WALDORF
PRODUCTION

Garrow pipelines (PL2160 and PL2161) Decommissioning Options Comparative Assessment

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Terms and Abbreviations

API	American Petroleum Institute (reference organisation used to define pipeline specifications)
CoP	Cessation of Production
DESNZ	Department for Energy Security & Net Zero
ESDV	Emergency Shut Down Valve
FBE	Fusion Bonded Epoxy
GVI	General Visual Inspection
HDPE	High Density Polyethylene
JNCC	Joint Nature Conservation Committee
KM	kilometres
KP	Kilometre Point (KP 0 at the Garrow pipeline initiation point, ~KP 22.2 at Kilmar bottom riser flange)
MCZ	Marine Conservation Zone
MBES	Multi beam echo sounder (seabed mapping equipment)
MEG	Monoethylene Glycol (used to prevent hydrates forming within pipework)
NFFO	National Federation of Fishermen's Organisations
NSTA	North Sea Transition Authority
NUI	Normally Unmanned Installation
OD	Outside Diameter
ODEAM	ODE Asset Management (Operator of Tors installations and pipeline systems)
OEUK	Offshore Energies UK

OPRED	Offshore Petroleum Regulator for Environment and Decommissioning
PUK	Perenco (UK) Limited
SAC	Special Area of Conservation
S lay	Term used to describe pipeline installation method where individual pipe sections are welded together on a vessel and laid in a string under tension onto the seabed
Spool goose necks	Term used to describe the bends on pipework that lifts the pipe off the seabed to a connection point above it (usually a riser flange)
Reel lay	Term used to describe pipeline installation method where pre welded pipe lengths are pulled off a large diameter reel and laid in a string under tension onto the seabed
ToP	Top of Pipe (term used to describe the level below natural seabed of a buried pipeline or umbilical)
Tors	Combined field name for the Garrow and Kilmar reservoirs
UHB	Upheaval buckling (the process where pipelines expand when filled with warm gas pushing the pipeline upward unless physically restrained by soil or rock above it)
UKCS	United Kingdom Continental Shelf
3LPP	3 layer polypropylene (corrosion coating system for steel)

1. EXECUTIVE SUMMARY

A Comparative Assessment of potential decommissioning options has been completed for the PL2160 8" gas export pipeline and the PL2161 3" service pipeline between the Garrow NUI platform and the Kilmar NUI platform. This Comparative Assessment is in support of Garrow Decommissioning Programme document APR_TORS_PMGT_012 which is further supported by the Garrow Decommissioning Environmental Appraisal document APR-TORS-PMGT-014.

The Garrow field is in the Southern Basin of the UKCS, across blocks 42/25a and 43/21a and comprises one gas field which was first discovered in 1991. The Field was previously covered by licence P1034; however, this was relinquished on 4 February 2022. The development consists of a NUI with 2 wells, tied back to the Waldorf owned and ODEAM operated Kilmar NUI platform installed in 2006. The wells are completed with dry production trees and the pipeline systems run between the riser isolation valves, upstream of the ESDV's, on the topsides of the Garrow and Kilmar Installations. At Kilmar, Garrow gas is comingled with Kilmar gas and exported onward to the PUK operated Trent platform complex via the PL2162 pipeline. Production has declined from Garrow and PUK shut in production and export via Trent as a result of low gas pricing in July 2020. At this time the Garrow pipelines and facility was put into gas safe mode. Trent has since begun their Cessation of Production (CoP) process. Remaining reserves in Garrow are not sufficient to support the investment to return the facilities to production and meet the ongoing operating costs. Garrow CoP is 2nd June 2020

The pipelines are both ~22.4 km long and are a welded carbon steel pipeline construction. The 3" service pipeline PL2161 was installed simultaneously to the larger PL2160 pipeline as a piggyback and lies within the same protection trench for the majority of the route. The pipelines were trenched and backfilled to a burial depth of 1.5-1.8m below seabed. Approximately 98.2% of the route is trenched with 1% surface laid at the platform approaches. The remainder of the pipelines are in the jacket risers and topsides pipe sections. Of the surface laid sections ~75% is mattress protected and ~25% is rock dump protected. In total <1% of the route is rock protected either within or outside the trenched and buried sections. Neither pipelines are concrete coated but are corrosion coated with 3 layer polypropylene (3LPP) for the majority of their lengths. Rock dump, concrete mattresses and gravel bags were used to protect pipeline sections laid on the seabed at the platform approaches that were not trenched and buried. This report presents a description of the potential decommissioning options considered, the method used to complete the Comparative Assessment and the findings of the work undertaken.

Three main options have been considered:

- Complete removal – this involves the full removal of both pipelines including the de-burial of the pipelines and return to shore of the materials used.
- Partial removal – this involves the removal to shore of various elements of the pipelines and protection materials, but leaves the majority of the trenched and buried sections in situ. Sub options for the pipeline approaches at each platform end have also been considered.
- Full leave in situ – this option involves leaving in place all pipeline sections and protection materials other than short sections of the riser spools that will be cut and returned to shore to allow the Garrow and Kilmar jackets to be removed.

The options were assessed using the DESNZ Decommissioning Guidance Notes and project specific guidelines developed for a detailed assessment workshop. During the assessment process, evaluations were made principally on a qualitative basis, however, where quantitative data was available this has been used. The following components were assessed from a short-term (project) and longer-term (legacy) perspective:

• Safety;

• Environmental;

• Technical;

• Societal;

• Economic.

Following the detailed assessment workshop it is recommended for both the PL2160 and PL2161 pipelines that a partial removal option is adopted for the decommissioning work. Option 2b as further detailed in this report is the preferred option. This reflects recovery of the pipeline and spool sections of pipe and their respective protective concrete mats at the Garrow and Kilmar platform approaches. The remainder of the pipelines that are either buried under rock dump or below 0.6m of natural seabed material will be left in situ.

2. INTRODUCTION

The purpose of this Comparative Assessment is to provide an assessment of potential decommissioning options available for the Garrow PL2160 and PL2161 pipelines against a set of assessment criteria derived from DESNZ Guidance Documents and in line with OEUK's 'Guidelines for Comparative Assessment in Decommissioning Programmes: Issue 1: Oct 2015'. The output of this Comparative Assessment will assist in identifying the preferred decommissioning options and methods and supports the submission of the decommissioning programme to OPRED.

Details of the pipelines are shown in table 2.1.

Pipeline	Size, OD	Length	Material	Wall Thickness	Corrosion coating	Design pressure	Burial status
PL2160	219.1 mm	22410 m	API 5L X65 carbon steel	15.9 mm	3 LPP and epoxy paint	215 barg	Trenched, mat/rock dumped at ends
PL2161	88.9 mm	22410 m	API 5L X65 carbon steel	7.6 mm	3 LPP and epoxy paint	296 barg	Trenched, mat/rock dumped at ends

Table 2.1 PL2160 and PL2161 pipeline data

Garrow comprises of one gas field (Blocks 42/25a and 43/21a) which is located approximately 72km offshore to the north-east of the nearest landfall at Flamborough Head, on the east coast of England. The nearest international boundary to the development is the UK/Dutch median line, which lies approximately 115 kilometres to the east of the Garrow platform. Figure 2.4 shows the Garrow location relative to nearby marine protected areas. The Garrow NUI and pipeline routes are located within the boundary of the Southern North Sea SAC, designated for the protection of harbour porpoises (see Figure 2.4 below).

The development lies in an area of sandbanks, which form a series of ridges parallel to the coast, with comparatively deep channels between them. Water depth along the proposed pipeline route varies between 29 metres and 53 metres and is approximately 52.6 metres at the Garrow NUI location and 54.8 metres at the Kilmar NUI location. The seafloor along the route generally comprises featureless sands and areas of megarippled sands. A number of sand waves exist along the Garrow to Kilmar pipeline route. Figs A.1 to A.4 in Appendix A show samples of these features. Seabed surveys carried out in the vicinity indicate they are mainly comprised of very loose to loose fine sands, becoming dense to very dense as they reach a depth of 2 to 10 meters below seabed. The area appears to be supported by the Boulder Bank Formation, overlying very stiff to hard clay.

MEG for hydrate and corrosion inhibition was supplied from Kilmar via the PL2161. The PL2161 pipeline was installed simultaneously to the larger PL2160 pipeline into the same protection trench for the majority of the route. The two only separate at the final approaches to the Garrow and Kilmar platforms but both are protected by the same concrete mattresses.

Garrow production is currently shut in following the closure of the Trent export route. Remaining reserves are not sufficient to support an alternative export route investment or ongoing maintenance and operating costs. A Cessation of Production (CoP) application will be submitted to NSTA.

Prior to decommissioning activities commencing the PL2160 and PL2161 pipelines will be flushed and cleaned and left filled with filtered seawater.

This document will be used to help determine the scope of work for decommissioning activities associated with the Garrow pipelines.

Figure 2.1 Tors location

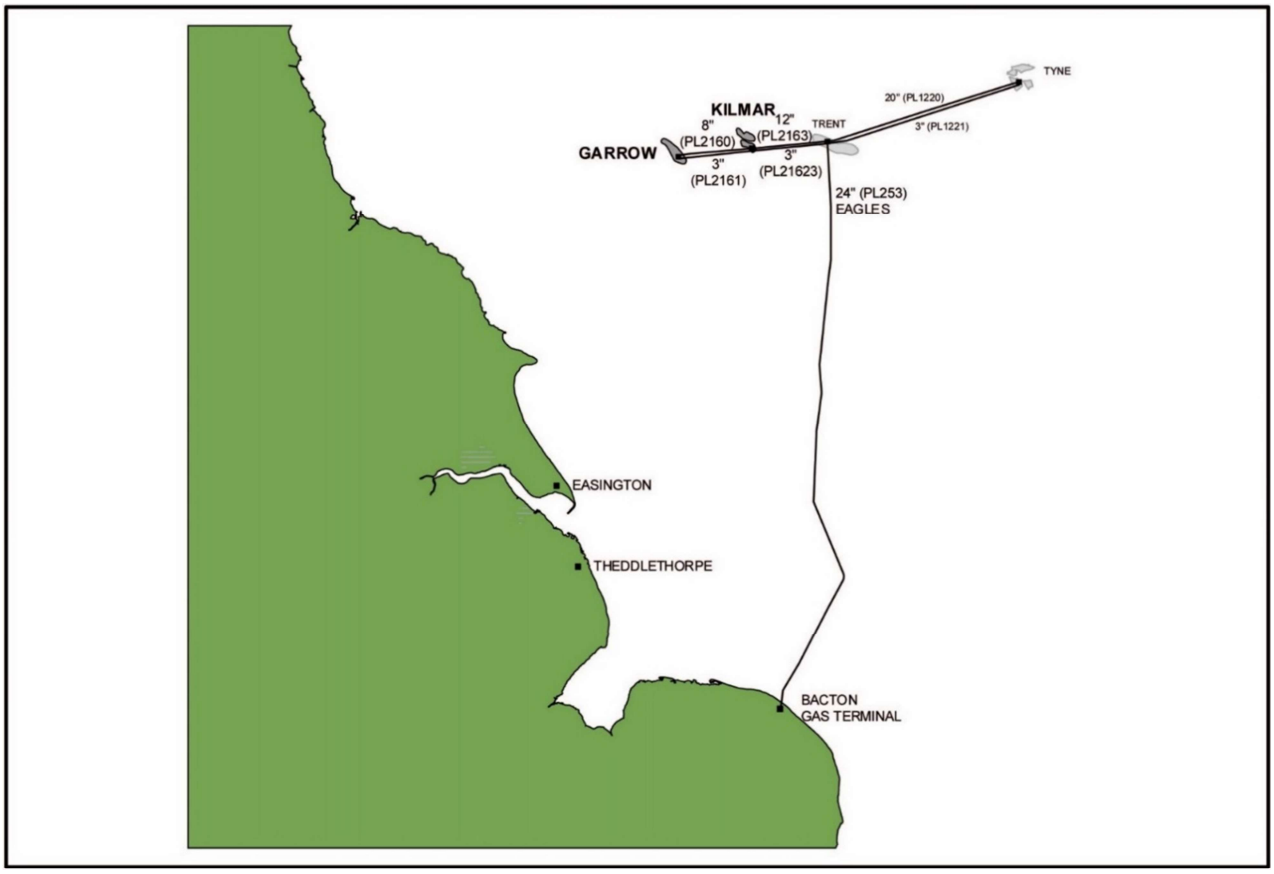


Figure 2.2 Overall field layout

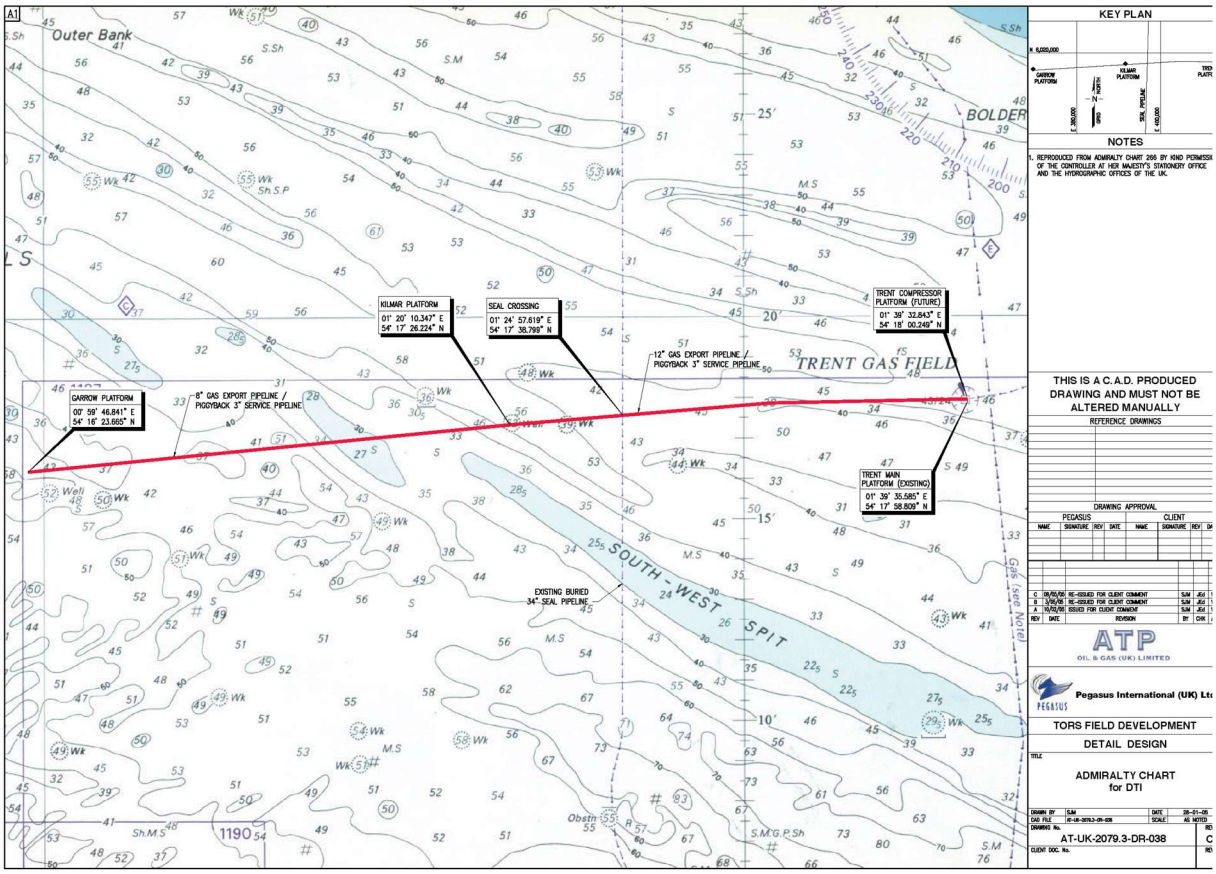


Fig 2.3 Garrow Field layout

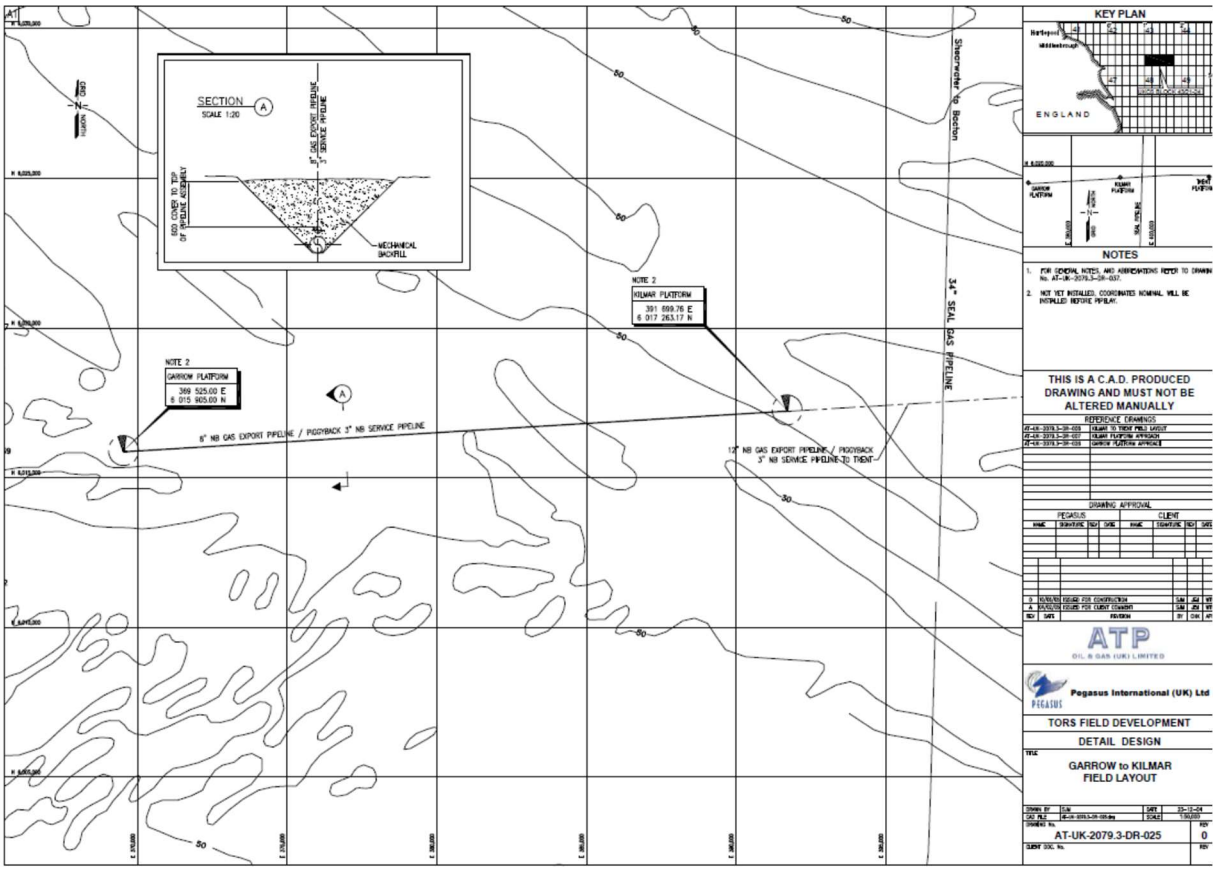
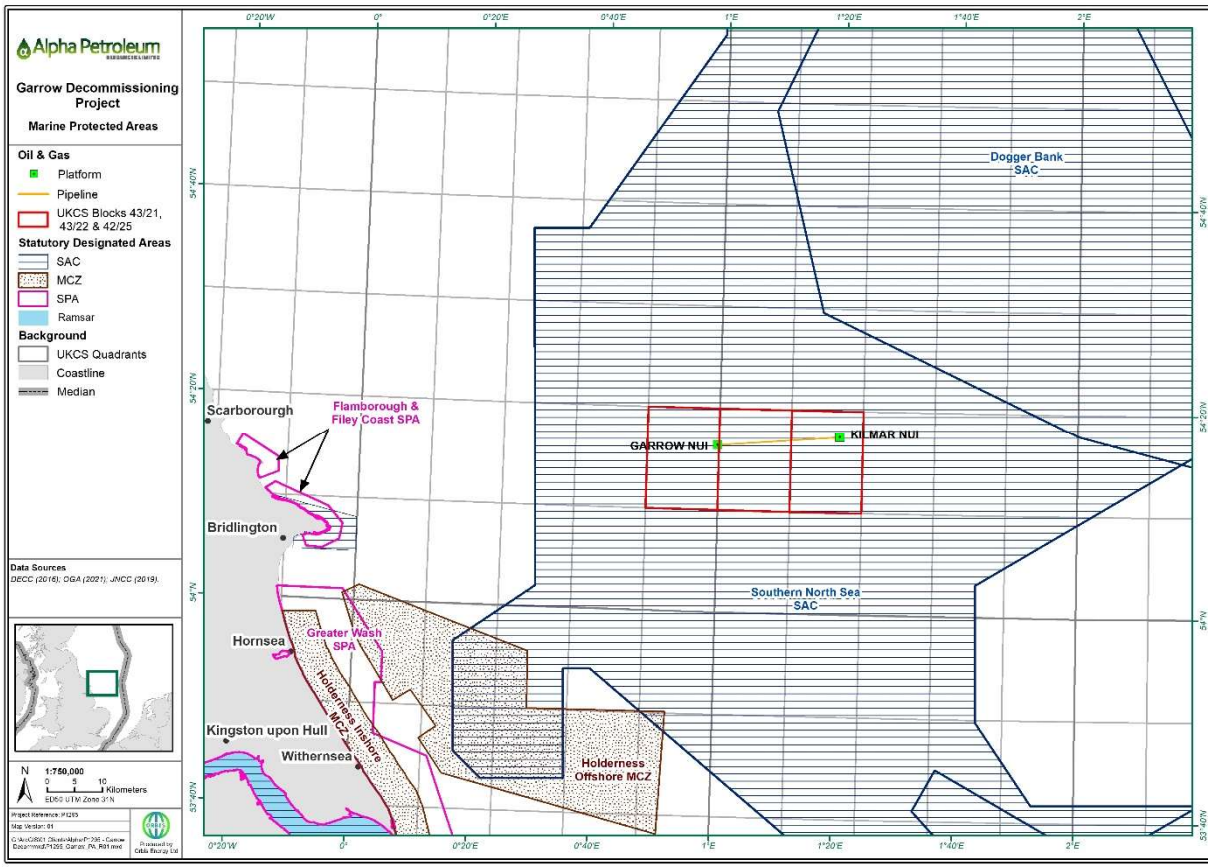


Fig 2.4 Marine Protected Areas in the Garrow proximity



3. STATUS OF THE INFRASTRUCTURE

This section contains a summary of the overall pipeline route and key features along it. Survey charts and video footage of the platform approaches are available on request along with the full route as trenched charts and intermediate MBES survey data.

3.1 Overall layout

The two pipelines were installed as piggy back pipelines and trenched to a target depth of 1.8m. The trench was then subsequently backfilled with a backfill plough. Where the pipelines were not trenched (at the platform approaches) a combination of concrete mattresses and rock dump were installed over the pipelines to provide protection. A total of 24 mattresses were used on the Garrow pipelines.

3.2 Burial status

Based upon the original as backfilled surveys and operational life interim general inspection surveys it can be concluded that the full length of pipelines are currently buried to a depth well in excess of 0.6m and normally between 1.5m and 1.8m deep with the exception of the following locations:

- Pipeline approaches at the platform ends

The status at these locations are detailed in section 3.4.

The latest operational survey of the full route was completed in 2022 with the latest visual inspections of the mattress protection sections in March 2022. Interim operational surveys have been carried out in 2008, 2010, 2013 and 2016 on the full route with visual mattress surveys also in 2010, and 2016. These surveys have been taken into account in preparing this document.

The development lies in an area of sandbanks which are mainly comprised of very loose to loose fine sands, becoming dense to very dense as they reach a depth of 2 to 10 meters below seabed. Water depth comparisons for the original as backfilled survey in 2005 and operational interim surveys in 2008, 2010, 2013, 2016 and 2022 appear to have shown some migration back and forth of the sand waves but no continuous migration and 2022 profiles match the original 2005 surveys very well. No pipeline exposures have been seen in any of the operational surveys. These comparisons are detailed in Appendix A, figures A1-A4. From the surveys it can also be seen that the seabed has a number of ripples of around 0.2m in height with 5-15m wavelengths throughout the route of the pipelines. It has been known for megaripples to migrate along the surface of the seabed. Given the burial depths of the pipelines even if this does occur the pipelines will remain buried below 0.6m. Appendix A, figure A5 shows further illustrations of the impact of potential ripple migration.

The PL2160 and PL2161 lines are made of carbon steel, API grade 5L X65 with a 0.5mm FBE and 3LPP coating. They also have offshore welded pipe joints covered with a sheet of HDPE as an outer coating overlapping with the FBE and 3LPP coating. As part of the design for the pipeline system, stability and upheaval buckling calculations were performed to ensure no movement of the pipeline during operational life was expected. In this operational condition the gas export pipeline was filled with warm gas which is more buoyant than water. In a water

flooded condition both pipelines are significantly negatively buoyant and so no upward movement of the pipeline would be expected in a left in situ condition.

3.3 Crossings

There are no crossings along the Garrow pipeline routes.

3.4 Pipeline and Spools at Garrow and Kilmar platform approaches

The pipeline and spool sections at the Garrow and Kilmar approaches are laid on the seabed surface and protected with concrete mats or rock dump. At the riser to spool goose necks the pipelines were indicated to have fronded mats placed underneath the goose necks, however, the latest inspection surveys show no indication of these mats below the pipelines. Beyond the spool sections running away from the platform, there are short section of the pipelines that are also laid on the seabed and protected with concrete mats. At each platform approach where the mat protection ends on the outboard side of the platforms, the pipelines have been rock dumped to provide a minimum of 0.8m cover. This continues through the pipeline trench transitions where the pipelines are then buried under natural seabed sediment. Of the total surface laid pipeline and spool sections (225m), ~70m of pipeline are rock protected, ~60m of pipeline are mat protected, ~95m of spools are mat protected.

Layouts of both the Garrow and Kilmar platform approaches are detailed in Appendix A figures A6 and A7.

3.5 UHB locations

There are no UHB rock dump locations along the pipeline routes. Sufficient burial with natural backfill was mechanically put in place to prevent any upward pipe movement during operational conditions.

4. COMPARATIVE ASSESSMENT PROCESS

The CA has been undertaken in line with DESNZ Guidance Documents. Comparative assessment decisions have also been made broadly in line with principals set out in the OEUK guidance report 'Guidelines for Comparative Assessment in Decommissioning Programmes: Issue 1: Oct 2015'.

A two-stage process with an early option screening assessment to narrow options to a manageable number followed by a detailed comparative assessment of selected options has been adopted.

Stage 1: Option screening

A list of potential decommissioning options was developed for each pipeline which included an option for full removal of pipeline by reverse reeling and cut and lift methods, leave full pipeline in situ (including buried, rock dumped and mattressed sections) option and several partial removal options. Potential reuse options of the pipelines were considered including use of the pipelines as part of a possible alternative export route for the Kilmar field, however, these options were found to be uneconomic or not in the same time frames for possible 3rd party field development programmes. In a desktop exercise each of these options were then evaluated against the categories and considerations detailed in Table 4.1. They were then given a traffic light rating where green represents an acceptable solution, amber represents a solution that may be acceptable with appropriate actions or control measures and red represents an unacceptable option. Each option was then reviewed across all categories to establish whether the option should be selected for a more detailed comparative assessment. The outcome of this desktop exercise was then peer reviewed by an independent subsea specialist from Subsea and Sea Limited and was shared with OPRED to ensure agreement that all potentially viable options were considered as part of the stage 2 detailed assessment.

Table 4.1 Categories and Considerations considered during stage 1 option screening.

Category	**Considerations**
Safety	
Risk to other users (post ops)	Snagging, collision, seabed movement, scouring, inspection survey risks
Risk to those offshore (during ops)	Dropped objects, number of lifts involved, sea fastening of retrieved items, contamination, NORM, duration of offshore vessel days
Risk to 3rd parties (during ops)	Collision, snagging,
Durations of diving intervention	Manual operations, ROV operations, confined space working
Risk to those onshore (during ops)	Handling of recovered items, volume of road transportation, extent of marine growth
Environmental	
Discharges	Chemical or hydrocarbon leaks, erosion due to high volume flows, sewage/food waste

Seabed disturbance	Volume of disturbance, durations for seabed to recover, impact on flora and fauna (smothering), Impact to SAC.
Impact on Marine protected areas	Impact on qualifying features of southern North Sea SAC (harbour porpoises).
Energy usage (during and post ops)	Fuel consumption required; type of fuel used
Atmospheric emissions	Vessel emissions, onshore emissions
Noise (underwater and onshore)	Disassembly onshore, cutting operations offshore, excavation techniques
Accidental spills	Duration of ROV work, onshore contamination, vessel lubes/chemicals
Technical	
Technical challenge	Difficulty level of operations, established technology or not, access to work locations, seabed currents, consumables required, integrity of protection materials
Weather sensitivity	Limiting sea states, susceptibility to fog, tidal current limitations
Risk of major project failure	Break up of items being recovered during recovery operation, damage to other infrastructure (on and offshore)
Societal	
Access to site for other users	Any restrictions to fisheries during or post ops, impact to merchant shipping during ops
Community disturbance (onshore)	Visibility of materials brought onshore, traffic volume increase, job creation, any benefit from use of recycled materials, volume of disposal materials
Economic	
Cost of work	Fixed cost or what is the range of cost outcome, any scrappage value/resale of equipment
Ongoing cost liabilities	Any inspection surveys required post ops; any further intervention required at later stage

Stage 2: Detailed assessment

Following development and approval of the 'Garrow pipelines (PL2160 and PL2161) Terms of Reference for Stage 2 Comparative Assessment Workshop, document number APR_TORS_PMGT_017' a workshop with available stakeholders and Waldorf decommissioning project team members was held. The workshop was conducted in the Guildford offices and via MS Teams. This, along with pre workshop reading material and post workshop sharing of the output result worksheets ensured all relevant parties input to the assessment was captured.

In order to rate the impact of the selected options a review against each of the below criteria set out in table 4.3 was carried out. Each sub category was initially allocated a red, green or amber rating code for each option. A guide table to the ratings codes is included as Appendix B. It should be noted that for this initial impact rating the colour allocation indicates the relative

impact of each option and does not define acceptability/non acceptability at this stage. Once the impacts were allocated the workshop attendees assigned an overall rating for each Category along with a degree of definition based on;

1- High certainty (high understanding of the methods to be used, status of the infrastructure, equipment required, public opinion perception and any hazards)
2- Mid certainty
3- Low certainty (low understanding of the methods to be used, status of the infrastructure, equipment required, public opinion perception or any hazards)

The workshop group initially reviewed the 3 main options. Complete removal (option 1), partial removal (option 2b) and complete leave in situ (option 3b).

On completion of the sheets the workshop group reviewed the option summaries and allocated a final colour rating to each option/sub option in line with the below table 4.2.

Table 4.2 Final rating options

Preferred solution	
Broadly acceptable	
Tolerable not preferred	
In tolerable, not acceptable	

Table 4.3 Categories and Considerations reviewed during the detailed assessment workshop.

Category	**Considerations**
Safety	
Risk to other users (post ops)	Snagging, collision, seabed movement, scouring, inspection survey risks
Risk to those offshore (during ops)	Dropped objects, number of lifts involved, sea fastening of retrieved items, contamination, NORM, duration of offshore vessel days
Risk to 3rd parties (during ops)	Collision, snagging,
Durations of diving intervention	Manual operations, ROV operations, confined space working
Risk to those onshore (during ops)	Handling of recovered items, volume of road transportation, extent of marine growth
High consequence event	Event needing de/re-mobilisation of vessel(s) or yard, significant delay to work, etc
Environmental	
Discharges	Chemical or hydrocarbon discharges, erosion due to high volume flows, sewage/food waste
Seabed disturbance	Volume of disturbance, durations for seabed to recover, impact on water column, impact on seabed communities (physical loss, smothering etc.)

Impact on Marine protected area (Southern North Sea SAC)	Impact on qualifying features of Southern North Sea SAC (harbour porpoises).
Impact on Marine Protected area (Greater Wash Area SPA)	Amount of Marine traffic and duration in the SPA. Is the marine traffic limited to shipping lanes? Impact to Red Throated Diver bird.
Energy usage (during and post ops)	Fuel consumption required; type of fuel used
Atmospheric emissions (during and post ops)	Vessel emissions, onshore emissions
Noise (underwater and onshore)	Disassembly onshore, cutting operations offshore, excavation techniques
Accidental spills	Duration of ROV work, onshore contamination, vessel lubes/chemicals
Smell (onshore)	Amount of marine growth decay at disassembly yard
Waste processing	Tonnage sent to landfill
Technical	
Technical challenge	Difficulty level of operations, established technology or not, access to work locations, seabed currents, consumables required, integrity of protection materials
Weather sensitivity	Limiting sea states, susceptibility to fog, tidal current limitations
Risk of major project failure	Break up of items being recovered during recovery operation, damage to other infrastructure (on and offshore)
Repurposing opportunity	Pipeline availability in full or part for a repurposing use after decommissioning. Is this opportunity available for a short or long term period
Societal	
Access to site for other users	Any restrictions to fisheries during or post ops, impact to merchant shipping during ops
Community impact (onshore)	Visibility of materials brought onshore, traffic volume increase, job creation, any benefit from use of recycled materials, volume of disposal materials
Reputational Impact (during and post ops)	Are Companies seen to be setting good or poor precedents, are stakeholders representing their interests, how visible in the public eye is the project
Economic	
Cost of work	Fixed cost or what is the range of cost outcome, any scrappage value/resale of equipment

Ongoing cost liabilities	Any inspection surveys required post ops; any further intervention required at later stage

5. COMPARATIVE ASSESSMENT SCREENING (Stage 1 results)

The below table shows the outcome of the comparative assessment screening for the pipelines PL2160 and PL2161.

Table 5.1 Garrow pipelines Comparative Assessment option screening.

Number	Option	Safety	Environment	Technical	Societal	Economic	Selected for further study
1	Leave full pipeline in situ (including buried, rock dumped and mattressed sections)						SELECTED
2	Partial removal of pipeline (see below for sub options considered)						SELECTED
3	Full removal of pipeline by reverse reeling/S lay and cut and lift methods (sub option 3a)						SELECTED

Number	Sub Options	Safety	Environment	Technical	Societal	Economic	Selected for further study
1a	Rock dump all mattress protection areas and leave in situ						
2a	Leave pipeline as is but remove surface laid pipeline sections (including rock removal)						
2b	Leave pipeline as is but remove only mat covered pipeline and spool sections						SELECTED
3a	Remove by combination of reverse reeling/S lay and cut and lift (but leave in situ rock dumped sections)						SELECTED

Given the pipelines have been laid together with the PL2161 pipeline piggybacked to the 8" pipeline the assessment screening is the same for both pipelines.

Full removal option (Option 3)

A full recovery of all infrastructure for each pipeline has been considered in the screening assessments. For most of the pipeline lengths the most appropriate option considered for this was the removal by reverse reeling or reverse S lay. The platform approach sections would require separate recovery solutions, which have also been considered in the screening exercise as separate sub options to the partial removal. Full recovery by cutting and lifting of separate sections over the full 22.4 km would involve significantly greater vessel time and risk so was not identified as viable option for screening.

As a consequence of the burial condition of the pipeline prior to reverse reel or S lay recovery the vast majority of the length of the pipelines would require de-burial (*mostly 1.5-1.8 m deep with full natural backfill*). This would require extensive disturbance of the seabed likely using a mass flow technique. Large volumes of sediment would be put into suspension. It is also likely to leave a temporary trench along the route for a period of time until natural backfill occurs. This carries a risk of smothering of benthic animals, however, given the mobile nature of the sandy seabed this is not considered to be critical and so has been assessed as amber in the Environmental category (where rock is left in situ). Similarly, the high number of vessel days and subsequent onshore handling of materials involved in this option mean the cost associated with it is extremely high. It was given a red ranking in the Economic category. There is also a higher safety risk associated with reeling back or S lay recovering the pipelines given the unknown level of corrosion through the pipe wall. Where the pipe has a thinner wall thickness there is an increased risk that the pipeline may part in an uncontrolled manner during the re-reeling or S lay process. In addition, the condition of the strapping attaching the two pipelines together is unknown and may part causing risks in recovering the two products on the stern ramp of the reel or S lay vessel. These will further be considered in the detailed assessment workshop. It should also be noted that the pipelines were installed by the Seaway Falcon pipelay vessel which used a hybrid of S lay and reel lay techniques. The Seaway Falcon is now no longer in service. The pipeline wall thicknesses are therefore not specifically designed for existing reel vessels and after detailed engineering an S lay technique may be the only option technically acceptable for full recovery. This option has been given a red ranking in the safety category.

At the two platform approach sections the trench transition areas and initial pipeline end sections have been rock dumped for protection. To recover the full pipeline lengths these rock dump sections would require excavation prior to pipeline recovery. It is likely that this would be carried out using mass flow technique's but the pressures and flow rates required to remove the rock will be much greater than for the natural sandy seabed. As a result, it is highly likely that larger irregular trenches would be created in these sections and the rock would be distributed across the seabed over a much wider area of seabed than it currently covers. The assessment raises the rating to red in the Environmental category for this rock dump removal option. For this reason a sub option (3a) has been considered which would leave the sections of pipeline buried under the rock in situ but recovering all other sections. Given that the rock dump sections are of graded rock with profiled side slopes to allow passage of any fishing gear and show no evidence of migration or of damage by fishing gear, no concerns have been raised about leaving this rock in situ. This is the full recovery option carried forward into the detailed assessment.

Partial removal option (Option 2)

Sub option 2a involves the removal of rock dump prior to recovering the pipeline sections underneath. This would require similar mass flow excavations of the rock as for the full removal options described above. There is less total disturbance to the seabed however than for the full removal option. Rankings in the Environmental, Social and Economic categories were assessed as amber. Option 2b leaves these rock dump sections in situ and therefore has a reduced seabed disturbance, less lifts and materials returning to shore. It has been assessed with a green ranking in the Environmental, Technical and Societal categories. Options 2a and 2b would also not involve working below the natural seabed level as the pipelines were laid on the seabed before being rock dumped or matted in these areas. The techniques involved are well known and the lengths involved and the subsequent number of lifts to a vessel are limited. The options were therefore given a green ranking in the Safety category. As a result, it is not recommended to carry the rock dump removal option 2a forward to the detailed assessment stage.

Full leave in situ and Rock dump and leave in situ options (Option 1)

During the operational life of the field no interventions have been required and no issued with other sea users have been reported. There is no evidence of any protection features moving or creating a snagging impact with fishing gear. Option 1 to leave all stabilisation features and pipelines as is will therefore be further assessed during the detailed assessment.

The option to rock dump areas covered by protection mattresses was identified as an option for screening (1a) but is highly likely to be opposed by some stakeholders. It is only likely to be considered by all stakeholders as an acceptable solution where no other viable option exists. This does not appear to be the case for the Garrow pipelines and therefore the rock dump solution has not been carried forward to the detailed assessment stage.

6. SELECTED OPTIONS COMPARATIVE ASSESSMENT (Stage 2 results)

The full impact assessment worksheets with all main and sub category ratings are included in Appendix C for reference, however, the following is a brief overview of each of the assessed options.

Leave in situ (option 1)

The full leave in situ option was found to be broadly acceptable. This option has the least scope and impact during decommissioning activities with the work limited to the cutting and removal of the exposed riser to spool goose neck sections of pipeline at the Garrow and Kilmar pipeline ends. Safety risks and onshore impacts are therefore low during the work. Legacy surveys are likely to be required over a longer time frame to ensure the status of the left in situ infrastructure does not change and create hazards to other users.

Given the relatively small surface area of the mats and the stable fully buried nature of the majority of the pipeline it is felt this option would not adversely impact the existing seabed communities or other users of the area. There is some legacy snagging risks associated with this option with the potential for a high consequence legacy event. As a result of this the option was given a medium overall safety rating. No known snagging events or damage to the mats has been seen during the operational life of the pipeline systems with some mats at least partially buried by natural seabed material deposition. The removal work and ongoing surveys that would be required are well within existing technologies for the industry and this option represents the lowest cost of the options taken into the detailed assessment stage.

The workshop group felt there is some uncertainty around the public perception associated with not removing infrastructure and the subsequent impact this may have on stakeholders but did not think this is of high concern to prevent the option being considered.

The option, however, does not meet OPRED's expectation that mats not buried to greater than 0.6m should be removed. As a result, the workshop group felt that option 2b was a preferred option given that both options were broadly acceptable.

Partial removal (Option 2b)

The partial removal option 2b was found to be broadly acceptable and the preferred solution of the detailed workshop options. In addition to the riser to spool goose neck sections of pipeline this considered removal of the concrete protection mats and underlying pipeline sections at the Garrow and Kilmar platform approaches. The remainder of the buried and rock dumped pipeline sections would be left in situ. In order to recover the mats and cut sections of pipework an MSV or DSV will be required to make a significant number of lifts to the deck of the vessel. It is anticipated that the mats will be stacked subsea and bulk lifted to deck reducing the number of lifts required and the risk of break up of individual mats during the recovery process. Similarly, there will be a significant number of lifts required onshore for the break up and recycling of the recovered materials. For this reason the option was given a medium risk rating in the safety category. Equipment and technologies required to recover and break up the materials are well known to the industry and are not technically challenging. It is estimated that 7 days vessel time would be required to recover the mats and underlying pipe sections. A greater volume of emissions and waste is associated with these vessel days

compared to the leave in situ option. There are also some localised seabed disturbances associated with the recovery work. As a result, there are some medium ratings associated with this option in the environmental category, however, given the short term and temporary impacts on seabed and/or marine communities the workshop group felt an overall low environmental impact is associated with this partial removal option.

Other than the areas where rock dump overlies the pipelines, the seabed surface is expected to be returned to it's natural status along the entire area impacted by the Garrow facilities. Given the relatively stable nature of the seabed no left in situ facilities would be expected to be seen over time at the seabed surface. It should be noted that at the cut ends of the recovered spool / pipe sections that any exposed ends will be covered by a remaining mat and will be flush with seabed and overtrawlable.

Again, the workshop group felt there is some uncertainty around the public perception associated with not removing all infrastructure although any impact is less than for the full leave in situ option and should not impact the partial removal options being considered.

The costs for this option are expected to be approximately two times those of the leave in situ option but given the high level of available survey information, the on seabed location and known condition of the infrastructure a high level of definition is expected with this cost outcome.

Full removal (Option 3a)

This option considers leaving the pipeline sections protected by rock dump in situ but recovering the remainder of the pipelines in their entirety. This would be done most likely by a combination of mass flow excavation to expose buried pipelines, hydraulic cutting of pipe at the burial points of rock dump sections, reverse reeling or reverse S lay, mat recovery and cut and lifting of the platform approach sections of the pipelines. The option was considered to be tolerable but not preferred and will not be undertaken.

A number of safety concerns that may occur during the removal work were highlighted at the workshop. These include those associated with reverse reeling/s lay of the pipelines where the remaining wall thickness of the pipelines and therefore their residual strength in the pipelines is not a definitive number. When applying tension to the pipeline to recover it back to the lay vessel deck there will be a chance of pipeline failure with an associated sudden release of tension. The unknown 'suction' effect of pulling up the pipelines through the excavated trench will also increase the risk of a pipeline failure during recovery. The status of the piggyback attachment mechanism is also unknown and there is a significant risk that attachment straps may have corroded. There is therefore a risk that the 2 pipelines separate during recovery or that the 2 pipelines need to be recovered separately after having 1st cut any remaining attachment straps. These concerns also led the workshop group to assign a low certainty to the level of definition in the economic category and medium certainties to the safety and technical categories. There is a high level of lifts required with this option both offshore and onshore along with working at height issues associated with personnel working on the reel lay vessel ramp to detach piggyback blocks and strapping. Overall, this option was given a high impact rating in the safety category.

The environmental impacts associated with this option are also much higher. The area of seabed disturbance is vastly increased in comparison with other options and volume of seabed material put into temporary solution (smothering risk) is a lot higher, although not in a

highly sensitive location. Fuel usage, emissions and noise are increased as a result of the increased durations of vessels and cutting operations that are required for the option. Although the recycling tonnage is increased the associated waste tonnages and landfill are also increased as most of the pipeline materials are all returned to shore. This will have more visibility and impact to the public onshore. Overall, the workshop group gave the option a medium impact rating in the environmental category.

Technically each of the operations required for this option are feasible and are within the industries capabilities, however, the combination of the activities are not common practise for the industry and would require new procedures and risk assessment processes. The requirement to subsequently attach the reel vessel abandonment and recovery winch line to severed sections of pipeline may preclude the use of hydraulic cutters which also flatten the pipeline sections at the cut location preventing the use of ball grab type recovery tools. Other recovery techniques would need to be specifically engineered for the operation(s). The option was therefore given a medium risk rating with mid certainty in the technical category.

The workshop group felt that a full recovery option for a well buried and stable pipeline system (as is the case for the Garrow pipelines) would set an unwelcome precedent within the industry and would negatively effect the reputation of the stakeholders involved. The community impact onshore was given a medium impact rating due to both positive and negative impacts associated with the option. The higher tonnages being return to shore create a boost to the local economy, however, increased traffic, noise and landfill need to be accounted for. Overall, the societal category was given a medium rating.

The cost for the decommissioning work with this option is approximately seven times that of the lowest cost option and over 3 times that of the workshop's preferred option. It also carries a significant risk for cost escalation. Legacy surveys would still be required to confirm that the excavated pipeline trench has naturally backfilled itself close to or to the natural surrounding seabed level. The option was given a high impact rating with high uncertainty in the economic category.

7. RECOMMENDATIONS OF THE COMPARATIVE ASSESSMENT PROCESS

The below summary table shows the final outcome of the detailed assessment with a recommendation to adopt the partial removal option (2b). This represents removal of the concrete protection mats and underlying pipeline sections at the Garrow and Kilmar platform approaches. The remainder of the buried and rock dumped pipeline sections should be left in situ.

Table 7.1 Final detailed assessment ratings table

	Main Options			
Aspect	**Complete removal (option 3a)**	**Partial removal (option 2b)**	**Full leave in situ (option 1)**	**Comment**
Safety overall rating				
Safety overall definition	2	1	2	
Environmental overall rating				
Environmental overall definition	1	1	1	
Technical overall rating				
Technical overall definition	2	1	1	
Societal overall rating				
Societal overall definition	2	1	2	
Economic overall rating				
Economic overall definition	3	2	2	
Final rating				1

Comments

1. OPRED expectation is that mats with <0.6m burial are recovered. Option 2b complies with this where as option 1 does not. Given both options were 'Broadly Acceptable preference was to go with option 2b.

Key

Preferred solution	
Broadly acceptable	
Tolerable not preferred	
In tolerable, not acceptable	

8. REFERENCES

1. APR-TORS-PMGT-012 Garrow Decommissioning Programmes
2. APR-TORS-PMGT-014 Garrow Decommissioning Environmental Appraisal
3. Department for Energy Security & Net Zero (DESNZ) 'Guidance Notes: Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998' (November 2018)
4. OEUK's, Guidelines for Comparative Assessment in Decommissioning Programmes: Issue 1: Oct 2015
5. 220318-R-002 Pre-Decommissioning Environmental Baseline Survey Garrow Field Southern North Sea, UKCS Blocks 42/25a and 43/21a Habitat Report.
6. 220318-R-004 Pre-Decommissioning Environmental Baseline Garrow UKCS Blocks 42/25a and 43/21a Pre-decommissioning Environmental Baseline

APPENDIX A

Water depth comparisons

Water depths along the route have been compared from the original as installed surveys (2005) and interim operational surveys between 2008 and 2022 to establish if any migration of the seabed along the route has occurred. Figure A.1 below shows the 2005 as backfilled survey chart over a sand wave section of the pipelines route between KP 5.2 and KP 6.55. It should be noted that the chart scales are highly exaggerated to emphasise features on what is essentially a flat seabed. The horizontal scale is in kilometres versus a vertical scale in metres. The natural seabed level indicated on the chart is the average of two locations either side of the trench (indicated in green on the below Figure A.1). The pipeline depth of burial can clearly be seen and is a similar burial consistency along the entire route. The extent of mechanical backfilling can also clearly be seen to completely fill the trench with some slightly higher mounds immediately above the pipelines where excess backfill sand will have been pushed. These mounds will have been levelled out by natural currents quite quickly in time.

Figure A.2 shows the same as backfilled chart with the interim operational survey seabed profiles superimposed onto it. Some clear differences can be seen in the peak locations of each sand wave through time and although some differences could be down to survey tolerances the distances involved (up to 50m horizontally) would be outside these tolerances. It is also clear that migration of the sand waves is not in a continuous direction. 2008 and 2016 surveys indicate a westerly migration occurred; however, the 2010, 2013 and 2022 peak locations appear to be more in line with the original 2005 locations. Any movement appears to be back and forth.

Figure A.3 shows a similar as backfilled chart with interim operational survey seabed profiles superimposed through a second sand wave section of the route closer to the Kilmar end. A similar back and forth migration of the peaks can be seen.

Figure A.4 is a final example in an area of predominately flat seabed. In these locations the seabed appears to be very stable through all of the surveys.

Full route survey data from the original as backfilled charting and the interim operational surveys are available on request.

Fig A.1 2005 As Backfilled survey chart extract (KP 5.2 – KP 6.55)

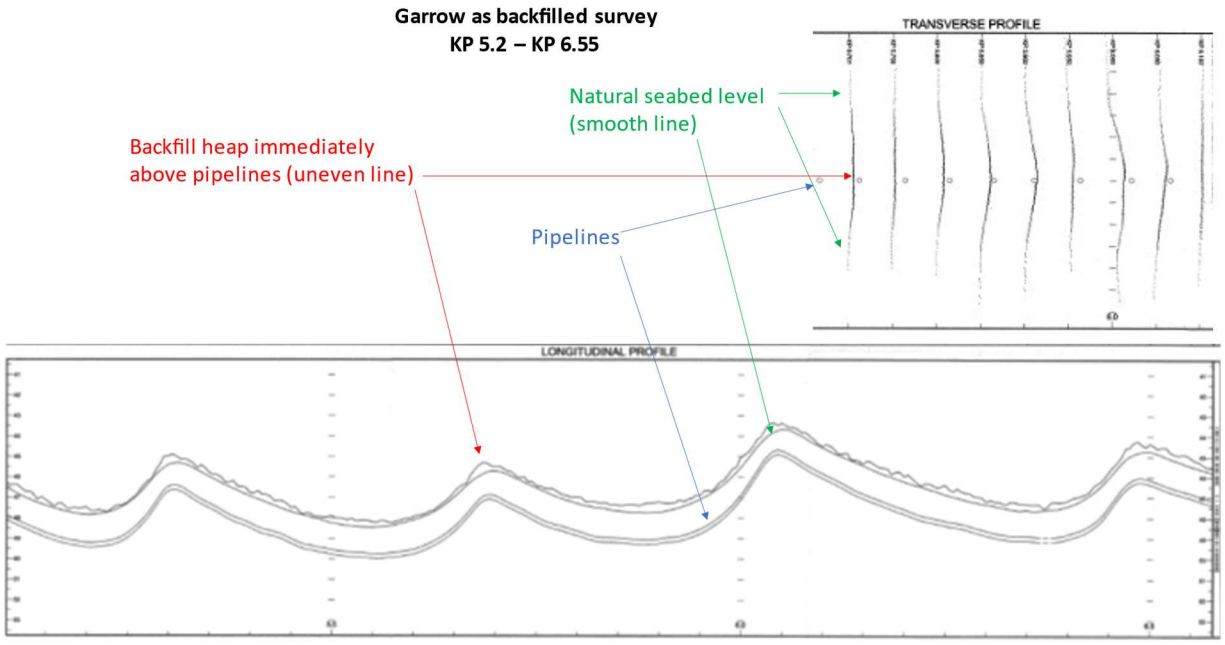


Fig A.2 As Backfilled chart and interim operational survey profiles (KP5.2 – KP 6.55)

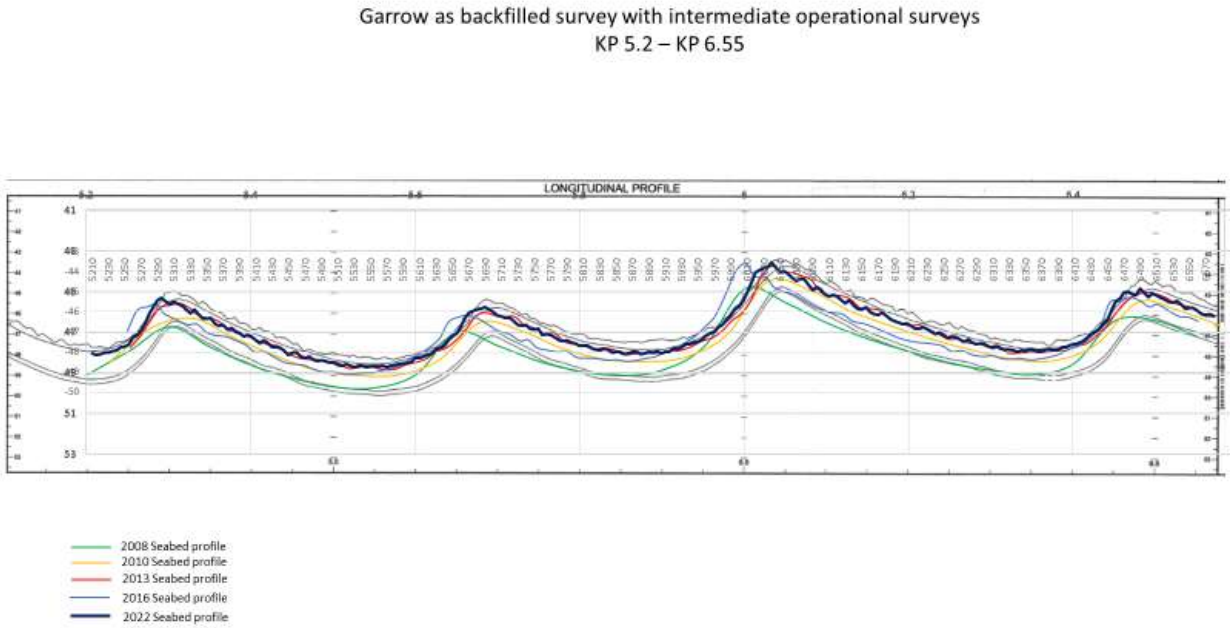


Fig A.3 As Backfilled chart and interim operational survey profiles (KP17.55 – KP 19.05)

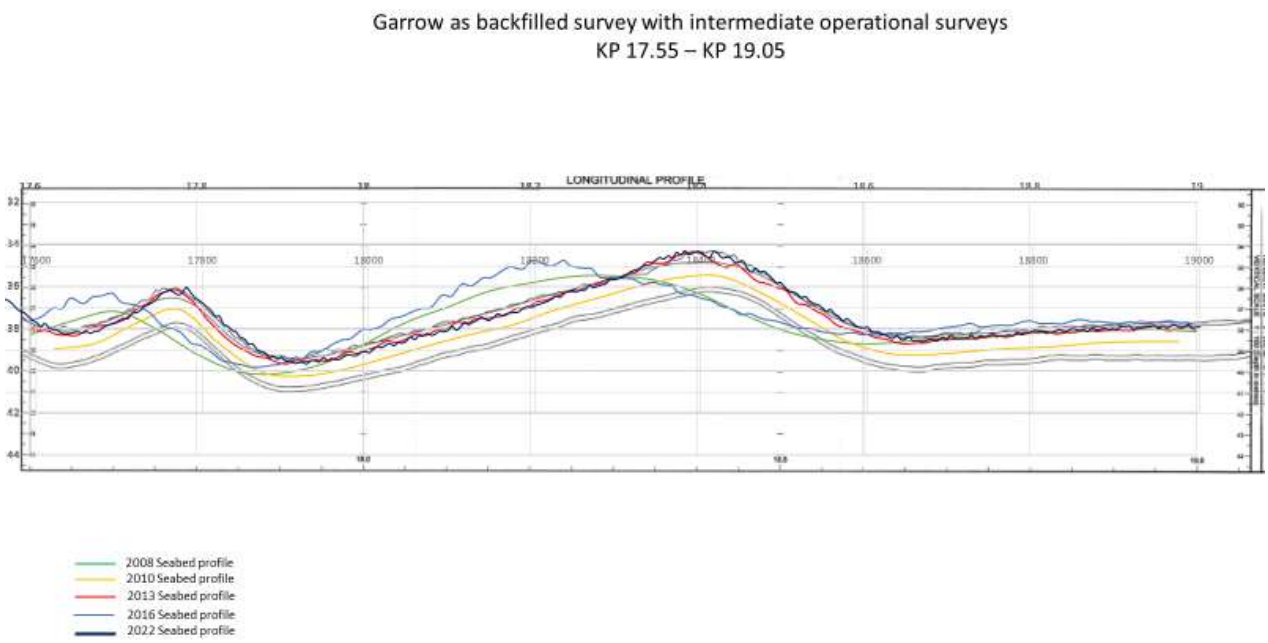
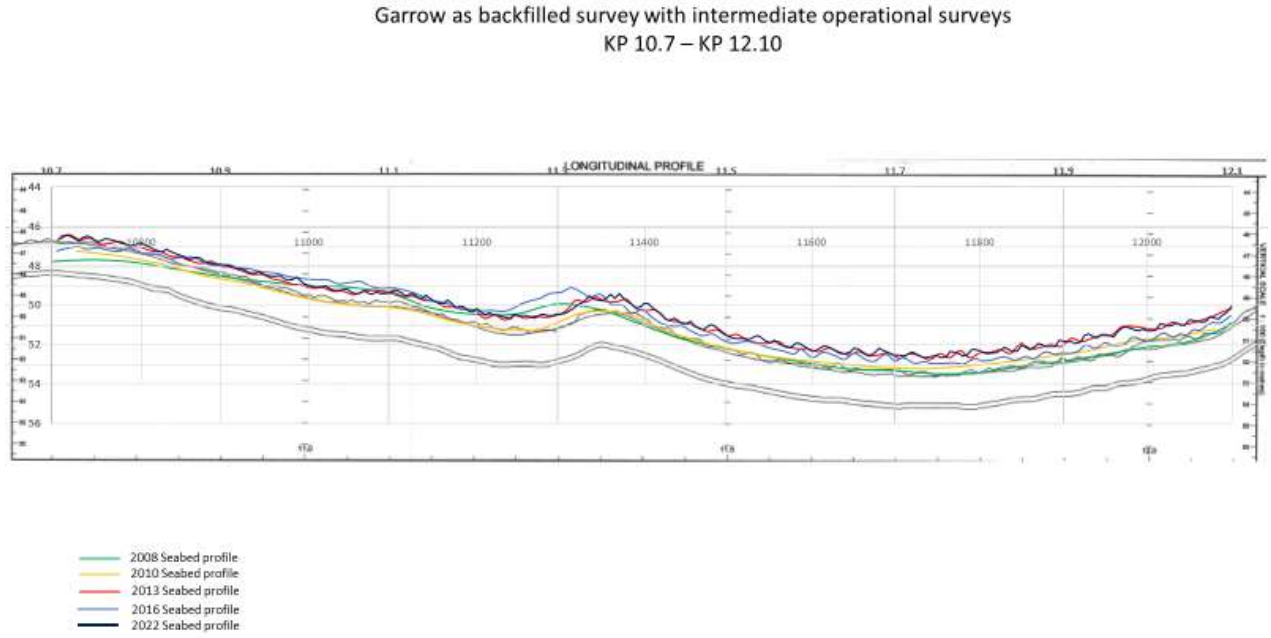


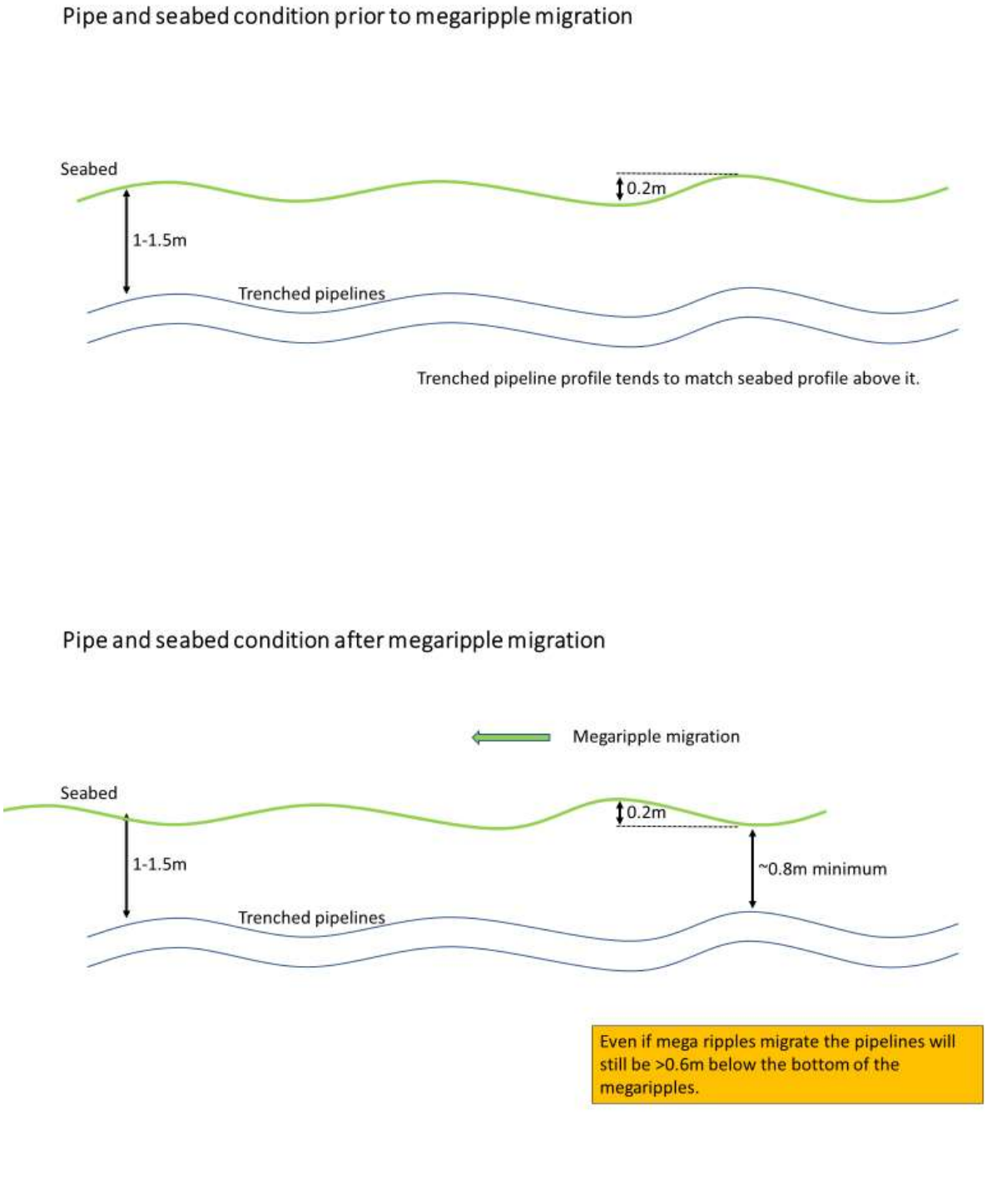
Fig A.4 As Backfilled chart and interim operational survey profiles (KP10.7 – KP 12.1)



Potential mega ripple migration impact on burial depths

The below figures show the minimum remaining burial depth even if the Garrow pipeline routes experience megaripple migration and a megaripple trough matches with the peak from the as trenched pipeline profile.

Fig A.5 Minimal burial depths after megaripple migration



Garrow and Kilmar Platform approaches

Fig A.6 and A.7 below shows the platform approaches. Note the 12” and 3” pipelines to the East of the Kilmar platform in Fig A.7 are PL 2162 and PL 2163 and are not part of this Comparative Assessment or the Garrow Decommissioning Plan. The March 2022 GVI surveys have confirmed the platform approaches remain in this condition.

Fig A.6 Garrow platform approach layout

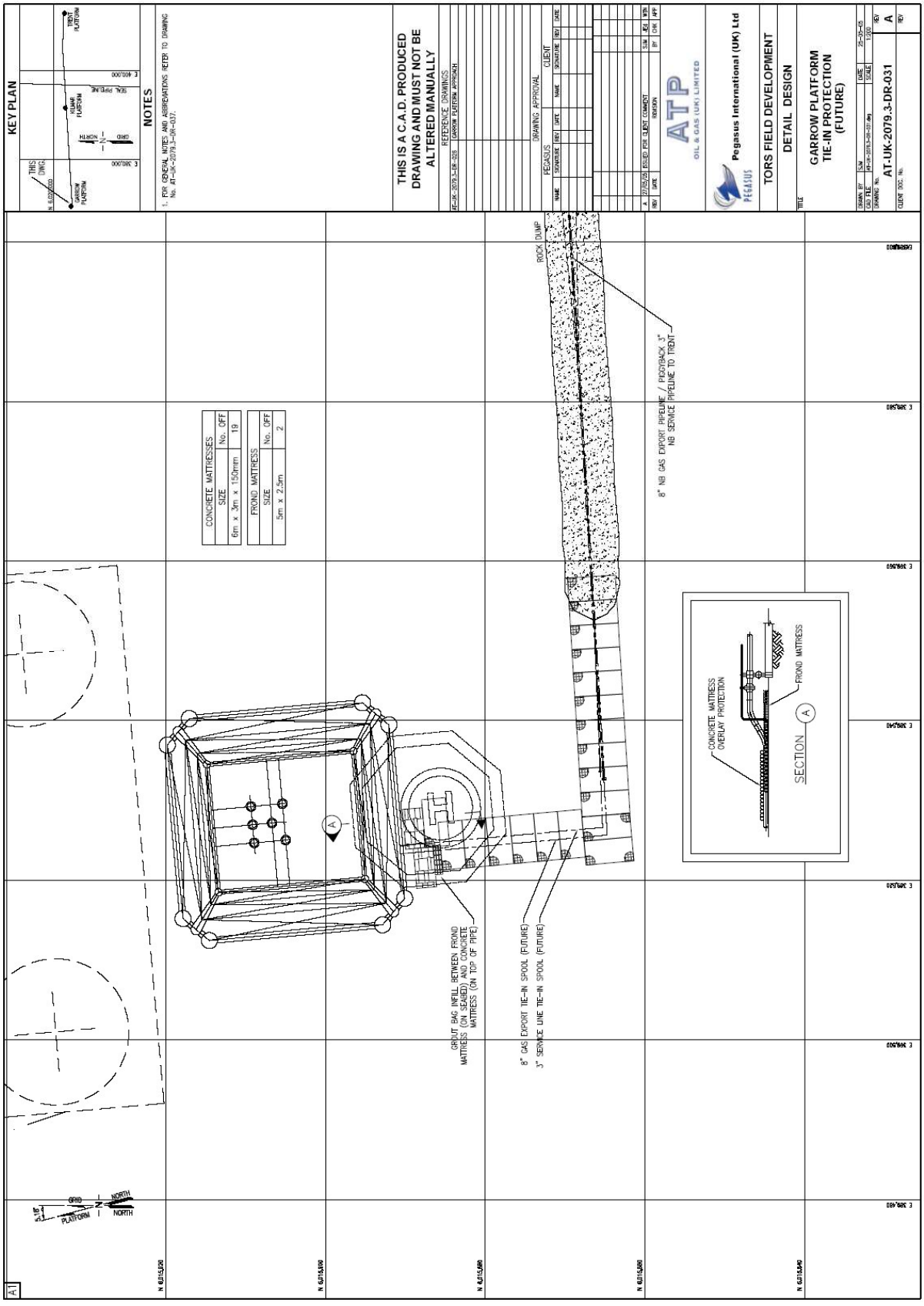
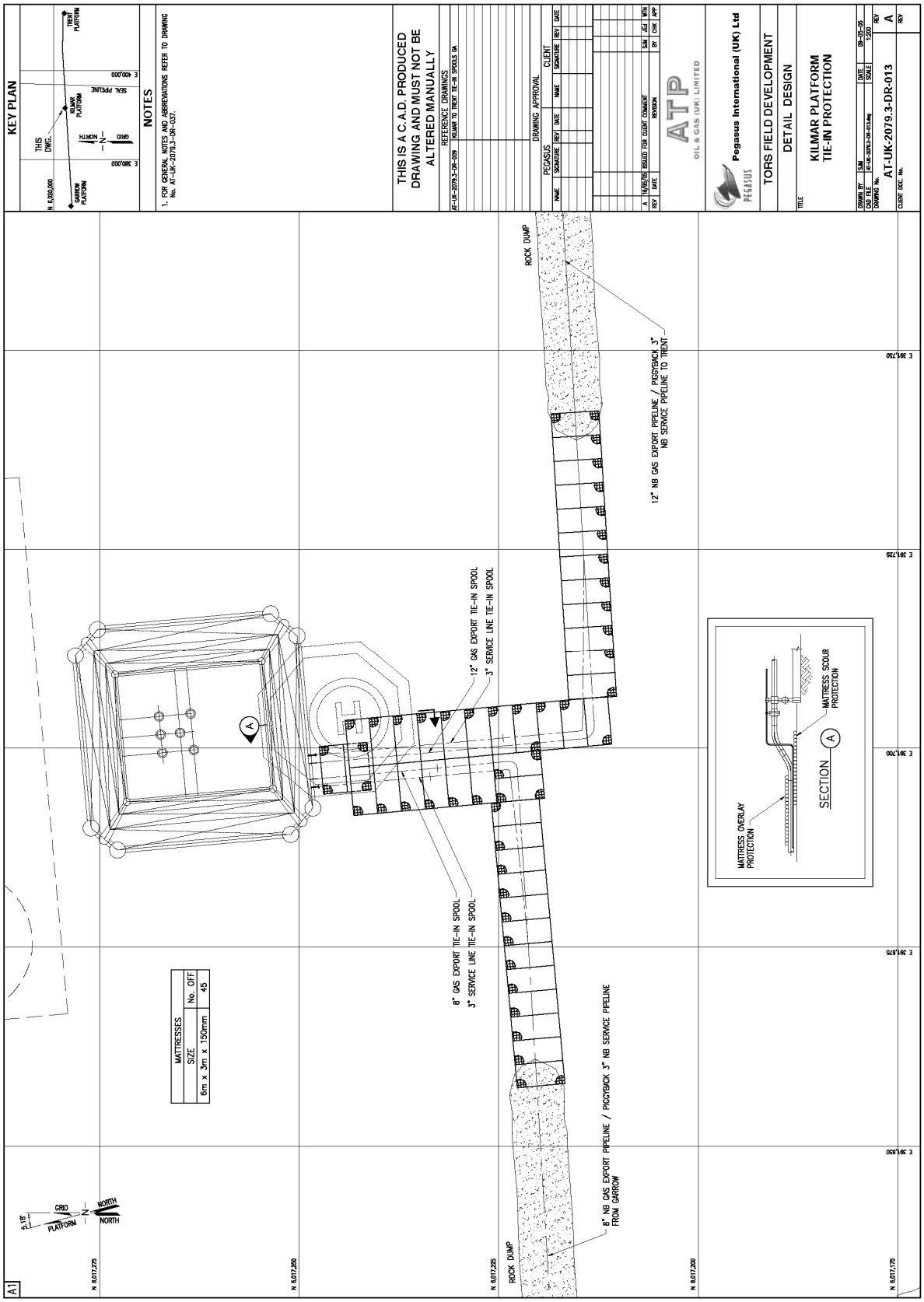


Fig A.7 Kilmar platform approach layout.



APPENDIX B

Category	Impact Assessment criteria		
	Low	Medium	High
Safety			
Risk to other users (post ops)	None to minor snagging, no personal injuries likely	Snagging hazard if protection deteriorates or is moved, minor damage or loss to equipment (fishing gear), minor injury (1st aid case to RWC)	Full loss of fishing gear and/or damage to vessel, 1 LTI to multiple fatalities or long term injuries
Risk to those offshore (during ops)	None to 2 vessel days reqd, low number of lifts to deck, no recovery of hydrocarbon contacted surfaces, no hot work reqd (seafastening)	3-20 vessel days, <20 deck lifts, recovery of cleaned pipework sections to deck (<200m of sections), minor hot work (eg cutting seafastening)	>20 vessel days, >20 deck lifts, multiple lifts to deck or working at height reqd, recovery of uncleaned hydrocarbon contacted surfaces or NORM contaminated equipment, welding or multiple hot work
Risk to 3rd parties (during ops)	None to 10 vessel days in field (zero to 7 days work outside marked 500m zones), no seabed obstructions left unattended during removal work,	11- 30 vessel days in field (8-14 outside marked 500m zones), snagging obstructions on seabed for short durations (port calls, WDT)	>30 days in field (>15 outside marked 500m zones), Obstructions left for long period unmarked on seabed.
Durations of diving intervention	None (tasks can be performed by remote tooling)	Intervention work requiring no tools or structure entry	Multiple diver time required with equipment left in situ over more than 1 dive
Risk to those onshore (during ops)	Zero to 50T returned to shore, minimal break up required before recycling/disposal	50-500T returned to shore, some break up and double handling of materials reqd	>500T returned to shore, multiple lifting, transportation and break up reqd as part of recycling/disposal
High consequence event	Low probability of collision, dropped object or pressure release near personnel. No working at height required	Some short term working at height, no lifts above 10Te, short term working with pressure or high voltage equipment	Major regular lifts required to deck, regular working at height, vessels working in congested areas (close to platforms)
Environmental			
Discharges	No or negligible discharge	Discharges may cause short term change to the ecosystem but with good recovery potential	Discharges cause long term or permanent change to the ecosystem
Seabed disturbance	No or negligible disturbance. Short term seabed clouding from ROV/diver/equipment movement, no or very	Localised disturbance up to 100% of the in situ equipment footprint, limited seabed material put	Wide area of disturbance >100% of equipment footprint, Large volumes of seabed material put

	low impact on seabed communities	into solution, short term impact on seabed communities from smothering	into solution (dredging or mass flow excavation equipment reqd), risk of smothering and loss of seabed communities
Impact on Marine protected areas (SNS SAC)	No or negligible impact to the qualifying features of the MPA.	Minor impacts which do not prevent the site's conservation objectives from being met	Impacts that are likely to adversely affect the integrity of the MPA and are not in line with the site's conservation objectives
Impact on Marine protected areas (GWA SPA)	No work in or minimal marine traffic passing through SPA	<10 transits through SPA or <30 restricted to shipping lanes	Work located within SPA. >10 transit through or >30 restricted to shipping lanes
Energy usage (during and post ops)	None to 10 vessel days in field, low energy equipment reqd (eg surveys)	11- 30 vessel days in field, some short term high energy equipment required (eg crane lifts, hydraulic cutters)	>30 days in field, high energy equipment used (eg trenching or mass flow excavators, multiple lifting)
Atmospheric emissions	None to 10 vessel days in field, up to 250Te fuel consumed, low onshore odour	11- 30 vessel days in field, up to 1000te fuel consumed, short term onshore odour	>30 days in field, >1000Te fuel consumed, weeks of onshore odour
Noise (underwater and onshore)	Low levels of subsea cutting/piling, minimal onshore handling/crushing/ cleaning of materials	Some subsea cutting/piling activities, short term noise from onshore activities	High levels of subsea cutting/piling, mass onshore handling/crushing/ cleaning of materials
Accidental spills	Zero to 10l of low hydrocarbon concentrations/ chemicals or very gradual release (drips/bubbles)	11l to 10 cu m of low hydrocarbon concentrations/ chemicals	>10 cu m of low hydrocarbon concentrations/ chemicals
Smell (onshore)	No or short term smell. <10 days to process materials returned to shore	Period of smell from returned materials up to 1 month	Long term exposure to smells >1 month to process materials
Waste processing	<50T returned to shore, materials readily recyclable, no or negligible landfill	50-500T returned to shore, partially recyclable materials	>500T returned to shore, some materials non recyclable, significant landfill anticipated
Technical			
Technical challenge	Regular construction tasks involved with common procedures, track record of similar tasks, tasks relatively independent of seabed conditions	Some new task specific procedures required, tasks partly influenced by seabed conditions	Untried working practise(s), Tasks volume/complexity vary with seabed conditions
Weather sensitivity	Generally workable operations for average	Small number of tasks require reduced	Sustained periods of reduced weather

	operational downtime statistics for time of year	weather window for short periods	required to complete tasks
Risk of major project failure	Standard equipment used, equipment spares readily available	Material break up or equipment failure leads to delay of up to 3 months	Likely break up of materials during recovery, requires new mobilisation with new equipment/procedures , major equipment damage incurred, delay in excess of 3 months
Repurposing opportunity	Full length of pipeline is available for others to use for up to 5 years	Full length or partial length of pipeline is available at time of decommissioning but may corrode quickly without intervention	None or very limited length of pipeline available for reuse.
Societal			
Access to site for other users	No or minimal access restriction to site, <100m^2	Short term access restriction over a wide area during decommissioning work, permanent access restriction <1000m^2	Permanent access restrictions over a wide area >1000m^2
Community impact (onshore)	Low or positive impact (jobs without significant noise/traffic/dust/odour impact)	Short term impact during material handling (noise/traffic/ dust/odour)	Long term impact, significant volume of landfill, eyesore, sustained noise/traffic/ dust/odour
Reputation impact	Very low project visibility, no 'new' precedents, costs within acceptable benchmark ranges, all regulator & stakeholder interests addressed in CA	Minor deviations from OSPAR derogation guidelines (eg small protection structure left in situ, <20m^2 area)	High project visibility, new precedents, low or high costs, some regulator stakeholder interests not addressed. Significant media interest.
Economic			
Cost of work	Within 50% of lowest option, high certainty of cost outcome (likely lump sum work)	50-300% of lowest option, likely part lump sum part reimbursable work	>300% of lowest option, low certainty of cost outcome
Ongoing cost liabilities	Zero to £100,000	£100,000 - £500,000	>£500,000

APPENDIX C

Main Options Worksheet

Aspect	Sub Category	Timing (D-during decom work L-post decom legacy)	Complete removal (option 3a)	Partial removal (option 2b)	Full leave in situ (option 1)	Comments	Action
Safety	Risk to those offshore performing the work	D					
	Risk to other offshore users	D					
	Risk to other offshore users	L					
	Durations of diving interventions	D				1	
	Risk to those onshore	D					
	High consequence event	D					
	High consequence event	L					
Safety overall rating						2	
Safety definition level			2	1	2	3	
Environmental	Discharges	D					
	Seabed disturbance	D					
	Seabed disturbance (scour or other)	L					
	Impact on Marine Protected areas (SNS SAC)	L					
	Impact on Marine Protected areas (SNS SAC)	D					
	Impact on Marine Protected areas (GWA SPA)	L				4	
	Impact on Marine Protected areas (GWA SPA)	D				4	
	Energy useage	D					
	Energy useage	L					
	Atmospheric emissions	D					
	Atmospheric emissions	L					
	Noise (underwater and onshore)	D					
	Accidental spills	D					
	Smell (onshore)	D					
	Waste processing	D					
Environmental overall rating							
Environmental definition level			1	1	1		
Technical	Technical challenge	D					
	Weather sensitivity	D					
	Risk of major project failure	D					
	Regulatory compliance	L					
	Repurposing opportunity	L					
Technical Overall rating						5	
Technical definition level			2	1	1		
Societal	Access to site for other users	D					
	Access to site for other users	L					
	Community impact (onshore)	D					
	Impact on reputation of stakeholders	D					
	Impact on reputation of stakeholders	L				6, 7	
Societal overall rating							
Societal definition level			2	1	2		
Economic	Cost of the work	D					
	Ongoing cost liabilities	L					
Economic overall rating							
Economic definition level			3	2	2		

Comments

1. Partial removal option has higher liklihood of diving activity than full leave in situ
2. Partial removal option is considered only marginally amber (close to green)
3. Option 1 uncertainty coming from legacy high consequence event.
4. Best practise will be to use main shipping lanes.
5. Technical challenge is considered higher weighting than repurposing opportunity
6. Full removal scored amber as full removal would set an industry 1st.
7. Full leave in situ considered amber as precedent would be set to leave unburried mats in situ