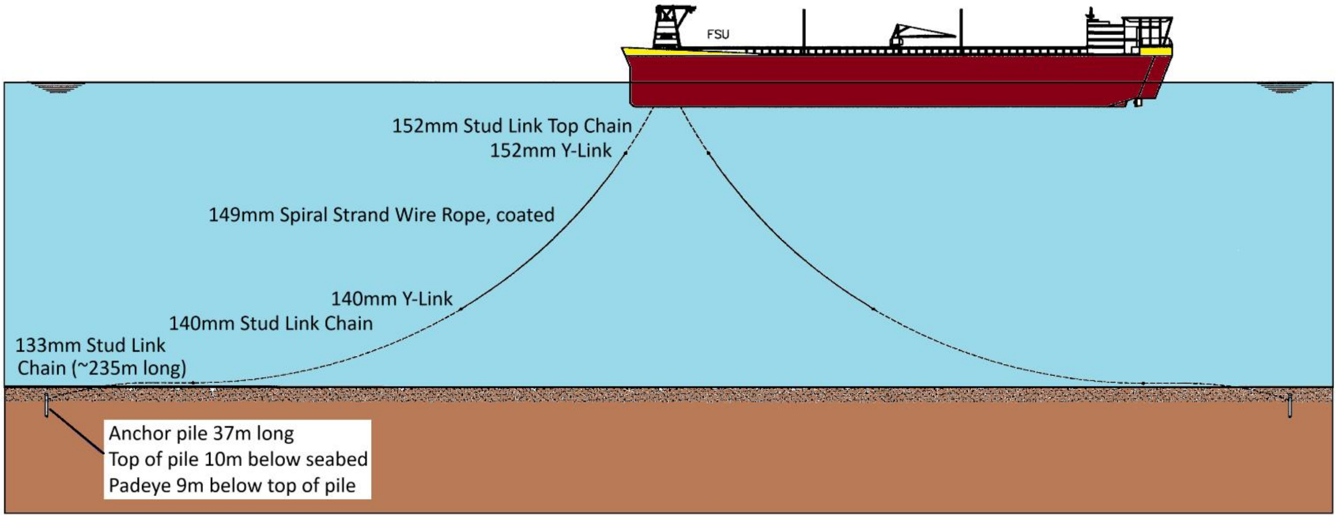

Figure 2.3.2: Alba FSU – typical mooring arrangement catenary

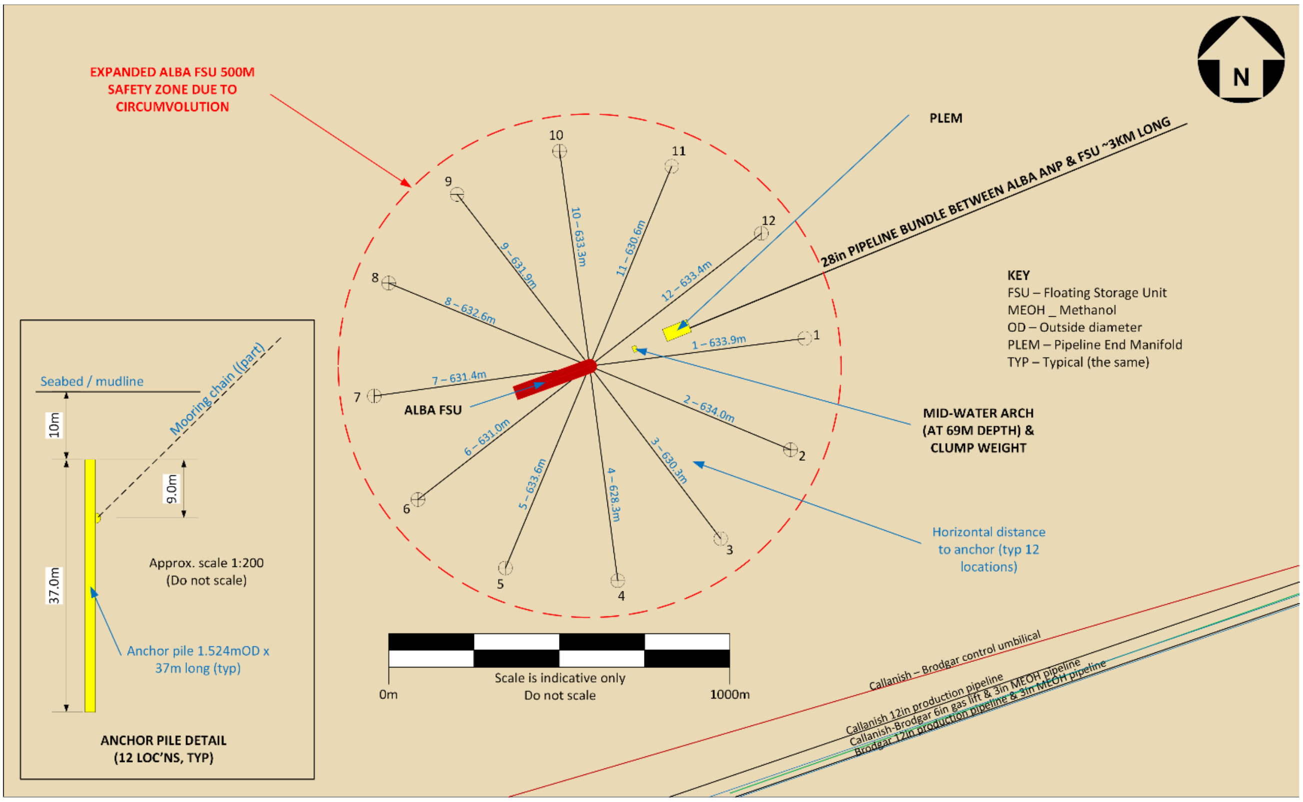

Figure 2.3.3: Alba FSU – mooring anchor pattern

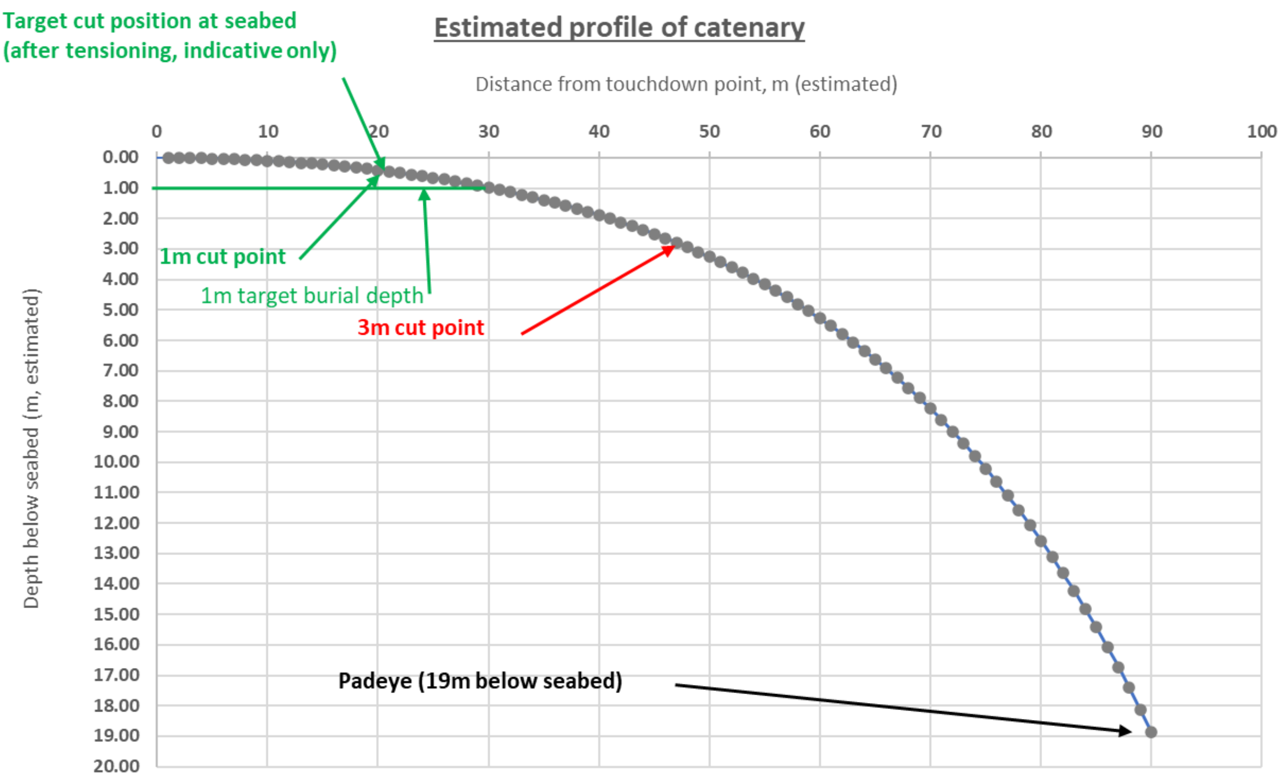

Figure 2.3.4: Alba FSU – estimated profile of catenary below seabed[3]

2.3.1 Decommissioning options

- **Removal to seabed with subsequent burial to 1 m below the seabed** – This would involve tensioning the mooring line to the point where the chain section enters the seabed and cutting it. Thereafter, the chain would be buried to a depth of at least 1 m below the seabed using a Mass Flow Excavator (MFE). No remedial work involving rock would be required.
- **Removal to 3 m below seabed** – This would involve excavating each mooring chain locally to 3.5 m below seabed to enable access to cut the chain. Use rock to backfill excavation.

'As-built' drawings show that the anchor piles are buried to such an extent that they would not present a snag hazard if left *in situ*, and the benefits of removal would be outweighed by the effort required to remove them. The leave *in situ* option is not a consideration as it does not comply with current offshore decommissioning oil and gas guidance notes [4] and has been discounted. Therefore, only the two 'partial removal' options are considered in this Comparative Assessment. The anchor piles are not included in the assessment.

Table 2.3.1: Mooring line dimensions

Aspect	-3 m depth of severance	-1 m depth of burial
Length recovered per ML (678.8 m)	629.6 m	610.6 m
O/A length recovered (8,145.8 m)	7,555 m	7,327 m
O/A mass recovered (3,565 Te)	3,311 Te	3,213 Te
O/A mass left *in situ*	254 Te	352 Te
O/A mass recovered as percentage of total	93%	90%
O/A estimated volume of excavated material[1,2]	12 x 234 = 2,804 m^3	0 m^3
O/A estimated volume of disturbed material	Same as excavated material	12 x 4.7 = 56.5 m^3
O/A area of seabed impacted (assume average 0.2m high berm)	2,804 / 0.2 = 14,020 m^2	0 m^2
O/A estimated quantity of rock required[3]	12 x 350 = 4,206 Te	No rock required

[3] The mooring chain will be tensioned and then cut where it exits the seabed. After cutting the remaining section of chain will be buried to a depth of at least 1 m below the seabed.

Table 2.3.1: Mooring line dimensions

NOTE

1. Based on an average angle of repose of 30 degrees. Clay might typically have an angle of repose between 20 and 40 degrees.
2. Area of seabed affected by deposition of excavated material indicative only as this depends on the (average) height of the distributed material. In this instance is has been assumed that an average height of 0.2m would result in an area 14,020 m^2 being impacted.
3. Assuming a bulk density of rock (e.g. crushed granite) in air of 1,500 kg/m^3.
4. All seabed disturbances will result in direct physical effects which may include mortality as a result of physical trauma, smothering and re-suspended sediment. Less impact and disturbance to the seabed would likely be preferred from an environmental perspective.

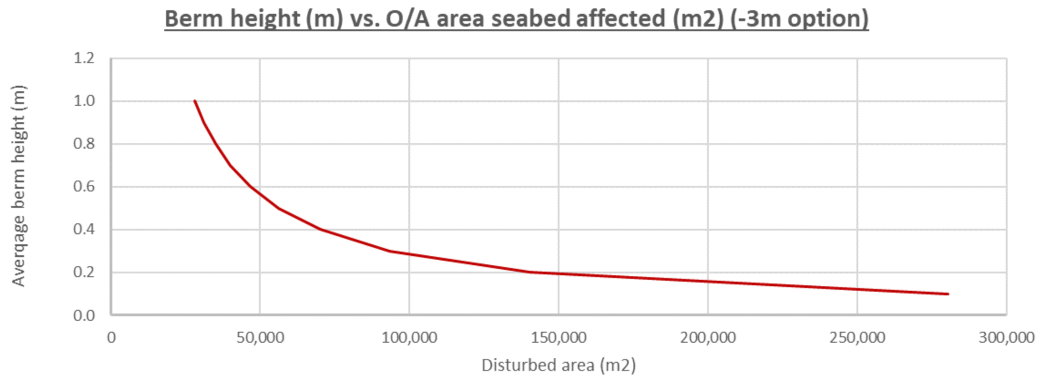

Figure 2.3.5: Mooring line recovery berm height vs. O/A area affected (-3 m option)

In Figure 2.3.5, the overall (O/A) area of seabed impacted outside of the excavated area is calculated by dividing the volume of excavated material by the (average) berm height. The overall area of seabed impacted is the sum of the excavated area (for 12x ML locations each with an average diameter 14.59 m)[4] and the area covered by the excavated material deposited on the seabed at the average berm height.

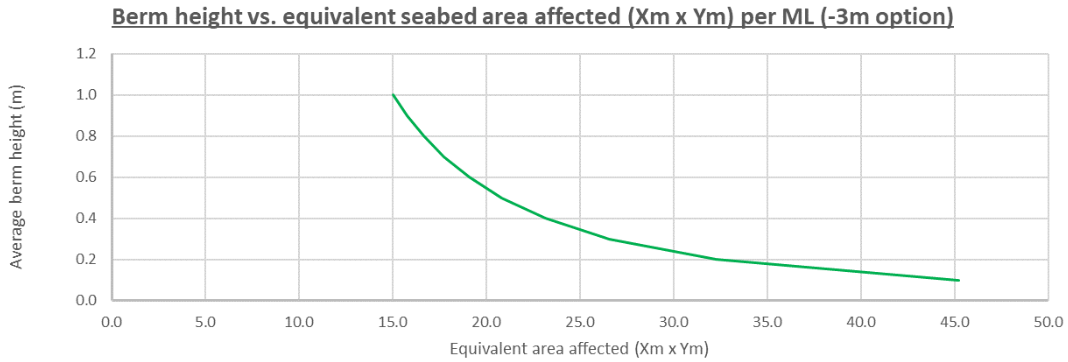

Figure 2.3.6: Mooring line recovery berm height vs. area affected per ML (-3 m option)

In Figure 2.3.6, for each ML, as an indication of the dimensions of area affected by deposition of excavated material for the -3 m option, the Xm x Ym (square) dimension is calculated by calculating the square root of the area affected. The total area affected is calculated by dividing the volume (234 m^3 for each ML) by the (average) berm height (0.1 m, 0.2 m, etc) and adding the area of excavation (average 14.59 m diameter converted to an Xm x Ym dimension, 12.9 m x 12.9 m). For example, this means that for an average berm height of 0.4 m, the area affected outside of the excavation would measure a nominal ~23 m x 23 m per ML. Note that due to the rudimentary nature of the excavation operations involved, sea currents, etc, the calculation is indicative only.

[4] Assuming an average angle of repose of 30 degrees.

A summary of excavation requirement for both the partial removal options is presented in Figure 2.3.7 below.

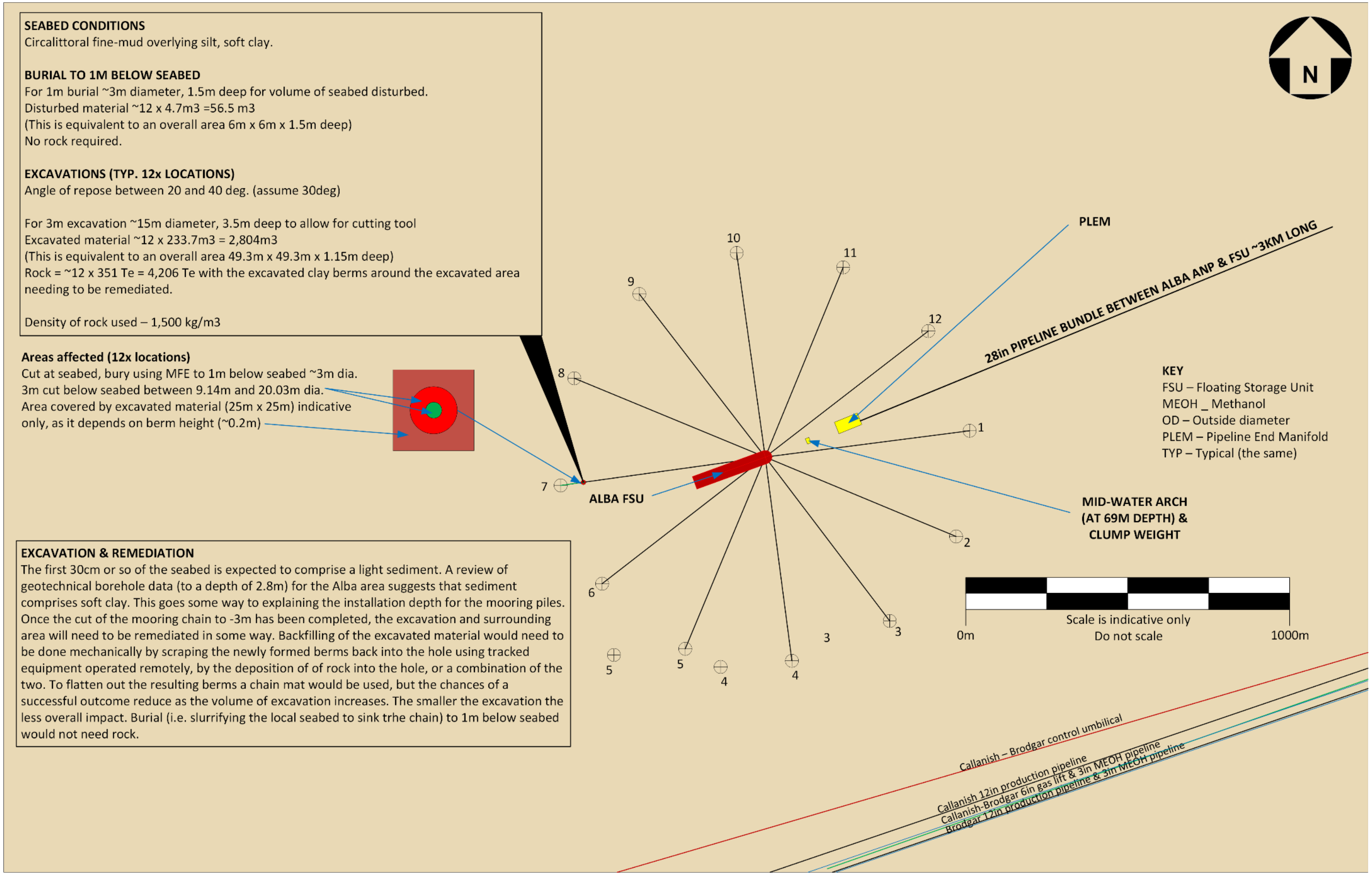

Figure 2.3.7: Mooring line recovery - excavation and remediation

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:

- A purely qualitative approach has been taken requiring a degree of judgement. Since most impacts are related to area of seabed impacted, duration of works and vessel time, this is deemed appropriate.
- Theoretically, it would be feasible to completely remove the mooring systems but the depth to which the anchor piles are buried (top of pile 10 m below seabed) would render the amount of work and impact to the surrounding seabed as disproportionate to the benefits of removal. Therefore, the removal of the piles has been discounted as an option.
- The profile of the catenary has been estimated.
- Note that due to the rudimentary nature of the excavation operations, sea currents, etc, the impacted area calculations should be treated as indicative only but sufficient to compare the impacts of the partial removal options on the seabed.
- Ithaca is not aware of any fishing gear snagging reports. Any potential snag hazards or snagging incidents are recorded via Kingfisher Information Services on FishSAFE (www.fishsafe.eu).

The following legacy assumptions have also been made:

- A post-decommissioning 'as built' survey would be required following completion of decommissioning activities.
- An environmental survey would be required on completion of decommissioning activities.
- The cut ends of a mooring chain (part of the overall mooring 'line') being left in situ and buried to less than 3 m below the seabed would be subject to at least three legacy burial surveys, although in practical terms taking this approach would need to be agreed with OPRED.
- The cut ends of a mooring chain being left in situ and buried to a depth of 3 m or more below the seabed would not be subject to legacy burial surveys, although in practical terms taking this approach would need to be agreed with OPRED.
- The seabed sediment type is such that any spoil heaps created during any decommissioning operations could present a snagging hazard should remediation not be completed satisfactorily. This would need to be verified by a trawl sweep.
- In the long term, assuming the size and profile or the resulting rock berm is suitable, deposited rock remaining *in situ* would not present a snagging hazard.
- The impact of the procurement of any new materials such as fabricated items or mining of new rock is ignored.
- Impact on commercial activities (fishing in particular) is proportional to the duration of vessel activity. The impact would be negligible while the decommissioning works are being carried out.
- 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. COMPARATIVE ASSESSMENT METHOD

3.1 Method

The assessment is qualitative, and considers five criteria for both the short-term decommissioning activities and the longer-term for 'legacy' related activities. The criteria were: technical feasibility with three sub-criteria, safety related risks with three sub-criteria, environmental with five sub-criteria, societal effects with three sub-criteria and cost.

No scores have been determined. However, risk matrices have been used 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. It should be noted that societal assessment looked at beneficial outcomes as well as detrimental outcomes. Where a comparison of options varies by shades of green rather than by red or orange it means there is little to choose between the options.

High costs also attract a 'less desirable outcome'; the cost of implementing a decommissioning option is compared against the others. A relatively high cost therefore would be coloured red or orange whereas a relatively low cost would be coloured green. Costs are assessed in relation to the cheapest cost. A red coloured cell would indicate that the incremental increase in cost would be an order of magnitude greater (i.e. more than 10x greater) than the cheapest cost.

Table 3.1.1: Comparative Assessment method – criteria & sub-criteria

Criteria	Definition	Criteria - short-term & legacy, UNO	Comments
Technical	A technical evaluation of the complexity of a job that can be expected to proceed without major consequence or failure if it is adequately planned and executed.	Risk of project failure.	The risk of project failure given the technical and technological challenges. The technical challenge considers the viability of a task should the technology be available. The technological challenge concerns the availability of specific technologies to perform a task and the extent of research & development that may be required. The technical aspects of replenishing excavated material and the deposition of rock could be a consideration.
		Technological challenge.	
		Technical challenge	
Safety	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 risks for project personnel carrying out decommissioning activities offshore.	Typical offshore hazards might include loss of dynamic positioning, sudden movements during decommissioning works, dropped objects, collision between vessels, dealing with residual quantities of hazardous materials. Typical diving hazards might include, loss of heat or air supply, trapped cables and hoses, trapped limbs. After decommissioning has been completed typical hazards could relate to exposed mooring chains leading to a possibility of snagged fishing nets. Consider effects of a change in scour patterns due to the deposition of rock (more relevant to SNS than CNS). Typical onshore hazards might include dealing with residual hazardous materials, onshore cutting, sudden movements or dropped objects.
		Residual risks to marine users on successful completion of decommissioning.	
		Safety risks for project personnel engaged in carrying out decommissioning activities onshore.	
Environmental	An assessment of the significance of the risks / impacts to the environmental receptors because of operational activities or the legacy aspects.	Energy and emissions to atmosphere.	The assets are located outside of environmentally sensitive areas, so the dominant environmental criteria would likely be the effect on the seabed, the amount and type of waste recovered, or replacement materials needing to be manufactured to compensate for materials left *in situ*. The mooring system(s) are not within a SAC or an MPA.
		Effect on seabed: Seabed disturbance and area affected. Permanent disturbance more significant than temporary disturbance.	
		Effect on water column: Liquid discharges to sea Liquid discharges to surface water Noise.	
		Waste creation and use of resources such as landfill. Recycling and replacement of materials.	
Societal	Assesses the significance of the work on societal activities, including offshore and	Effects on commercial activities e.g., fishing.	Decommissioning projects involve work that is generally temporary in nature. On its own this type of work might typically lead to an extension
		Employment.	

Table 3.1.1: Comparative Assessment method – criteria & sub-criteria			
Criteria	**Definition**	**Criteria - short-term & legacy, UNO**	**Comments**
	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, accommodation, etc.).	Communities or impact on amenities.	of employment rather than new employment. Any impact on commercial fishing offshore is temporary and of relatively short duration.
Economics or cost	Difference in cost.	Difference in cost compared for like-for-like activities.	In the short-term it is cheaper to do nothing, but this needs to be compared with the need for future surveys and potential remedial work.

4. COMPARATIVE ASSESSMENT DISCUSSION

4.1 Technical considerations

The risk of failure for either option is low, because contingency planning could be put in place to cover potential eventualities.

Although MFE are a proven technology, the backfilling of excavations (e.g. for the -3m option) has only really been used for the installation of pipelines when backfilling during trenching operations. This means that the only viable option would be to deposit rock into the excavated area. With a concerted effort it may be possible to remediate the excavated material that lands on the seabed, and a smaller berm height would be easier to remediate. The difficulty with remediation increases with the volume of excavated material (2,804 m^3 for the -3 m option). It is also worth noting that tracking devices become less accurate with depth. This means that for the -3 m option 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 twelve times, once for each of the lower mooring chains.

The -1m option involves using an MFE to slurrify the seabed locally; no excavations would be required for the -1 m option.

Cut ends of mooring lines have been buried using MFE before so there should be no issues with cutting the mooring chain at seabed and then burying it to 1 m below seabed.

Post-decommissioning surveys will be required. Legacy surveys will be required to confirm extent of burial for the -1 m option but will unlikely be required for the -3 m option.

4.2 Safety considerations

During decommissioning operations there would be no discernible difference to the safety of mariners as the work would be executed using standard processes and procedures for vessel movements.

Both options would be executed using remotely operated equipment. The risk to Potential Loss of Life for the -3 m option would be slightly higher due to the increased vessel use and threat of collisions at sea, but standard procedures, procedures and protocols would be used to manage vessel movements. Therefore, in this regard the difference between the options is negligible. All equipment would be remotely operated and deployed using standard processes and procedures, but the vessels would be operating for longer for a cut at -3m.

Any material recovered to shore would we dealt with using existing procedures and protocols. The difference in the quantities of material being handled would be relatively small (98 Te more the -3m option) so there is no discernible difference between the options from a safety perspective when considering the management of materials onshore.

As both options would result in the ends of the mooring chains being buried, there would be no residual snagging risk from the ends of the chains for either option. There may be small snagging risk associated with any berm material from the -3 m option being left on the seabed, but trawl sweeps would be conducted to confirm that the remedial work had been completed successfully.

4.3 Environmental considerations

Typically mooring lines would only be recovered using an AHV. The -1 m option would require a cutting and MFE spread to be included on the AHV and it is estimated that the AHV work would only be increased by a couple of days. However, the -3 m option would involve the deployment of additional vessels (a CSV, estimated 13 days, and FPV, estimated 10 days) that would need to be mobilised specifically for the -3 m option to address the need to excavate to the required cutting depth and to replenish the excavation with deposited rock. Therefore, the -3 m option would result in significantly more energy and emissions.

The -3 m option would have much more of an impact on the seabed, both in terms of quantity of excavated material (2,803 m^3) as well as area of seabed covered by the excavated material. As it depends on the dispersal of the excavated material, the area of seabed covered by excavated material is more difficult to quantify but in any event it would be significantly more than the area affected by the -1 m option. Please refer section 2.3 (Figure 2.3.5, Figure 2.3.6 and Figure 2.3.7) for an indication of the differences. Furthermore, the -3 m option would require the excavations to be back filled using a hard substrate (rock) that is not native to the area. No rock would be required for the -1 m option.

Natural redistribution (remediation) of the excavated sediment for the -3m option (to naturally backfill the excavations) would not be expected, due to the sediment type present and the low energy environment. Natural sediment movement in the Alba area is low, compared to high energy environments, such as the southern North Sea, where sediment type (fine sand) and strong currents can result in significant sediment redistribution.

4.4 Societal considerations

Both options would involve working in the field, with the -3 m option requiring more vessel time. However, vessel movement procedures and protocols would be used, and so there should be minimal disturbance to mariners transiting or working in the area.

With more vessel time, the -3 m option would impact more positively on employment but the effect on employment would result in the continuation of existing jobs rather than lead to the creation of new jobs. For either option the significance of a positive impact on employment is low.

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

4.5 Cost considerations

Ordinarily it can be expected that mooring lines would be recovered using only an AHV. The -1 m option would require cutting and MFE spreads to be included on the AHV and the duration of work would be extended by an estimated 2 days for the cutting and burial work. However, the -3 m option would involve the deployment of additional vessels (a CSV ~13 days and FPV ~10 days) that would need to be mobilised specifically for the -3 m option to address the need to excavate to the required cut depth and to replenish the excavation with deposited rock.

On this basis, it is estimated that the incremental cost for the -3 m option would be ~£4,155,000. The reason for this is that as a standalone scope the CSV (13 days) and FPV (10 days) would need to be mobilised specifically for the excavation, cutting and backfill works, whereas the -1 m option would be an extension of the mooring line recovery work already being conducted using an AHV. The MFE would be deployed from then AHV using an ROV. The incremental increase for the -1 m option which would be ~£200,000 (equivalent to an additional 2 days). The incremental increase in cost will depend on the vessel rates committed to at the time, but on the basis of the foregoing the incremental cost of the -1 m option would be ~5% of the incremental increase for the -3 m option. This suggests that the incremental increase in cost for the -3 m option would be an order of magnitude (i.e. 10x) greater than for the -1 m option.

It is likely that any future burial surveys would be conducted as part of a wider survey campaign, in which case the incremental legacy costs associated with the -1 m option would not be significant.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

There is a significant difference between the partial removal options from a technical and environmental perspective. The volume of excavation and requirement for backfill material is significantly greater for the cutting of the mooring chain section at -3 m option; no rock would be required for the -1 m cut at seabed and burial option. Much more vessel time and energy would be required for the -3 m option compared to the -1 m cut at seabed and burial option. For the -3 m option, unlike the methods used for pipeline trenching and backfill operations, it is unlikely that the backfill material could readily be swept back into the excavated area, so mounds of excavated sediment material would be left behind. The mechanical remediation of such material may not be practical and natural redistribution of this excavated sediment would not be expected due to the sediment type (typically mud) and relatively weak currents in the area (i.e. compared to the southern North Sea where sediment is typically sand and is a high energy system with seabed sediment movement). Disturbance to the seabed for the -1 m cut at seabed and burial option would be significantly lower and no berms of material would be created or left behind.

From a health and safety perspective there is little to differentiate the options. The decommissioning works for both options would be conducted using remotely operated equipment. Theoretically, there would be a slightly higher threat posed by PLL simply due to the presence of the additional vessels and increased possibility of a collision present for the -3 m option although procedures and protocols would probably render the difference between the options as being insignificant. For the -3 m option a potential snagging risk could remain from any excavated material remaining on the seabed. Following completion of the decommissioning works, no snagging risk would arise from the severed mooring chains below seabed level for either option.

There is a ~3% difference[5] relative to the entire mooring system between the options in material being brought to shore for recycling, so there would be little to choose from a waste perspective.

There is little to choose between the options from a commercial and employment perspective. Any associated work would be extension of existing workloads rather than a creation of new and sustainable employment.

Finally, the incremental cost would be more than an order of magnitude (10x) greater for severing the mooring lines at -3 m rather than cutting them where they enter the seabed and burying them to -1 m. The reason for this is because while the burial to -1 m could be conducted using the AHV already deployed to remove the mooring lines, the cut to -3 m would involve mobilising an additional CSV and FPV dedicated to the task. These vessels would not otherwise be required. Future burial surveys for the -1 m option would be conducted as part of a wider survey campaign and so would not be significant.

5.2 Recommendations

Bury the severed mooring chain end to 1 m below the seabed using a MFE on the basis that no snagging risk would remain, and environmental impact would be minimised. Proposals for monitoring and remediation of any potentially exposed sections of the cut chain ends will be explained in the decommissioning Close Out Report following a completion of decommissioning activities and a post-decommissioning survey.

[5] 98 Te vs. 3,565 Te overall. The -3 m option would result in the recovery of slightly more material than the -1 m option

6. REFERENCES

[1] ERT (1992). Alba Field Environmental Baseline Survey (June 1991). ERT 91-069-R2

[2] ERT (2000). Chevron Alba Northern Platform (UKCS Block 16/26), seabed environmental survey (July 2000). ERTSL 00/219

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[4] OGUK (2007). Government/Industry Offshore Environmental Monitoring Committee 2005/2006 Platform Specific Surveys Alba Platform Data Report May 2007 Rev 1

[5] OPRED (2018) Decommissioning of Offshore Oil and Gas Installations and Pipelines Guidance Notes, November 2018.

APPENDIX A MOORING LINE CA TABLES

Table A.1: CA operational summary table			
Main criteria (operational)		**Mooring lines cut -3 m**	**Mooring lines cut & buried -1 m**
Technical feasibility	Technical feasibility of offshore activities; risk of project failure	Risk of project failure is low, as contingency planning could be put in place.	It would be technically feasible to bury the end of chain using Mass Flow Excavator (MFE) without the risk of project failure; this type of work has been done before.
	Technological challenge (is there technology available)	MFE are a proven technology but backfill has only really been used as part of a pipeline trenching process, not to backfill large excavations in the seabed.	MFE are a proven technology that has been used to slurrify or excavate soft seabed sediments.
	Technical challenge (can the work be done?)	It would be technically feasible to dredge the sediment, but not straightforward to backfill with original sediment. Difficulty increases with volume (2,804 m³).	The burial of cut ends of pipelines, chains, etc. has been achieved without issue when decommissioning subsea infrastructure.
Health & safety risk	To offshore project personnel	Dredging and cutting of mooring lines -3m would be done using remotely operated equipment. The equipment would be deployed using standard processes and procedures, but the vessel would be on location for longer for a cut at -3 m.	Cut the chains at surface and bury the cut ends of the chains to -1m. This would be done using remotely operated equipment. The equipment would be deployed using standard processes and procedures. The vessel would be on location for less time than for -3m.
	Onshore project personnel	Any material recovered to shore (7,555 m, 93%) would be recycled dealt with as part of existing procedures and protocols. No discernible difference.	Any material recovered to shore (7,327 m, 90%) would be recycled dealt with as part of existing procedures and protocols. No discernible difference.
Environmental impact (planned)	Atmospheric emissions (E&E)	CSV (13 days) & FPV (10 days) required in addition to AHV time. Anchor Handling Vessels will be used to remove the mooring lines. In addition to an AHV a construction support vessel (CSV) or similar and a fall pipe vessel (FPV) will be required. These would need to be mobilized specifically for the chain cutting operation and subsequent remedial works.	AHV (+2 days) c/w MFE to bury end of chain. Anchor Handling Vessels will be used to remove the mooring lines. It is expected that only an Anchor Handling Vessel (AHV) vessel c/w MFE spread would be required to bury the cut ends of the chain. This means that the work would be an extension of the work being executed by AHV for the removal of the mooring lines. Mobilisation of additional vessels would not be required.
	Seabed	Max depth: 3.5 m; Volume 12 x 234 = 2,804 m³ (temporary/permanent). Note that accuracy of tracking devices decreases with depth below seabed leading to an uncertainty in the volume of excavation required. Rock – see legacy impact	Cut chain at seabed. Bury to -1 m using MFE. Volume affected 12 x 4.7 = 56.5 m³ (temporary)

Table A.2: CA operational summary table cont'd/…

Main Criteria (operational)		Mooring lines cut -3 m	Mooring lines cut & buried -1 m
Environmental (cont'd)	Water column	The temporarily disturbed volume of seabed sediment will be significantly more than that associated with a -1 m burial. Disturbed sediment will initially be dispersed into the water column.	The temporarily volume of disturbed seabed sediment will be significantly less than that displaced for a -3 m cut will initially be dispersed into the water column.
	Waste	Mass of material recovered: 3,311 Te (92.9%) Mass of material left *in situ*: 352 Te. (7.1%) No discernible difference (98 Te) between options.	Mass of material recovered: 3,213 Te (90.1%) Mass of material left *in situ*: 276 Te (9.9%) No discernible difference (98 Te) between options.
	Affect on objectives of protected areas	The impact of the works associated with both mooring chain decommissioning options will not affect any Special Protection Areas, Special Areas of Conservation or Marine Protected Area, as they are all too distant. The impact of the works on benthic fauna, including pennatulid sea pens, and habitats such as sea pens and burrowing megafauna, is considered in the DP. Note, however, that the scale of the works associated with the option to remove the moorings to 3m below seabed could impact a wider area of seabed both directly, and indirectly through smothering and remediation.	
Societal effect	Commercial activities	The impact of decommissioning vessel traffic on commercial activities such as fishing would be greatest for complete removal. The transit of work vessels and their presence in the field would be managed using existing procedures and protocol. Despite there being more vessel traffic (AHV, CSV, FPV) for this option, the difference between the two options is not significant.	The impact of decommissioning vessel traffic on commercial activities such as fishing would be greatest for complete removal. The transit of work vessels (AHV) and their presence in the field would be managed using existing procedures and protocols. The difference between the two options is not significant.
	Employment	Cutting the mooring lines 3 m below seabed will result in an extension to existing jobs rather than create new jobs.	Cutting the mooring lines at seabed and burying them 1 m below seabed will result in an extension to existing jobs rather than create new jobs.
	Communities	For any ports and disposal sites the any increase in work would be nominally larger for an increase in quantity of material recovered to shore for -3 m.	For any ports and disposal sites the any increase in work would be nominally less for the slightly smaller quantity of material recovered to shore for -1 m.
Cost	Incremental cost difference	The incremental cost for cutting the chains to -3 m would be more than 10x more expensive than burying the cut ends to -1 m. This is because additional CSV and FPV would be required.	Anchor Handling Vessels would be used to remove the mooring lines. Burial to 1 m below seabed would be an extension to the work already being carried out.

Table A.3: CA legacy summary table

Main criteria (legacy)		Mooring lines cut -3m	Mooring lines cut & buried -1m
Technical feasibility	Technical feasibility of offshore activities	Legacy surveys unlikely to be required.	Surveys may be required. If sufficiently buried, equipment may not be able to detect the cut ends.
Health & safety risk	To offshore project personnel	Legacy surveys unlikely to be required.	Seabed surveys may be required, but from an HSE perspective these are usually performed with no issues.
	To mariners, fishermen	Once the mooring chains have been cut and buried there would be no snagging hazards once the ends had been buried.	Once the mooring chains have been cut and buried there would be no snagging hazards once the ends had been buried.
		The presence of the larger quantity of excavated material on the seabed will present more of a snag hazard. Larger volume of excavated sediment material hard to remediate, if at all.	Once the ends of the chain had been buried, no additional remedial work would be required, and no berms of excavated material would be left behind.
	Onshore project personnel	Legacy surveys unlikely to be required.	Legacy surveys may be required. To have to perform surveys at all means that vessel would need to be mobilised. From an HSE perspective such activities are (usually) performed without issue
Environmental impact (planned)	Atmospheric emissions (E&E)	Legacy surveys unlikely to be required.	Should seabed surveys be required, atmospheric emissions will arise.
	Seabed	Legacy surveys unlikely to be required. No difference between the options.	Any seabed surveys would be non-intrusive. No difference between the options.
		Backfill of excavated material not practical. Excavation will be backfilled using a hard substrate (rock): 12 x 350 = 4,206 Te.	No hard substrate (rock) used.
	Water column	Legacy surveys unlikely to be required.	Any disturbance to the water column would be minimal. No discernible difference between the options.
	Waste	N/A	N/A
Societal effect	Commercial activities	Legacy surveys unlikely to be required.	Minimal impact on commercial activities during transit and in the field. Managed by procedure and protocols. No discernible difference between the options.
	Employment	Legacy surveys unlikely to be required.	Any surveys would result in an extension to existing jobs rather than create new jobs. No discernible difference between the options.
	Communities	Legacy surveys unlikely to be required.	For any ports the any increase in vessel activity in the port would be nominal for survey related activities. No discernible difference between the options.
Cost	Incremental cost difference	Legacy surveys unlikely to be required.	Any future surveys will attract cost.