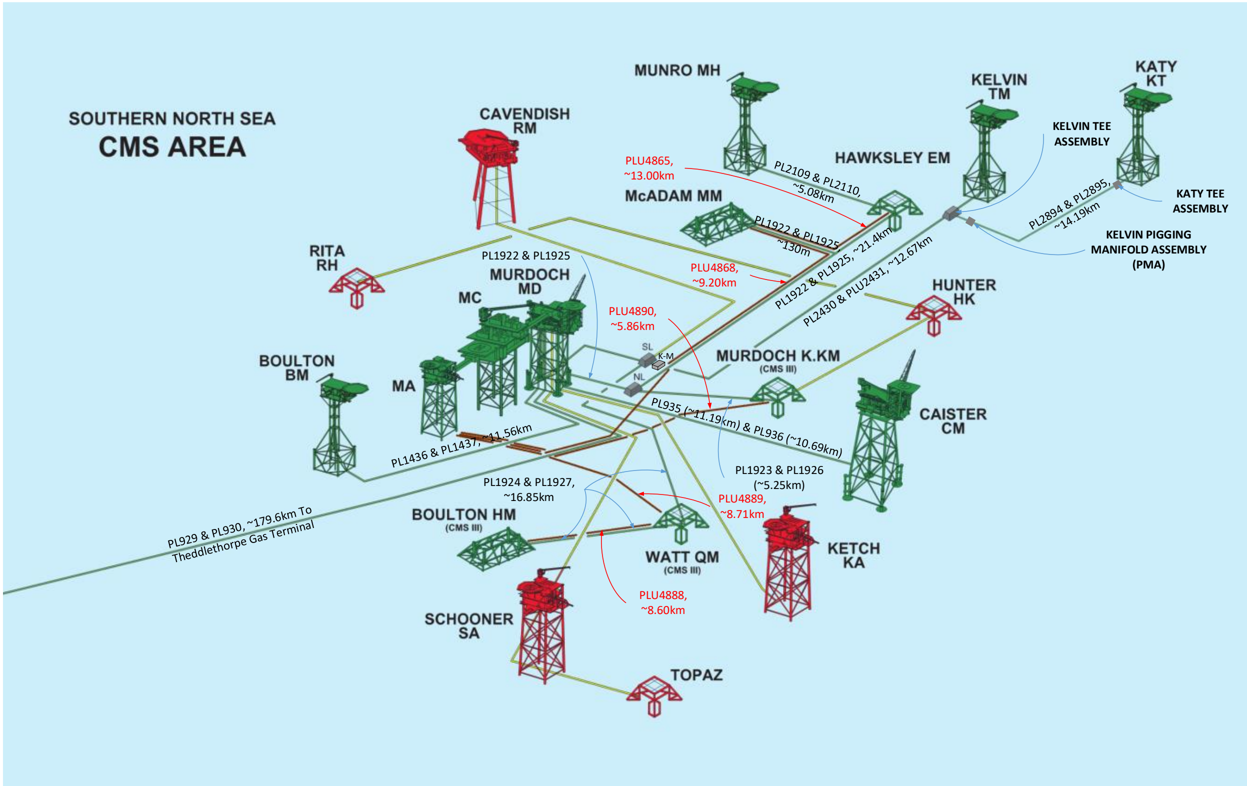

Comparative Assessment for Pipelines and Mattresses in the Caister-Murdoch System

This Comparative Assessment accompanies the Decommissioning Programmes for CDP1b, CDP2 and CDP3

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TABLE OF TERMS AND ABBREVIATIONS

Abbreviation	Explanation
~	approximately
3LPP	3-Layer Polypropylene, coating used for carbon steel pipelines and pipework
ADJL	Adjacent Seabed Level. That is, level of seabed directly over the pipeline as distinct from Mean Seabed level. Usually measured relative to LAT
ALARP	As Low As Reasonably Practicable
approaches	Refer to pipelines as they come nearer to the installations or pipeline structures
Backfill	Reburial of pipeline inside a trench
BEIS	Department for Business, Energy, and Industrial Strategy
Boulton BM	Surface installation located in UKCS block 44/21a; uses PL1436 & PL1437
Boulton HM	Subsea Installation located in UKCS block 44/22b and uses the same pipelines as Watt QM; PL1924 & PL1927
CA	Comparative Assessment (Report)
CCUS	Carbon Capture Usage & Storage
Caister CM	Surface installation located in UKCS block 44/23a; uses PL935 & PL936
Chrysaor	Chrysaor Production (UK) Limited
CMS	Caister-Murdoch System; includes Caister, Murdoch and the CMS satellite installations
Crossing	Pipeline crossing. A pipeline with a higher identification number will usually cross over the top of a pipeline with a lower identification number. Typically pipeline crossings might be protected with concrete mattresses and overlain with deposited rock
CSPS	Cavendish Subsea Pigging Skid (also known as Pigging Skid Southern Lobe, PSSL)
Cut and lift	The ‘cut and lift’ method of removing trenched and buried pipelines would involve excavating the pipelines from within the seabed and thereafter cutting the pipeline into recoverable and transportable lengths. The method is usually only viable for short pipelines.
CWC	Concrete Weight Coated
DOC	The blue line on the burial profiles shows the profile of cover. The area between the blue line and maroon line (DOL) shows the depth of sediment above the top of the pipeline. Rock can be used for DOC mitigation to increase DOC to the minimum design requirement
DOL	Pipeline trench profile; depth of lowering to top of pipe
DP	Decommissioning Programme(s)
EA	Environmental Appraisal
e.g.	*exempli gratia*, for example
EMS	Environmental Management System
ESDV	Emergency Shutdown Valve
Exposure	An exposure occurs when the ‘crown’ of a pipeline or umbilical can be seen
FBE	Fusion Bonded Epoxy
FishSAFE	The FishSAFE database contains a host of oil & gas structures, pipelines, and potential fishing hazards. This includes information and changes as the data are reported for pipelines and cables, suspended wellheads pipeline spans, surface & subsurface structures, safety zones& pipeline gates (www.fishsafe.eu)
Freespan	Refer “span”
Full removal	The full removal options for decommissioning the pipelines would involve using the ‘cut and lift’ method of removal especially for the larger pipeline and the presence of concrete weight coating and piggyback clamps on the platform approaches
GMG	Global Marine Group
Hawksley EM	Subsea Installation located in UKCS block 44/17a; uses PL1922 & PL1925
HSEQ	Health, Safety, Environment, Quality
ID	Identity (as in tabulated feature)
“, in	Inch; 25.4 millimetres

Abbreviation	Explanation
IMCA	International Marine Contractors Association
J-Lay	Method used for installing pipelines whereby pipe stalks with a length up to 6 joints are upended and welded to the seagoing pipe in a near vertical ramp. The ramp angle is chosen in such a way that it is in line with the catenary of the pipe to the seabed
Katy KT	Surface installation located in UKCS block 44/19b; uses PL2894 & PL2895
Kelvin PMA	Kelvin Pigging Manifold Assembly
Kelvin STA	Kelvin Subsea Tee Assembly
Kelvin TM	Surface installation located in UKCS block 44/18 & 44/23b; uses PL2430 & PLU2431
kg	kilogram
km	kilometre
K-MSPS	Kelvin/Murdoch Subsea Pigging Skid (PL2430 & PLU2431 upstream of PSSL)
KP	Kilometre Point, usually measured from point of origin, the start of the pipeline at the pipeline flange. A negative KP means that the feature lies between the riser flange and the start of the pipeline
KPMA	Kelvin Pigging Manifold Assembly (on PL2894 & PL295 upstream of Kelvin Subsea Tee Assembly (KSTA)
KSTA	Kelvin Subsea Tee Assembly (on final approach to Kelvin TM, comingles gas and MeOH associated with Katy KT)
LAT	Lowest Astronomical Tide
Leave *in situ*	Leave *in situ* for pipelines would involve leaving trenched and buried pipelines in situ and risk assessing any exposures and spans
m	metres
MBES	Multi-Beam Echo Sounder. A type of sonar used to map the seabed. Attached to the vessel rather than towed. Uses narrower directed sonar beams and is often used in conjunction with Side Scan Sonar (SSS)
McAdam MM	Subsea Installation located in UKCS block 44/17c and uses the same pipelines as Hawksley EM; PL1922 & PL1925
MeOH	Methanol
MFE	Mass Flow Excavator provides a method of clearing sediment material from buried objects
MLWM	Mean Low Water Mark
MPA	Marine Protected Area
MSB	Mean Seabed, Usually measured relative to LAT
Murdoch Installation	Comprises Murdoch MA, Murdoch MC and Murdoch MD that are all bridge linked, located in UKCS Block 44/22a
Murdoch MA	Murdoch Accommodation installation; comprises temporary refuges and helideck
Murdoch MC	Murdoch Compression installation; comprises process facilities for separation and compression as well as accommodation installed to support decommissioning activities
Murdoch MD	Murdoch Drilling Installation containing risers and wellheads; source and destination for PL929 and PL930 respectively
Murdoch K.KM	Subsea Installation located in UKCS block 44/22a and uses PL1923 & PL1926
n/a	Not Applicable
N,S,E,W	North, South, East & West
NDR	National Data Repository (https://ndr.ogauthority.co.uk)
NEO	Neoprene (rubber)
NFFO	National Federation of Fishermen's Organisations
NIFPO	Northern Ireland Fish Producers Organisation
NORM	Naturally Occurring Radioactive Material
NPT	Non-productive time
NTS	Not to scale (used on illustrations and schematics)
NUI	Normally Unattended Installation

Abbreviation	Explanation
O/A	Overall
OGA	Oil and Gas Authority
OGUK	Oil and Gas United Kingdom
OPRED	Offshore Petroleum Regulator for Environment and Decommissioning
Order of Magnitude	Size difference by factor of 10: one (10^1) means 10-times, two (10^2) means 100-times difference
Partial removal	The partial removal decommissioning option for pipelines would involve excavating trenched and buried pipelines local to the exposed ends of the pipeline and thereafter effecting removal of the section of pipeline using the 'cut and lift' method. Typically, the excavated locations and cut pipeline ends in the seabed may need to be remediated in some way, either by back-filling the excavated material or by depositing rock
PCP	Polychloroprene
Piggybacked	Clamped or connected to another pipeline along part or all of its length
Pipeline	Pipeline or umbilical
Pipeline crossing	A pipeline with a higher identification number will usually cross over the top of a pipeline with a lower identification number. Typically, pipeline crossings might be protected with concrete mattresses and overlain with deposited rock
Pipeline end	Pipeline to pipespool connection; either a flanged or welded joint
PL	Pipeline identification numbers
Platform	Installation, typically comprising topsides and jacket
PMA	Pigging Manifold Assembly
Post-trenching	Post-trenching involves cutting, ploughing, or jetting a trench underneath the pipeline, such that it is lowered into the seabed. Often referred to as re-trenching
PSNL	Pigging Skid Northern Lobe; used by PL1922 & PL1925, PL1923 & PL1926
PSSL	Pigging Skid Southern Lobe, also known as the Cavendish Subsea Pigging Skid. Used by PL1924 & PL1927, PL2430 & PLU2431
PWA	Pipeline Works Authorisation
Q1, Q2, Q3, Q4	Quarter 1, Quarter 2, Quarter 3, or Quarter 4 of any given year
Qualitative	Result determined using judgement and use of risk and impact matrices
Quantitative	Result determined using numerical data and by calculation
Remediation	For the purposes of this document remediation can mean one of, or a combination of the following: post-trenching, removal of exposures and spans, deposition of additional rock
Reportable span	A reportable span is a significant span which meets set criteria (FishSAFE criteria) of height above the seabed and span length (10m long x 0.8m high)
Reel lay	Using the reel-lay method a flexible pipeline or small diameter rigid pipeline is installed from a large reel mounted on a pipelay barge. A pipe is spooled from a drum (reel) straightened with tension applied and laid over a ramp to the seabed
Riser	Pipe that connects the pipeline to the topsides' pipework
Risk	Threat or opportunity; in this report the word "risk" is used to describe a "threat"
ROV	Remotely Operated Vehicle
ROVSV	Remotely Operated Vehicle Support Vessel
SAC	Special Area of Conservation
Scour	Natural degradation of seabed in one area and its aggradation in another caused by local flow of seawater
S-lay	A pipelay method whereby sections of pipe are welded together on a horizontal deck, their transition down to seabed taking the form of an elongated "S"
SFF	Scottish Fishermen's Federation
Shell	Shell U.K. Limited
SNS	Southern North Sea
Span	Sometimes referred to as a 'freespan'. Similar to an exposure except that the whole of the section of pipeline is visible above the seabed rather than just part of it. Once the

Abbreviation	Explanation
	height and length dimensions meet or exceed certain criteria the span becomes a reportable span
Splash Zone	The splash zone is the section of a jacket that is intermittently in or out of seawater during its service life
SSS	Side Scan Sonar. Category of sonar system that is used to create a high-resolution image of large areas of the sea floor; scans horizontally Port and Starboard while being towed
SSV	Subsea Support Vessel
Surface installation	Refer “Platform”
Tampnet	Formerly NorSea Com 1 Fibre-optic Cable, connecting Draupner, Ula, Ekofosk, Valhal and Murdoch platforms to Lowestoft in Suffolk, UK and Kårstø, Rogaland, Norway
Te	Tonne(s)
Tee	Pipeline junction, usually includes a valve assembly as well as a protection structure
Template	Protection structure that typically contains wellheads, pipe manifolds, valves, and pipework
TGT	Theddlethorpe Gas Terminal (WGS84 Degrees: 53.362438° N .237783° E)
TOP	Top of Pipe. Usually measured relative to LAT.
Trench	Excavation or depression in the seabed to accommodate pipeline or umbilical
TSA	Thermal Sprayed Aluminium
UHB	Upheaval buckling
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
UM	Umbilical number referenced in some Chrysaor documentation
Umbilical	Flexible pipeline manufactured of various materials including steel and plastics typically used to send electrical power, communication signals, chemicals and hydraulic fluid to a manifold or wellhead. An umbilical pipeline will include cables and tubes that are covered with an outer sheath to protect them from damage
Uraduct	Protective sleeve on fibre-optic cable
UTM	Universal Transverse Mercator (Coordinate System)
WGS84	World Geodetic System 84 is the reference coordinate system used by the Global Positioning System
WHPS	Wellhead Protection Structure
x	Number of (e.g. 16x = 16 in Number)

COMPARATIVE ASSESSMENT COLOUR SCHEME

Assessment	Description
Broadly Acceptable / Low & least preferred[1]	Risks broadly acceptable but controls shall be subject to continuous improvement through the implementation of the HSEQ Management System and considering changes such as technology improvements; performance in other 'broadly acceptable' options marginally better.
Broadly Acceptable / Low & in-between least & most preferred[1]	As above, but performance of this option is marginally better or marginally worse than others.
Broadly Acceptable / Low & most preferred[1]	As above but performance in other 'broadly acceptable' options marginally worse.
Tolerable / Medium Non-preferred[1]	Risks are tolerable and managed to ALARP. Controls and measures to reduce risks to ALARP require identification, documentation, and approval by responsible leader.
Intolerable / High Not acceptable[1]	Impacts are intolerable. Controls and measures to reduce impact to ALARP (at least to Medium) and require identification, documentation, implementation, and approval.

Table 1.1.1: Comparative Assessment colour scheme

[1] The colour of this highlighted cell is used in the assessment tables in Appendix 5, Appendix 6, Appendix 6, Appendix 7 and Appendix 8.

1 Executive Summary

1.1 Overview

A comparative assessment of the pipelines or umbilicals is a key consideration within the Decommissioning Programmes submitted to the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED). The Caister Murdoch System (CMS) are situated in Block 44 of the United Kingdom Continental Shelf. With the exception of the trunklines that extend to the Theddlethorpe Gas Terminal (TGT), the CMS installations and associated pipeline infrastructure are located within the southern part of the Dogger Bank Special Area of Conservation. The Dogger Bank SAC covers an area 12,331km[2].

The Murdoch installation is located in UKCS block 44/22a and comprises three bridge-linked platforms MA, MC, and MD, although only MA and MD support the pipeline and umbilical infrastructure. MA provides the electrohydraulic power for the umbilicals, while Murdoch MD used to receive gas and export it to TGT while it also imported methanol from TGT and distributed it to the various satellites and beyond. MD was built and installed in 1993, MC was built and installed in 1996 and MA was built and installed in 2002. First production was achieved in 1993 and production ceased in 2018.

The surface installation wells that are tied back to Murdoch installation (44/22a) include Boulton BM (44/21a), Caister CM (44/23a), Katy KT (44/19b), Kelvin TM (44/18 & 44/23b), Munro MH (44/17b) , The subsea wells that are tied back to Murdoch include Murdoch K (KM) (44/22a), McAdam (MM) (44/17c), Hawksley (EM) (44/17a), Boulton H (HM) (44/22b) and Watt (QM) (44/22b). Collectively this is called the CMS.

The pipelines are all now shutdown, but gas used to be exported from the CMS via Murdoch MD to TGT using the 26" trunk gas pipeline PL929. PL930 is a 4" methanol pipeline originating from TGT and tied into Murdoch MD which used to supply to the various satellite installations using 3" pipelines. It lies in a separate trench to PL929 although it crosses over PL929 about 20km from mean low water mark (MLWM). Most of the smaller 3" pipelines are piggybacked to the larger gas pipeline from each facility. The exception to this is the 3" Caister pipeline that was buried in a separate trench to its sister 16" gas pipeline.

There are pipelines from other installations such as Cavendish RM, Hunter HK, Rita RH, Ketch KA, Schooner SA that also tie into Murdoch, but these are subject to comparative assessments and decommissioning programmes being prepared by others and are therefore out of scope. All these third-party decommissioning programmes are available on the regulator's website[2].

Murdoch trunklines

Murdoch pipelines: PL929 & PL930. All gas collected at Murdoch MD from the various satellites was exported to TGT using PL929, a 26" trunkline ~179.6 km long. TGT also provided CMS with MeOH using PL930, a 4" trunkline ~179.6km long. Apart from the approach to Murdoch and from KP20 to MLWM the pipelines lie in separate trenches.

Caister pipelines

Caister pipelines: PL935 & PL936. Caister CM comprises a single surface installation that is tied back to Murdoch MD using PL935 (16" gas, ~11.2km long) and PL936 (3" methanol, ~10.7km long). Apart from the approaches where they are piggybacked the pipelines lie in separate trenches.

CMS pipelines (i.e. all except Murdoch & Caister)

CMS Pipelines: PL1311 & PL1312 (risers), PL1436 & PL1437, PL1922 & PL1925, PL1923 & PL1926, PL1924 & PL1927, PL2109 & PL2110, PL2430 & PLU2431[3], PL2894 & PL2895, PLU4685, PLU4686, PLU4888, PLU4889, and PLU4890.

The elements of CMS considered within this report comprise the pipelines that service four surface installations and five subsea installations. All of these are tied back in some way to Murdoch using a total of fourteen pipelines and five umbilicals ranging from 5.2km to 21.6km in length. Some of the pipelines from the satellites are interspersed with tee and pigging manifold protection structures. Seven pairs of pipelines are piggybacked for the majority of their length. All the pipelines and umbilicals are trenched and buried except for the

[2] https://www.gov.uk/guidance/oil-and-gas-decommissioning-of-offshore-installations-and-pipelines;
[3] Although designated a PLU number this is a 3" steel pipeline.

approaches which are more often than not buried under a mixture of fronded mattresses with concrete bases and concrete mattresses. The trenches for all but two of the pipelines were mechanically backfilled. The Munro MH piggybacked pipelines PL2109 & PL2110 were furnished with 'spoilers' and were designed to self-bury.

1.2 Mattresses & Grout Bags

Several hundred fronded and concrete mattresses were installed to protect the pipelines and umbilicals on the approaches and to protect the installations, pipeline tee and pigging manifold assembly protection structures from scour. In recognition that most lie with the Dogger Bank Special Area of Conservation (SAC), these were also subject to a comparative assessment, except for a small number of concrete mattresses that are buried under rock. It is assumed that these would remain *in situ*.

Mattress decommissioning options

Two decommissioning options are considered for the removal of fronded and concrete mattresses. These are:

- **Complete removal** – This would involve the complete removal of the mattresses by whatever means would be most practicable and acceptable from a technical perspective;
- **Leave *in situ*** – This would involve leaving the mattresses *in situ* with no remedial works but carrying out a post-decommissioning survey possibly followed by future surveys using a risk-based approach.

Most of the mattresses are associated with the approaches, and should they be removed it is assumed that any pipelines or umbilicals underneath them would also be removed. There were some mattresses installed to protect structures or at pipeline crossings. A small number may be buried under deposited rock and an implicit assumption of this assessment is that mattresses buried under rock will be left *in situ*.

Grout bags

The intention would be to leave all fully buried grout bags *in situ* when decommissioning the pipelines, but should they be disturbed as part of decommissioning operations or should they be exposed, they will be removed. Although several different methods could theoretically be used to remove the grout bags, from a practical perspective it is not known whether the bag material has remained intact.

Mattress assessment

Technically, complete removal of the fronded and concrete mattresses would be achievable. Complications could arise where they are buried and not visible but using a mass flow excavator there should be no issues in displacing any overlying sediment. With planning the recovery works could be carried out using remotely operated equipment subsea and could be done with minimal manual intervention on deck, so from a health and safety perspective the risk to project personnel should be manageable and could be considered low. There could be complications with recovering the fronded mattresses that are anchored because the synthetic base material would likely rip as it is being recovered, but this would also be achievable. However, to recover the mattresses at all would pose more of a threat to offshore and onshore project personnel than leaving the mattresses *in situ*.

The onshore threat to safety would increase with the quantity of material being handled, and the expectation would likely be that using mechanised equipment such concerns would be largely mitigated.

Should the mattresses be buried[4], both complete removal and leave *in situ* options would leave the seabed free of snagging hazards. However, by completely removing the mattresses the risk of snagging is removed in perpetuity so the complete removal option would result in lower residual risks to mariners and other users of the sea. The inference here is that as long as the mattresses remain *in situ* there would be the possibility that they become exposed. The deposition of any new rock at cut pipeline ends, for example, could play a part in creating unpredictable local scour patterns and might be discouraged on this basis.

If it could be demonstrated that the mattresses are fully buried under sediment, there would likely be no increased snagging risk associated with the leave *in situ* option. Surveys would need to be done in future, however, in order to verify that the risk of snagging would remain low.

[4] Burial assumes that the edges of the mattresses and most of the fronds are buried under sediment, although the tops of the fronds may be visible.

Energy requirements and emissions to air would be such that there would be a significant difference between the options. However, the gap between complete removal and leave *in situ* would reduce when indirect energy requirements such as that required for replacement of unrecovered material are accounted for.

Conservatively if it could be assumed that the removal of each mattress would affect a 5m wide perimeter around each[5], the overall area of seabed affected would equate to 0.197km^2. Remembering that the seabed area of the Dogger Bank SAC is 12,331km^2, this would mean that 0.0016% of the Dogger Bank SAC seabed area would be directly impacted by the disturbance created by the mattress removal activities. That is, the area affected would be negligible. Decommissioning activities associated with PL929 and PL930 would have a negligible effect on the conservation objectives of the Southern North Sea (SNS) SAC.

Should the mattresses be left *in situ*, the area affected would be much less than this albeit permanently. The area impacted by leaving the mattresses *in situ* would equate to ~0.018km^2. This would equate to 0.00015% of the area covered by the Dogger Bank SAC, but this would be classed as a permanent 'disturbance', even though the mattresses have been in position for several years and could now be considered part of the seabed. Over time it can be expected that small quantities of synthetic materials would be released into the water column as the fronds and as the anchored fronded mattress bases eventually degrade. The area disturbed would be an order of magnitude smaller than that disturbed by removal activities, albeit permanently. In percentage terms neither the temporary nor permanently affected areas would be significant.

Should the mattresses be completely removed experience would suggest that all the recovered materials (~7,060Te) would be recycled either as base material or in the case of the synthetic materials used for the fronds, anchored frond bases and polypropylene rope the materials could be used for recovery as energy. This has been done before.

From societal perspective, offshore recovery operations would have little impact on commercial fishing activities with much of the work being required in the 500m zones of the various installations and in the Murdoch 500m safety zone. It is unlikely that the recovery operations would result in new jobs, but rather would result in an extension to existing jobs.

For the pipeline and umbilical ends on the approaches, the costs for completely removing the mattresses and underlying pipelines and umbilicals would be an order of magnitude greater than for leave *in situ*. The costs for removing the mattresses dedicated to all the subsea installations (Boulton HM, Hawksley EM, McAdam MM, Murdoch K.KM, and Watt QM) and two of the pipeline related protection structures (Kelvin Subsea Tee Assembly, and PSNL) would be less than an order of magnitude greater for complete removal than for leave *in situ*. The costs for removing the mattresses around the Kelvin Pigging Manifold Assembly and Katy Tee would cost more than an order of magnitude than leave *in situ* because of the quantity combined with mass of mattress material that would need to be recovered. Note that for the purposes of the assessment the mattresses around PSSL and the Kelvin-Murdoch Subsea Pigging Skid are allocated to the pipelines on the approaches rather than the PSSL protection structure itself and so are not categorised as being 'dedicated' to the structures.

However, the difference in cost would likely be reduced by the need to recover those mattresses that would have been disturbed anyway as a result of the removal of installations, tee protection structures and pigging manifold structures, as it is likely that an MFE would be used to clear away local sediment exposing further adjacent mattresses. This means that the cost by difference might not be as great as portrayed in this assessment.

Further, leave *in situ* costs include incremental costs for carrying out 1x post decommissioning survey and 3x legacy surveys of the short sections of mattresses and any underlying pipelines and umbilicals left *in situ*. Ordinarily these costs would be borne as part of the pipeline surveys, but there could be a scenario where just the pipeline ends and overlying mattresses would need to be surveyed, with the burial status of the remaining pipelines being such that they would no longer be such a requirement.

In conclusion the recommendation is that the mattresses and where applicable the underlying pipelines and umbilicals on the approaches and adjacent to the subsea installations and pipeline protection structures should be fully removed.

[5] The calculation is conservative as most of the mattresses are laid side-by-side rather than individually.

1.3 Pipelines and umbilicals

Decommissioning options and pipeline groups

For the purposes of the assessment the pipelines and umbilicals were split into three groups:

Group 1: Individual pipelines such as PL929, PL930, PL935 and PL936 laid in their own trench but piggybacked on the approaches, possibly with multiple exposures (PL929 and possibly PL930 only);

Group 2: These include all the CMS pipelines referred to earlier except PL1311 & PL1312[6]. Excepting PL1311 and PL1312 that are platform risers, these are all piggybacked pipelines with good depth of cover although exposures have only been found along PL2109 & PL2110;

Group 3: These include all the umbilicals. Although PLU4685 has exhibited short exposures and freespans (total length ~59m)[7] and spans in historical surveys the umbilicals otherwise show good depth of cover, with no exposures.

Three decommissioning options are considered for the pipelines and umbilicals:

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

In all instances these options exclude the surface laid pipeline or umbilical ends on the approaches which are assessed separately as part of the mattress comparative assessment.

There are no useable survey data for PL930. Therefore, for the purposes of this assessment and given the bathymetry of the seabed it is assumed that PL930 would exhibit the same burial characteristics as PL929. PL929 was originally trenched to a minimum between 0.5m and 0.7m to top of pipe below seabed. By comparison, according to the as-built data PL930 was trenched to a minimum 1.0m below seabed to top of pipe. This assumption is considered conservative and appropriate, but the burial status of PL930 will need to be confirmed by survey.

There are no useable survey data for PL936. Therefore, for the purposes of this assessment and given the bathymetry of the seabed it is assumed that PL936 would exhibit the same burial characteristics as PL935. PL935 was originally trenched to a minimum 0.5m to top of pipe below seabed, by comparison, PL936 was trenched to a minimum 1.0m below seabed. This assumption is considered conservative and appropriate, but the burial status of PL936 will need to be confirmed by survey.

Pipeline and umbilical comparative assessment

The comparative assessment was undertaken with a focus on the decommissioning options for the various mattresses and pipelines associated with the Caister-Murdoch System developments. A general comparative assessment was carried out for the mattresses, while the pipelines were split into three groups as indicated in Table 4.2.1. Pipeline groups 1 & 2 were assessed for the complete removal, partial removal and leave *in situ* decommissioning options, while pipeline group 3 (umbilicals) was assessed for complete removal, partial removal and leave *in situ*, noting that for PLU4685 there is a short exposure on the final approach and a few short exposures or possibly freespans between KP0.222 and KP0.280 (measured from Hawksley) that would need to be dealt with.

Except for approaches all the individual pipelines are trenched and buried with historical survey data suggesting that some exposures can be expected for two individual pipelines (PL929 & PL930) one pair of

[6] PL1311 and PL1312 are platform risers and will be removed along with the Murdoch MD jacket;
[7] 1x exposure ~7m long was found at KP0.028, and 3x freespans (3m, 4.5m, and ~11.4m) total ~19m long, and 1x exposure (33m long) were observed between KP0.222 and ~KP0.280 near Hawksley.

piggybacked pipelines (PL2109 & PL2110) and one umbilical (PLU4685). These are candidates for the partial removal option although classing PLU4685 as a partial removal candidate is debateable.

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

For the group 1 & 2 pipelines the assessment found that for the complete removal option the technical feasibility and short-term safety risk to project personnel both offshore and onshore would be 'tolerable' and non-preferred rather than broadly acceptable or preferred. For partial removal, the technical feasibility and short-term safety risk to project personnel both offshore and onshore would be considered tolerable and non-preferred for group 1 and broadly acceptable but non-preferred for group 2.

For group 3 umbilicals the assessment found that for the complete removal option the technical feasibility and short-term safety risk to offshore project personnel would be considered broadly acceptable but non-preferred. For onshore personnel health and safety hazards associated with removing umbilicals from reels was considered to be tolerable and non-preferred rather than broadly acceptable. By inspection removal of the short exposures and/or spans between KP222 and KP0.280 would be acceptable.

Many of the health and safety hazards described herein are common to all decommissioning options and would increase with amount of material removed. In the short-term the leave *in situ* option – which might include removal of the pipeline ends[8], would give rise to lower risks to project personnel and would be the preferred option.

Differences are found between the safety assessment with more work required offshore and onshore for complete removal and where applicable partial removal options rather than leave *in situ* and consequently higher safety risk. Conversely there would be lower safety risks to mariners arising from complete removal than either partial removal or leave *in situ* because the pipelines would no longer be present as a potential snag hazard. However, the assessment concluded that even with the pipelines remaining *in situ* the snagging risk posed to fishermen and other users of the sea would remain low on the basis that the pipelines would remain mostly buried - albeit with exposures, and the situation would be no different to what it is now outside of the 500m zones.

Should the deposition of rock be the decommissioning option of choice for dealing with exposures, the amount of seabed sediment affected would be proportional to the lengths of pipeline being remediated. Clearly the area impacted would be much less than that effected by complete removal, but the deposition of hard strata such as rock would have a permanent effect on the seabed and could alter the topography, movement of the sediment and cause unpredictable scour patterns. This also means that the partial removal option should aim to minimise the number of cut pipeline ends requiring the deposition of rock for burial and protection.

Post-trenching may work in the short-term for partial removal either to rebury exposures or to rebury cut pipeline ends, but with the movement of the sediment it would not be certain that the cut pipeline ends would not reappear.

From an environmental perspective, in the short-term lower risks and impacts would be incurred for the leave *in situ* option than for either the complete removal or partial removal options but higher risks and impacts would be incurred over the longer-term. Pipeline and mattress decommissioning activities would have a negligible effect on the conservation objectives of the Dogger Bank and SNS SACs.

The societal assessments showed that complete removal would be marginally beneficial because of the continuation of employment due to extended vessel use and onshore waste management activities, although in the short-term fishing activities might proportionally be disrupted as decommissioning activities increase. Conversely, fishing activities could be affected by legacy pipeline surveys that would be required for both the partial removal and leave *in situ* options.

For all pipelines, in the short-term the complete removal option would be more than the partial removal option, and an order of magnitude more than the leave *in situ* option. The partial removal option would also cost more than the leave *in situ* option in the short-term, but once completed no costs would be incurred for future surveys. The leave *in situ* option assumes that the surface laid pipeline ends, and associated mattresses would be removed, although this may not have been the recommendation of this comparative assessment. This means that should the pipeline ends be left *in situ* the by difference cost between the options would be more marked.

[8] The pipeline and umbilical ends being subject to a separate assessment dealt with under mattresses.

By inspection, the partial removal option for PLU4685 that includes removal of a total length ~52m of exposures (~19m long) and exposure (~33m long) between KP0.222 and ~KP0.280 would be acceptable from a cost perspective and preferred to complete removal.

For the four other umbilicals the difference in cost for removal would be more than the leave *in situ* option, but less than an order of magnitude more in the short-term, but once completed no more costs would be incurred for future umbilical surveys. The leave *in situ* option assumes that the surface laid umbilical ends and associated mattresses would be removed, irrespective of the recommendation of this comparative assessment. This means that should the umbilical ends be left *in situ* the by difference cost between the options would be more marked.

Further, leave *in situ* costs include incremental costs for carrying out 1x post decommissioning survey and 3x legacy surveys of the short sections of mattresses and any underlying pipelines and umbilicals left *in situ*. Ordinarily these costs would be borne as part of the pipeline surveys, but there could be a scenario where mattress status surveys would be required, but the burial and stability of the pipelines or umbilicals being left *in situ* is such that surveys are no longer required.

Summary of pipeline, umbilical and mattress decommissioning proposals

The comparative assessment for group 1 (individual pipelines PL929, PL930, PL935 & PL936) recommends that the pipelines should mostly be left *in situ* with no remediation.

The comparative assessment for group 2 pipelines (the piggybacked pipelines) concludes that most of the pipelines should be left *in situ* as they would seem to be sufficiently buried and no remedial work should be required. The exception to this are the Munro MH (PL2109 & PL2110) pipelines for which the recommended decommissioning option is partial removal as this should remove the potential risk of snagging hazards in perpetuity.

The comparative assessment for group 3 (all the umbilicals) recommends that the umbilicals should mostly be left *in situ* with no remediation. The exception is that a short section of PLU4685 ~52m long with should be removed with the cut ends remediated by the deposition of a small quantity of rock added to the existing rock. The remaining ~8m of exposed umbilical would be removed along with the end section on the final approach to Hawksley EM.

For the mattresses, there is little to choose between the options but after discussion with various stakeholders the recommendation is that the mattresses that act as protection and stabilisation on the approaches should be removed along with the underlying pipelines and umbilicals. Mattresses that are buried under deposited rock should be left *in situ*. Mattresses outside the 500m zones and that act as protection and stabilisation for third-party infrastructure for example at pipeline crossings should be left *in situ*.

As a general philosophy on the approaches the surface laid pipelines and umbilicals will be cut where they enter burial under rock to minimise the additional deposition of rock requirements. Note that to minimise the requirement for additional rock, rock from adjacent existing rock would be used to bury the cut ends supplemented with small quantities of additional rock as required. The requirement for additional rock is assessed in the Environmental Appraisal [10] that accompanies the Decommissioning Programmes.

Should the pipelines or umbilicals enter burial directly into the seabed local excavations would be performed and be mechanically backfilled if possible, otherwise rock would be placed on the cut pipeline ends.

This approach minimises the number of potential snagging hazards posed by cut pipeline or umbilical ends and reduces the requirement for deposition of additional rock which could have a lasting effect on the typography of the seabed and scour patterns.

Although removal of the pipeline ends would initially lead to disturbance to the Dogger Bank SAC this approach should satisfy the conservation objectives of the SAC and reduce the continued presence of hard substrate in the area.

Finally, should they remain buried the mattresses at the separation points for PL929 & PL930 (at ~KP4.8, KP20, and KP KP180.4 with the KP originating at MLWM near TGT) and for PL935 & PL936 (at ~KP0.493 and ~KP10.485 with the KP originating at Murdoch MD) should be left *in situ*, otherwise they should be removed. Removal of these will be addressed as contingency impacts in the Environmental Appraisal [10].

A summary of the recommendations for decommissioning of the pipeline and umbilicals in this comparative assessment is presented in Table 1.3.1 below.

Asset	Pipeline ID	Partial removal	Leave *in situ*
Murdoch MD	PL929, PL930		X
Caister CM	PL935, PL936		X
Boulton BM	PL1436 & PL1437		X
Hawksley EM & McAdam MM	PL1922 & PL1925		X
Murdoch K.KM	PL1923 & PL1926		X
Boulton HM	PL1924 & PL1927		X
Munro MH	PL2109 & PL2110	X (1.5km)	
Kelvin TM	PL2430 & PLU2431		X
Katy KT	PL2894 & PL2895		X
Hawksley EM	PLU4685	X (52m)	
McAdam MM	PLU4686		X
Boulton HM	PLU4888		X
Watt QM	PLU4889		X
Murdoch K.KM	PLU4890		X

NOTE:

1. PL929 and PL930 were ‘candidates’ for partial removal rather than recommended for partial removal whereas it is recommended that PL2109 & PL2109 and PLU4685 be partially removed. The dimensions presented in the partial removal column exclude the length of any exposures or spans on the approaches;
2. Pipelines and umbilicals on the approaches will be fully removed along with the overlying mattresses;
3. Mattresses that protect and stabilise the subsea installations including Murdoch K.KM, McAdam MM, Hawksley EM, Boulton HM and Watt QM will be completely removed;
4. Mattresses that protect and stabilise the Katy Tee Protection Structure, The Kelvin/Murdoch Subsea Pigging Skid, Kelvin PMA, Kelvin STA, PSNL and PSSL will be completely removed;
5. The intention would be to leave all fully buried grout bags *in situ* when decommissioning the pipelines, but should they be exposed or disturbed as part of decommissioning operations they will be removed.

Table 1.3.1: Pipeline decommissioning summary

2 Introduction

2.1 Overview

The Murdoch installation and Caister Murdoch System satellite installations are situated in Block 44 of the United Kingdom Continental Shelf. The Murdoch installation is located in UKCS block 44/22a and comprises three bridge-linked platforms MA, MC, and MD, although only MA and MD supported the pipeline and umbilical infrastructure. MA provided the electrohydraulic power for the umbilicals, while Murdoch MD received gas and exported it to Theddlethorpe while it also imported methanol from Theddlethorpe and distributed it. to the various satellites. MD was built and installed in 1993, MC was built and installed in 1996 and MA was built and installed in 2002. Initial production was achieved 1993 with fields being added up until 2013. Production ceased in 2018.

Boulton BM (44/21a), Caister CM (44/23a), Katy KT (44/19b), Kelvin TM (44/18 & 44/23b), Munro MH (44/17b), and the subsea wells that are tied back to Murdoch include Murdoch K (KM) (44/22a), McAdam (MM) (44/17c), Hawksley (EM) (44/17a), Boulton H (HM) (44/22b) and Watt (QM) (44/22b). Collectively this is called the Caister Murdoch System.

The pipelines are all now shutdown, but gas used to be exported from CMS via Murdoch MD to the Theddlethorpe Gas Terminal using the 26” trunk gas pipeline PL929. Methanol to the various satellite installations via PL930 the 4” methanol pipeline originating from TGT and tied into Murdoch MD.

There are pipelines from other installations (e.g., Cavendish RM, Hunter HK, Rita RH, Ketch KA, Schooner SA) that also tied into Murdoch, but these are subject to comparative assessments and decommissioning programmes that have been prepared by others and are therefore out of scope.

2.2 CMS area layout

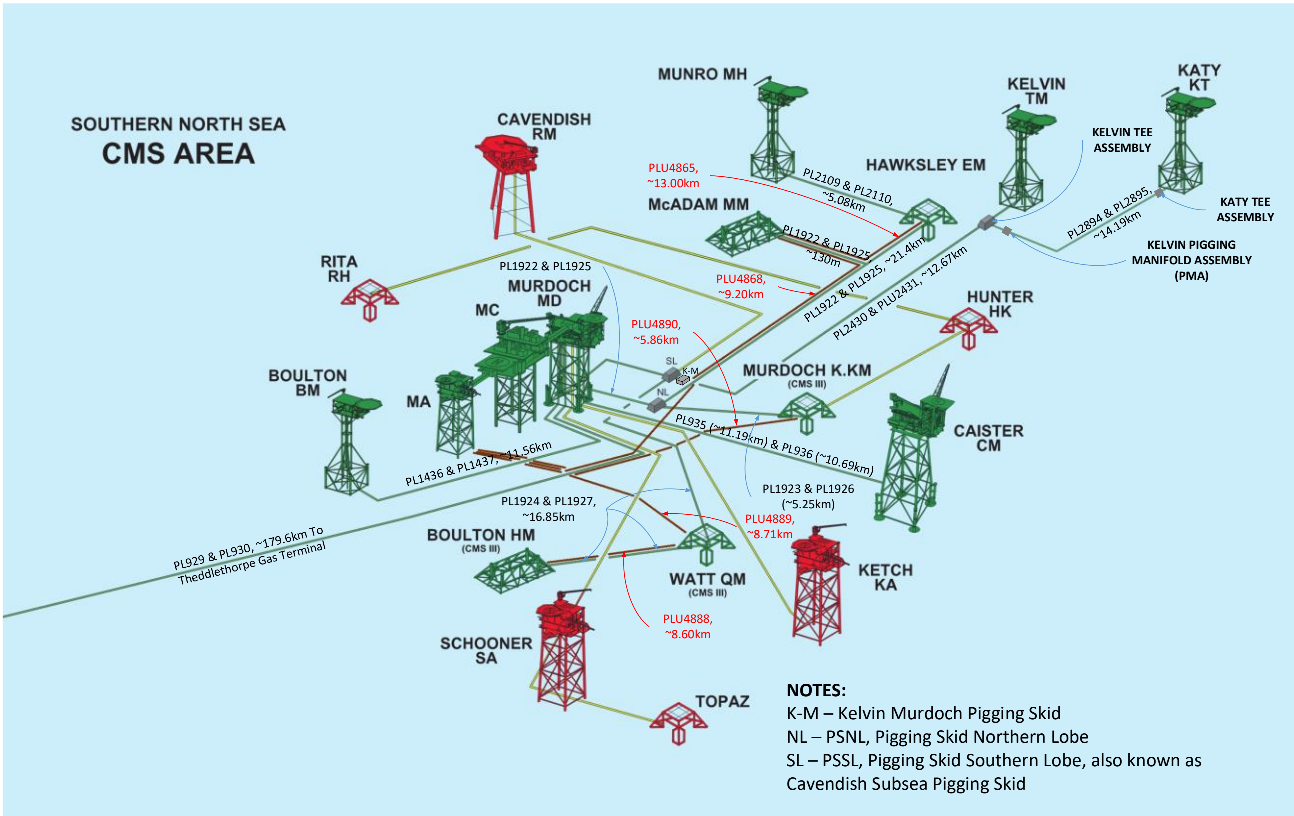


Figure 2.2.1: Southern North Sea – CMS area schematic

Excluding Cavendish RM, Ketch KA, Schooner SA the surface installations that are tied back to Murdoch installation include those listed in Table 2.2.1.

FACILITY	IMPORT ROUTE	TYPE	UKCS BLOCK	FIRST PRODUCTION
Murdoch MA	N/A	4-leg piled steel tower	44/22a	N/A
Murdoch MC	N/A	4-leg conventional steel jacket	44/22a	N/A
Murdoch MD	N/A	4-leg conventional steel jacket	44/22a	October 1993
Boulton BM	DIRECT	4-leg piled steel tower	44/21a	January 1988
Caister CM	DIRECT	4-leg conventional steel jacket	44/23a	November 1993
Katy KT	VIA Kelvin STA	3-leg piled steel tower	44/19b	January 2013
Kelvin TM	VIA PSSL	3-leg piled steel tower	44/18 & 44/23b	November 2007
Munro MH	VIA Hawksley EM	3-leg piled steel tower	44/17b	August 2005

Table 2.2.1: Surface installations tied back to Murdoch MD

The subsea installations that are tied back to Murdoch installation are listed in Table 2.2.1

FACILITY	IMPORT ROUTE	TYPE	UKCS BLOCK	FIRST PRODUCTION
Boulton HM	VIA Watt QM	Two-slot WHPS	44/22b	March 2004
Hawksley EM	VIA McAdam MM	WHPS	44/17a	September 2002
McAdam MM	VIA PSSL	Two-slot WHPS	44/17c	October 2005
Murdoch K.KM[1]	VIA PSNL	WHPS	44/22a	November 2002
Watt QM	VIA PSSL	WHPS	44/22b	October 2005
NOTE 1. Although Hunter HK and Rita RH are tied back to Murdoch K.KM they are out of scope.				

Table 2.2.2: Subsea installations tied back to Murdoch MA and MD

A summary of the pipelines is presented in Table 2.2.4 and Table 2.2.3 below.

PIPELINE ID[1]	SIZE (in, mm)	FROM / TO	LENGTH (km)[2]	PIPELINE MEMBERSHIP
PL935	16in (CTE, CWC)	Caister CM / Murdoch MD	11.19	Caister CM
PL936	3in (FBE)	Murdoch MD / Caister CM	10.69	Caister CM
PL1311	10in (NEO/TSA)	Riser tie in flange to ESDV Murdoch MD	0.75	Boulton BM
PL1312	3in (NEO/TSA)	ESDV Murdoch MD to subsea tie-in flange	0.72	Boulton BM
PL1436	10in (3LPP)	Boulton BM / Murdoch MD	11.56	Boulton BM
PL1437	3in (3LPP)	Murdoch MD / Boulton BM	11.56	Boulton BM
PL2109	10in (FBE, CWC)	Munro MH / Hawksley EM	5.08	Munro MH
PL2110	3in (3LPP)	Hawksley EM / Munro MH	5.08	Munro MH
PL2430	12in (3LPP)	Kelvin TM / PSSL	12.67	Kelvin TM (via KSTA,K-MSPS & PSSL)
PLU2431	3in (3LPP)	PSSL / Kelvin TM	12.67	Kelvin TM (via KSTA, K-MSPS & PSSL)
PL2894	10in (3LPP)	Katy KT / Kelvin Subsea Tee Assembly	14.19	Katy KT (via Kelvin PMA & PL2430)
PL2895	2in (3LPP)	Kelvin Subsea Tee Assembly / Katy KT	14.19	Katy KT (via Kelvin PMA & PLU2431)

NOTE

1. PL1311 and PL1312 are risers and are excluded from the comparative assessment; the expectation is that they will be removed, along with the Murdoch MD jacket, but please refer to the Decommissioning Programmes [8], [9];
2. The pipeline lengths quoted here include pipespool lengths to be consistent with their respective PWA;
3. PL1311 is the riser for PL1436 at Murdoch MD and PL1312 is the riser for PL1437 at Murdoch MD;
4. PL2895. The main pipeline is 2in nominal bore, whereas the pipespools at each of the surface laid ends are 3in nominal bore.

Table 2.2.3: Pipeline summary: Caister CM, Boulton BM, Munro MH, Kelvin TM & Katy KT

PIPELINE ID	SIZE (in, mm)	FROM / TO	LENGTH (km)[1]	PIPELINE MEMBERSHIP
PL929	26in (FBE, CWC)	Murdoch MD / MLWM TGT	179.64	CMS Trunklines
PL930	4in (FBE)	MLWM TGT / Murdoch MD	179.58	CMS Trunklines
PL1922	10in/12in (PP)	Hawksley EM / McAdam MM / Murdoch MD	21.62	CMS Satellites Northern Lines (via PSNL)
PL1925	3in (PP)	Murdoch MD / McAdam MM / Hawksley EM	21.53	CMS Satellites Northern Lines (via PSNL)
PL1923	10in (PP)	Murdoch K.KM / PSNL	5.25	CMS Satellites Northern Lines (via PSNL)
PL1926	3in (PP)	PSNL / Murdoch K.KM	5.25	CMS Satellites Northern Lines (via PSNL)
PL1924	10in (PP)	Boulton HM / Watt QM / Murdoch MD	16.76	CMS Satellites Southern Lines (via PSSL)
PL1927	3in (PP)	Murdoch MD / Watt QM / Boulton HM	16.85	CMS Satellites Southern Lines (via PSSL)
PLU4685 (UM6)	108.5mm	McAdam MM / Hawksley EM	13.00	Umbilical; CMS Satellites Northern Lines
PLU4686 (UM7)	108.5mm	Murdoch MA / McAdam MM	9.2	Umbilical; CMS Satellites Northern Lines
PLU4888 (UM4)	82mm	Watt QM / Boulton HM	8.6	Umbilical; CMS Satellites Northern Lines
PLU4889 (UM5)	96mm	Murdoch MA / Watt QM	8.71	Umbilical; CMS Satellites Northern Lines
PLU4890 (UM8)	82mm	Murdoch MA / Murdoch K.KM	5.86	Umbilical; CMS Satellites Northern Lines

NOTE

1. The pipeline lengths quoted here include pipespool lengths as per their respective PWA.

Table 2.2.4: Pipeline summary: Murdoch MD, Hawksley EM, Murdoch K.KM & Umbilicals

2.3 Purpose

The purpose of this document is to present a comparative assessment in support of the CDP1b Caister pipelines [1], CDP2 CMS (Excl. Murdoch & Caister) [8] and CDP3 Murdoch [9] Decommissioning Programmes as per the OPRED guidance notes [18]. The comparative assessment describes the options considered for decommissioning the CMS pipelines, concrete mattresses, fronded mattresses, grout bags and deposited rock. The findings have been determined using a qualitative approach similar to that adopted for other comparative assessments prepared in support of decommissioning programmes for several assets in the Southern North Sea.

2.4 Environmental setting

2.4.1 Overview

The pipelines are located in a European Protected Site within the Dogger Bank SAC. The Hawksley EM, Katy KT, Kelvin TM, McAdam MM and Murdoch MA, MC and MD installations all lie within the southern tip of the Dogger Bank SAC as indicated in Figure 2.4.1. Details of the Dogger Bank SAC and all other relevant environmental baseline data related to the area are provided in the environmental appraisal [10].

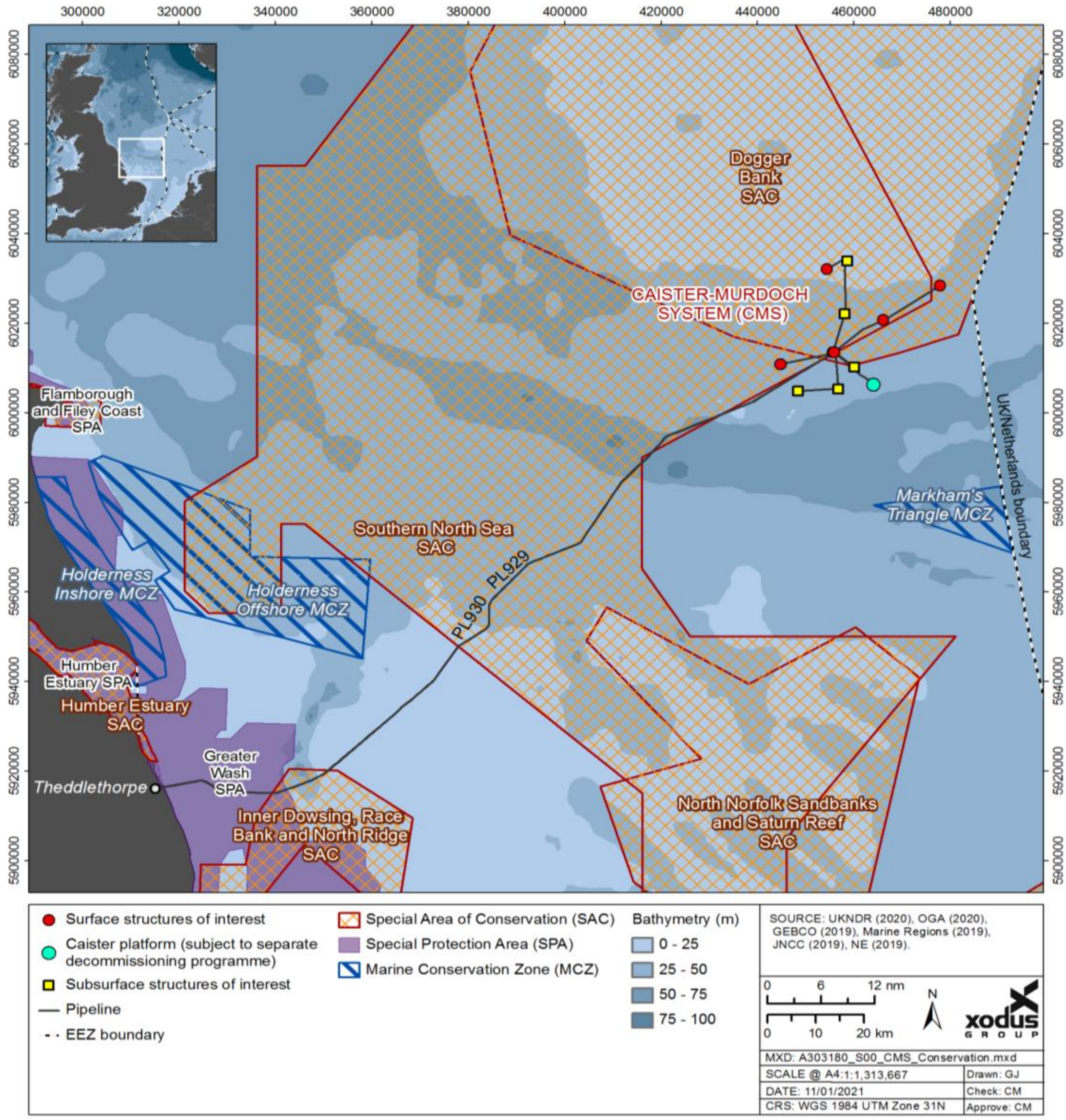


Figure 2.4.1: Oil & Gas Infrastructure with Dogger Bank SAC [1]

2.4.2 Dogger Bank SAC

The Dogger Bank SAC covers an area of 12,331 km^2 and is the largest sandbank within UK territorial waters. It is an extensive sandbank which was formed by glacial processes before being submerged through sea level rise and the site was formally classified as a SAC in September 2017 on account of its sandbanks which are slightly covered by sea water all the time. A large part of the southern area of the bank is covered by water seldom deeper than 20m below chart datum.

The bank is non-vegetated and comprises moderately mobile, clean sandy sediments. It is likely that the fauna of the bank has been damaged by bottom-trawling which may have reduced the number of long-lived or fragile organisms and resulted in a community dominated by robust short-lived invertebrates including polychaetes such as *Nephtys cirrosa*. However, the gross physical structure of the bank is intact, and the biology is likely to be representative of the habitat [1]. The basis for the classification is set out in a Natura 2000 Standard Data Form [21].

The Dogger Bank is home to a variety of species which live both on and within the sandy sediment. These species include segmented polychaete worms, shrimp-like amphipods, and small clams which burrow into the sand. Animals like hermit crabs, flatfish and starfish also live on top of the sandbank. The location of Dogger Bank in the open sea means that it is exposed to waves, which in turn prevents the shallower parts of the bank having any vegetation growing on it. Long thin silver sandeels can be found on the sides of the sandbank and are food for many seabirds, whales, dolphins, and fish such as cod. The Dogger Bank MPA overlaps with a Special Area of Conservation and has been identified for the protection of Harbour porpoise – the southern North Sea SAC.

The majority of sediments across the Dogger Bank SAC are classified as sand to muddy sand, with patches of courser sediments. Patches of courser sediments across the site, with notable larger areas towards the western and southern edges. The underlying substrate comprise mostly of clay material. Sand waves and mega ripples occur across the south-west and east central areas of the site [22].

Sandbanks can be highly mobile and so the introduction of solid material to this environment can create localised artificial habitats, scouring and sediment deposits. Removal of the sandbank features, including the substratum, would result in some localised temporary loss of its ecological communities. The structure and diversity of sandbank communities are determined by environmental characteristics such as sediment particle size distribution, seabed slope and water depth. Any change in these environmental parameters, for example by removing or smothering part of the feature could result in a loss of habitat and a possible shift in community organisation. The Dogger Bank and associated biological communities are:

- Highly vulnerable to physical disturbance or abrasion, for example by pipeline burial, and demersal fishing and selective extraction of species, for example by demersal fishing;
- Moderately vulnerable to obstruction, for example by oil and gas infrastructure; wrecks; and cables;
- Vulnerable at low levels to removal, smothering, changes in suspended sediment, and changes in turbidity, all these for example caused by activity on the seabed.

The sandbank is at risk of deterioration under the baseline as a result of the potential impacts of demersal fishing and infrastructure development. Some activities that take place at the site are already subject to regulations and conditions that are likely to prevent significant damage occurring to the features. These activities include oil and gas installations, aggregates industry operations and laying of submarine cables and pipelines. However, demersal fishing would be difficult to control if the site is not designated and this would likely have contributed to some level of decline of the features over the assessment period. Deterioration of the habitats would not achieve the aims of the EC Habitats Directive to maintain or restore Annex I habitats.

Based on current evidence the conservation objective for the management of Dogger Bank is to restore the sandbank to favourable condition. Activities that do not result in pressures to which the feature is sensitive may continue at current levels of spatial and temporal intensity. The management of other activities to which the feature is vulnerable may need to be reviewed by competent authorities. If new information suggests that the condition of the feature at the site is not significantly affected by current activities and assessment indicates the site is in favourable condition, then the conservation objective for the sandbank will be changed to maintain the features in favourable condition [20].

In their report BEIS [1] advise that the extent of physical disturbance relating to oil and gas decommissioning activities is estimated to be relatively small compared to the extent of habitat within the SAC and the impacts to the habitat and associated communities from decommissioning operational activities would be temporary.

The pipelines that lie within the Dogger Bank SAC include PL929 & PL930, PL935 & PL936, PL1922 & PL1925, PL1923 & PL1926, PL1924 & PL1927, PL2109 & PL2110, PL2430 & PLU2430, PL2894 & PL2895, PLU4685 (UM6), PLU4686 (UM7), PLU4888 (UM4), PLU4889 (UM5), & PLU4890 (UM8) [1]. In other words, most of the pipelines being dealt with within this comparative assessment lie within the Dogger Bank SAC. Given the physical nature of the designated boundaries, for the purposes of this comparative assessment all pipelines and infrastructure associated with CMS are treated as though they are all situated within the Dogger Bank SAC.

2.4.3 Southern North Sea SAC

Murdoch pipelines PL929 and PL930 are routed through the Southern North Sea SAC which covers an area of 36,950 km^2 [23]. the site was formally classified as a SAC in February 2019. The site qualifies as a Special Areas of Conservation for the harbour porpoise, *Phocoena phocoena*. [24] The focus of the Conservation Objectives for the SNS SAC focus on addressing pressures that affect site integrity and include:

- killing or injuring harbour porpoise (directly or indirectly);
- preventing their use of significant parts of the site (disturbance / displacement);
- significantly damaging relevant habitats; or
- significantly reducing the availability of prey.

The conservation objectives of relevance here for the management of Southern North Sea SAC is to avoid significantly damaging the habitat for the Harbour Porpoise and thereby significantly reducing the availability of prey.

2.4.4 Sand waves and sand banks

It is worth explaining what sand banks and sand waves are, as this will provide context for some of the uncertainties addressed in this comparative assessment.

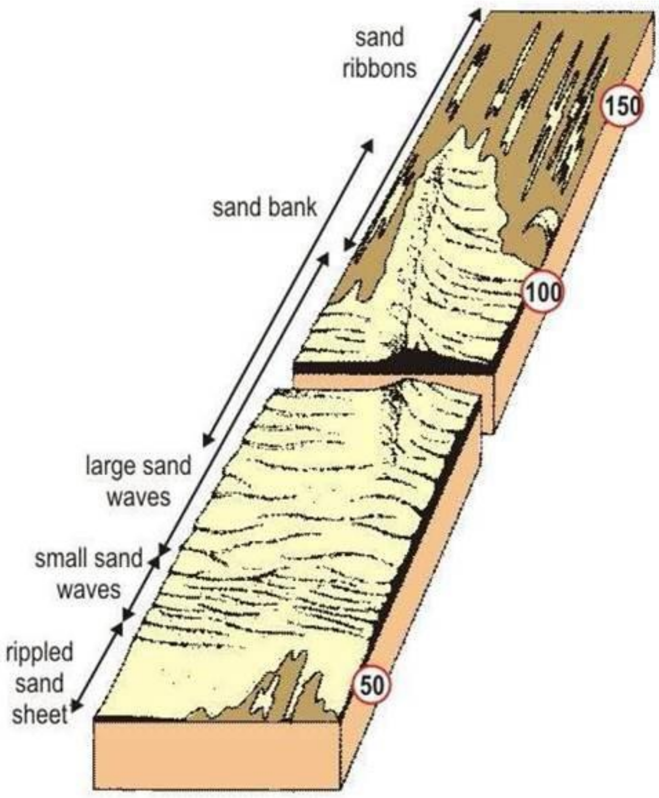


Figure 2.4.2: Sand waves and sand banks [4] [9]

[9] The numbers in red circles are mean spring near surface currents in cm/sec. That is, divide the figure by 100 to give speed in m/sec.

Sand waves: Sand waves are a periodic bottom waviness generated by tidal currents in shallow tidal seas. Typical wavelengths range from 100 to 800m and they can be up to between 1 and 5m high. The crests are almost orthogonal to the direction of tide propagation. They are not static bed forms and migration speeds can be up to tens of metres per year.

When local tidal flows interact with a bottom waviness it generates a steady streaming in the form of recirculating cells. When the steady velocity drags the sediment from the troughs towards the crests of the waviness, sand waves tend to appear. They can be complex to model, and subtle changes to the environment can change the dynamics of the local interaction between the tidal flows and the seabed.

Sand banks: The sand banks in the North Norfolk area of the southern North Sea are large-scale mobile seabed forms in dynamic equilibrium with the environment. They can have a wavelength between 1 and 10km, and they can achieve a height of several tens of metres [25]. Sand banks are found widely on shallow continental shelves where there is an abundance of sand and where currents exceed a certain speed [16]. This speed is much more than is needed to move seabed sediment and sand banks arise from an inherent instability of a seabed subject to tidal flow and mass transport. They can go from being active to a dying state, stranded in weak currents as the sea level rises.

2.4.5 Grout bags

The number of grout bags noted in the Decommissioning Programmes [7],[8],[9] has been estimated using engineering judgement based on available data such as as-built drawings and design sketches.

Ordinarily the intention would be to leave all fully buried grout bags *in situ* when decommissioning the pipelines, but should they be disturbed as part of decommissioning operations they will be removed. Although several different methods could theoretically be used to remove the grout bags, from a practical perspective it is not known whether the bag material has remained intact since the original installation.

2.4.6 Mattresses

When a pipeline or structure is placed into an area with a loose sedimentary material, under certain conditions the flow of water can cause erosion of the seabed, and this is called scour. Scour around a structure or pipeline will undermine its stability, and so is undesirable.

Fronded mattresses are put in place to provide protection against scour, and when they do their job the fronds act like natural seaweed, and silt and sediment that is carried in the water column builds up within the fronds. Eventually they become buried. Given the right conditions they can be very effective.

In general terms, there are two types of frond mattresses: the anchor retained type and the gravity-based type, but they both perform the same basic function. The anchor retained type are typically rolled out as a sheet with steel anchors pegged into the seabed, whereas gravity-based types might use concrete or some other medium to hold them in place while they become buried.

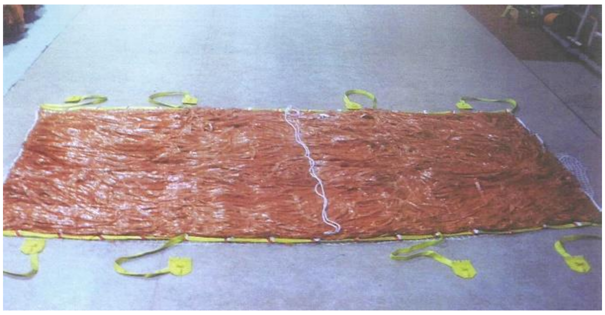


Figure 2.4.3: Typical Fronded Mattress Types (gravity based & anchored)[10]

[10] Photos courtesy of http://www.sscsystems.com/

Frond mattresses are generally used to a lesser extent than concrete mattresses in the southern North Sea [19] although as explained below, for the CMS associated infrastructure they are more prevalent. They were installed to protect the subsea installations and the pipeline and umbilical infrastructure. In many instances it is likely that they will have performed their function and are now indistinguishable from the surrounding seabed, except possibly from the frond tips being visible.

Much of their thickness is manufactured from flexible material designed to accumulate seabed sediment and should they be left *in situ* the expectation is that the fronds themselves would present a relatively benign snagging hazard.

Fronded Mattresses, Anchored

Within the CMS area there are 97 fronded mattresses that are physically anchored to the seabed. There are two sizes of anchored fronded mattresses used within the CMS area: 5m x 2.5m and 5m x 5m. Both types are anchored to the seabed using 8 and 16 steel anchors respectively, as indicated in Figure 2.4.4.

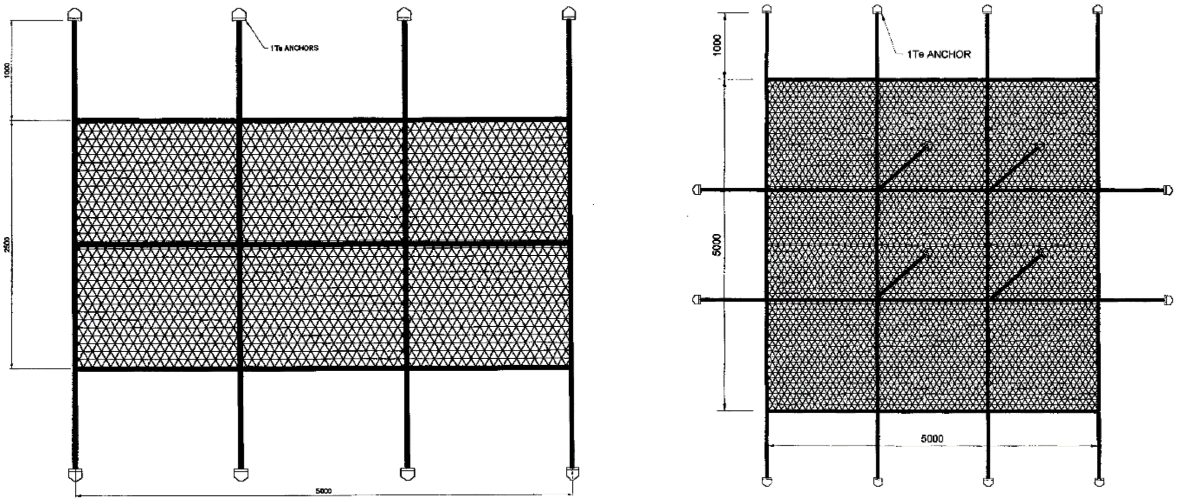


Figure 2.4.4: SPS 5m x 2.5m & 5m x 5m fronded mattresses, anchored

Fronded Mattresses, Concrete Bases

Within the CMS area there are 448 fronded mattresses that are held in place by their concrete bases and they are used for scour protection. They range in size as follows: 6.6m x 3m x 0.3m, 6m x 3m x 0.3m, 6m x 3.4m x 0.3m, and 6m x 3mx 0.15m. These are shown in Figure 2.4.5 and Figure 2.4.6.

There is one fronded concrete mattress within the Murdoch 500m zone that was installed over an initiation pile next to the PL2430 and PLU2431 pipeline bend (Figure A2.1.1).

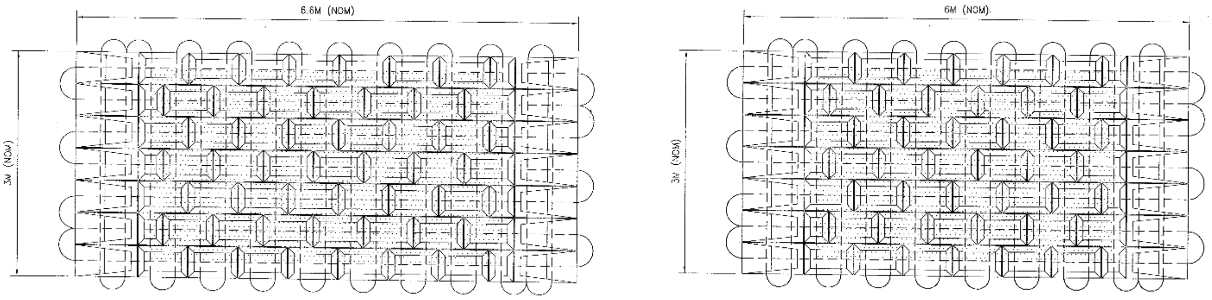


Figure 2.4.5: Fronded mattresses Type 6.6m x 3m x 0.3m & 6m x 3m x 0.3m

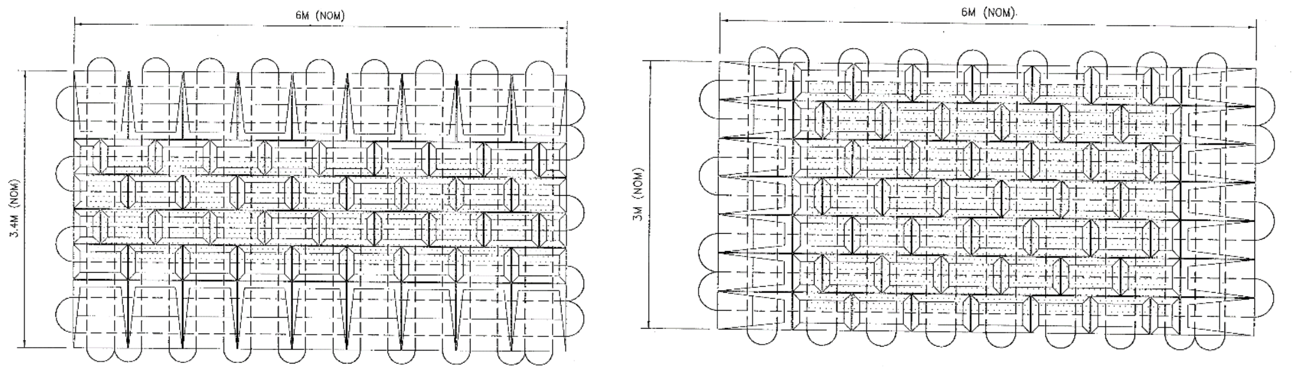


Figure 2.4.6: Fronded mattresses Type 6m x 3.4m x 0.3m & 6m x 3m x 0.15m

Concrete mattresses

There are 372[11] concrete mattresses within the CMS area are primarily proprietary 'Linklok', 'Fleximat' or 'Bi-flex' type mattresses with a diverse range of sizes They all perform the same function, that is, to protect and stabilise the pipelines infrastructure. These include:

- Linklok type: 12m x 0.4m x 0.15m, 6m x 4m x 0.3m, 6m x 4m x 0.15m, 6m x 2.4m x 0.3m, 6m x 2.4m x 0.15m;
- Bi-flex or Fleximat type: 6m x 3m x 0.3m;

Figure 2.4.7 gives an indication of what the concrete mattresses might look like, but the designs are constantly subject to change. Experience would suggest that the concrete blocks are held together with polypropylene rope, but the small diameter of the rope (typically ~8mm to 10mm) means that the mattresses can be prone to disintegrating as they are lifted.

Figure 2.4.7: Linklok, Fleximat and Biflex mattresses respectively (indicative only)

2.4.7 Deposited rock

The decommissioning philosophy in this document is consistent with the OPRED guidance notes [18] and the deposited rock has been considered for removal.

It is considered physically possible to remove deposited rock. Methods that could be used to remove the rock include:

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

All these proposed methods would impact the seabed and associated communities, create sediment plumes,

[11] Note that several concrete mattresses associated with the CMS pipelines need to be removed anyway due to commitments in third party decommissioning programmes for Ketch [11] and Schooner [12].

and require additional vessel use with the associated environmental impacts, safety risks, impacts on other users of the sea and additional costs.

Material left *in situ* will preserve the marine habitat that will have established over the time it has been on the seabed, and in this case its presence will not have a more negative impact on the environment than was presented when the material was originally installed, nor impact on the safety of other users of the sea.

On the basis of the foregoing, all deposited rock will be left *in situ*.

2.5 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, that includes the following technical assumptions:

- Technically, removal of the concrete coated and piggybacked pipelines could be achieved using the 'cut and lift' method of removal, assuming that the overlying rock could be excavated or displaced to allow access;
- Complete removal of the umbilicals would be achievable should the overlying deposited rock be displaced to allow the umbilicals to be pulled from the trench;
- It is possible that the smaller individual pipelines could be removed using reverse reel assuming that their integrity could be assured and that the overlying rock could be displaced to allow the pipelines to be pulled from the trench;
- Chrysaor is not aware of any fishing gear snagging reports. To the companies' knowledge no exposures have been of such a magnitude that they have warranted being recorded as a snagging hazard via Kingfisher Information Services on FishSAFE (www.fishsafe.eu).

The following legacy assumptions have also been made:

- Minimising the number of cut pipeline or umbilical ends is to be preferred from a legacy perspective and an environmental perspective;
- An environmental survey would be required on completion of decommissioning activities;
- Any pipeline being left *in situ* would be subject to at least three legacy burial surveys although given the depth of burial it is possible that this requirement could be re-assessed in several instances following the post-decommissioning surveys;
- The seabed sediment type is such that any spoil heaps created during any decommissioning operations would not present significant snagging hazards;
- In the long term, assuming the size and profile or the resulting rock berm is suitable, deposited rock remaining *in situ* would not present snagging hazards;
- The impact of the procurement of any new materials such as fabricated items or mining of new rock is ignored;
- Impact on commercial activities is inversely proportional to vessel activity;
- Societal benefits and vessel associated environmental impacts and risks are assumed to be proportional to vessel duration;
- Only a high-level comparison of what differentiates the costs is used;
- The procurement and deposition of additional rock on pipeline or umbilical ends is ignored in the cost assessment.

Please also refer Appendix 9.3 for assumptions that are specific to the cost assessment.

3 The pipelines and umbilicals

3.1 Overview

The pipelines and umbilicals are all laid in trenches, all of which were mechanically backfilled except for the main trunklines (PL929 & PL930) and the Caister pipelines (PL935 & PL936). They are protected and stabilised with a mixture of fronded and concrete mattresses and deposited rock. Rock was deposited in areas where as-built trenching surveys had determined that the design trench depth was not obtained. The fronded mattresses that are anchored were typically installed at pipeline bends and where it was anticipated that local scouring would occur. All but two MeOH pipelines (PL930 & PL936) are piggybacked onto the associated gas pipeline. PL2109 and PL2110 were provided with spoilers to enable the pipes to self-bury rather than excavate a trench.

Pipeline ID	Deposited rock function	O/A Length of rock (km)
PL929	PL253 crossing	0.360
PL930	PL253 crossing	0.360
PL929 & PL930	On approach to Murdoch MD	0.525
PL935 & PL936	On approach to Caister CM	0.200
PL936	On approach to Caister CM 500m zone at separation	0.045
	On approach to Murdoch MD 500m zone at separation	0.090
PL935 & PL936	On approach to Murdoch MD	0.200
PL1436 & PL1437	On approach to Boulton BM	0.15
	UHB & DOC mitigation	0.174
	On approach to Murdoch MD	0.184
PL1922	On approach to Hawksley EM	0.126
	UHB & DOC mitigation	0.644
	PL1220 & PL1221 crossing	0.349
	On northern approach to McAdam Tee	0.0605
PL1925	On approach to Hawksley EM	0.112
PL1922	UHB & DOC mitigation	0.644
PL1922 & PL1925	On southern approach to McAdam Tee	0.0605
	UHB & DOC mitigation	0.364
	On approach to Murdoch MD	0.372
PL1923 & PL1926	On approach to Murdoch K.KM	0.155
	On approach to Murdoch MD	0.494
PL1924 & PL1927	On approach to Boulton HM	0.185
	UHB & DOC mitigation	0.546
	PL1222 & PL1223 crossing	0.254
	On approach to Watt QM	0.580
	On approach to Watt QM	0.138
	UHB & DOC mitigation	1.289
	PL1612 & PL1613 crossing	0.506
	On approach to Murdoch MD	0.467
PL2109 & PL2110	Self-burial, On approach to Hawksley EM	0.032
PL2430 & PLU2431	On approach to Kelvin TM	0.255
	UHB & DOC mitigation	0.255
	On approach to Murdoch MD	0.110
PL2894 & PL2895	On approach to Katy KT	0.097
	UHB & DOC mitigation	0.240

Pipeline ID	Deposited rock function	O/A Length of rock (km)
PLU4685	On approach to Murdoch MD	0.102
	On approach to Hawksley EM	0.468
	UHB & DOC mitigation	2.859
	PL1220 & PL1221 crossing	0.168
PLU4685, PL1925	On approach to McAdam MM	0.048
PLU4686	UHB & DOC mitigation	0.019
	On spur joining rock over PL1922 & PL1925	0.072
	On approach to Murdoch MA	0.306
PLU4888	On approach to Boulton HM	0.024
	UHB & DOC mitigation	0.775
PLU4888, PL1924, PL1927	PL1222 & PL1223 crossing	0.180
	Tampnet crossing	0.156
PLU4889	UHB & DOC mitigation	0.531
	PL1612 & PL1613 crossing	0.087
	On approach to Murdoch MA	0.402
PLU4890	On approach to Murdoch MA	0.393

NOTES:

1. Several pipelines encounter pipeline crossings and a description of these is presented in sections 3.15 and 3.16 of this report;
2. Deposited rock was used for all the pipeline transitions and PLU4686 into and out of the trench except for the Munro MH pipelines, PL2109 & PL2110 and all the other umbilicals;
3. Length of rock may not be continuous. For example, upheaval buckling, and incidences of shallow cover were mitigated by spot rather than continuous placement of deposited rock for PL1922 & PL1925, PL1924 & PL1927, PLU4888.

Table 3.1.1: Overview of types of pipeline and their burial

3.2 PL929 & PL930 trunklines

PL929 is a 26in carbon steel pipeline that is coated using an asphalt enamel coating, on top of which lies a concrete weight coating (CWC) throughout its length except for the riser at Murdoch MD. PL930 is a 4in pipeline constructed using carbon steel that is also coated using fusion bonded epoxy. The length of PL930 is interspersed with four flexible transition spool pieces 40m (2x), 80m and 100m long[12]. The first flexible spool piece is 40m long and is located ~4.8km from mean low water mark (MLWM), the next, 80m long, is located ~20km from MLWM, the third is located at ~KP180.409 on approach to the 500m zone is 40m long, while the fourth and last flexible spool piece ~100m long, connects the end of the pipeline to the 4in riser at the platform. Apart from the ends of the pipelines where PL929 is piggybacked by PL930 (Figure 3.2.1, Figure 3.2.4), the pipelines lie in separate trenches. PL929 was originally trenched to a minimum 0.5m to top of pipe and on approach to the Murdoch MD and approach to MLWM for a few hundred metres it is piggybacked by PL930 and protected and stabilised by 200m of deposited rock with concrete mattresses being used on most of the final approach (Figure 3.2.1). PL930 is protected by several mattresses where it separates from PL929 and ~KP20 and ~500m from Murdoch (Figure 3.2.1, Figure 3.2.3). PL930 is also protected by ~50m of deposited rock where it separates from PL929 ~500m from Murdoch.

[12] The ‘as-built’ lengths and number of the flexible pipespools may differ from the PWA details.

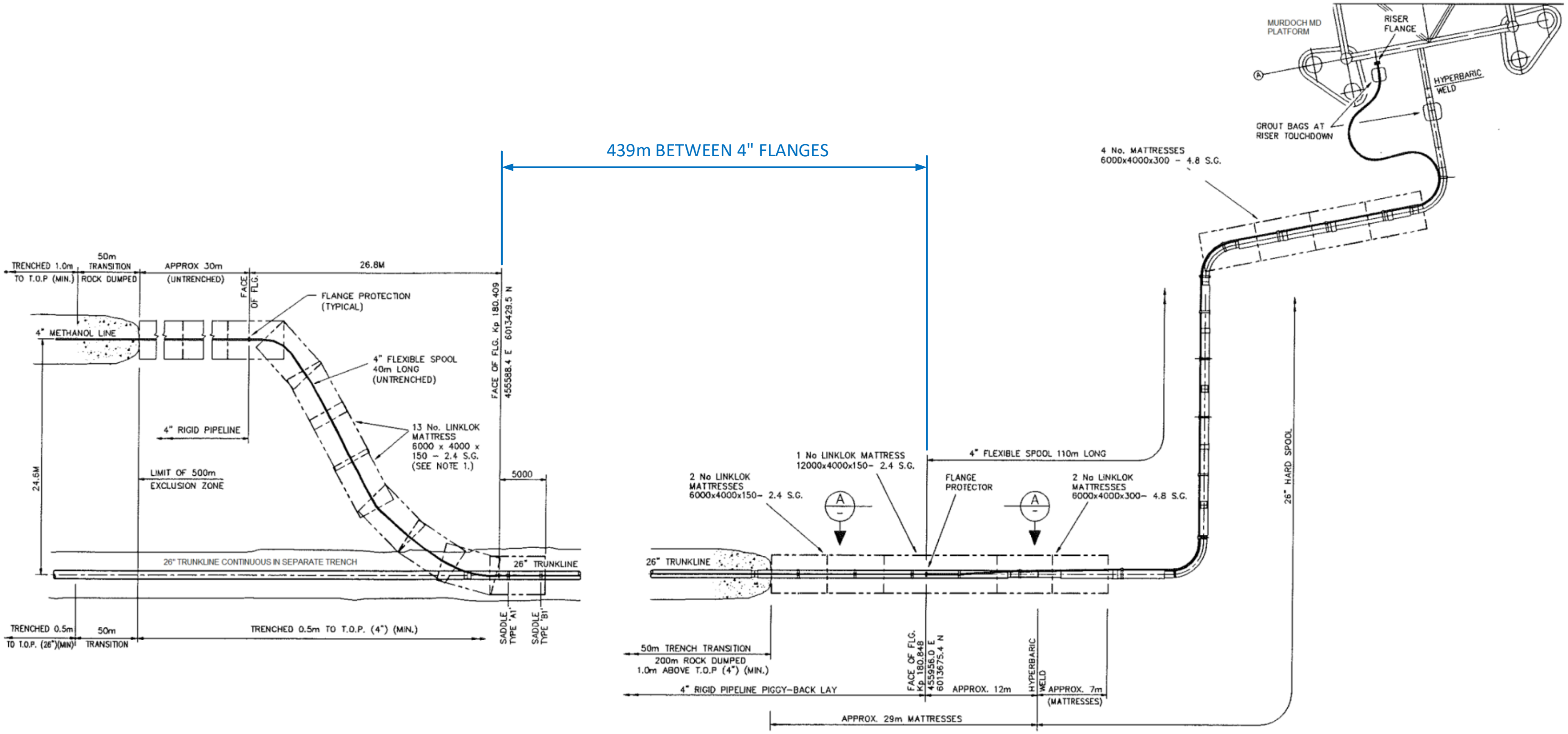


Figure 3.2.1: Separation of PL929 & PL930 at ~500m from Murdoch MD (NTS)

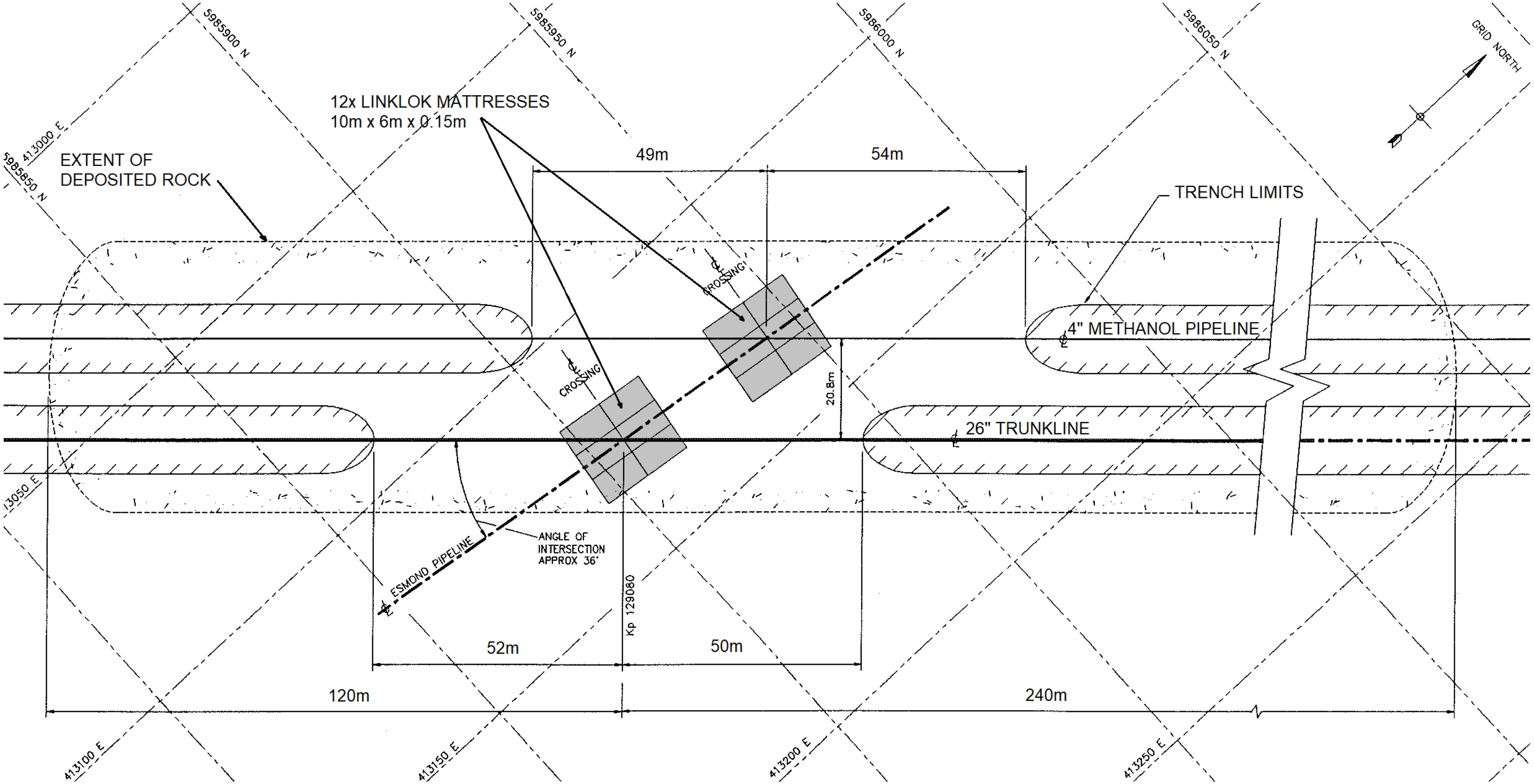


Figure 3.2.2: PL253 Esmond pipeline crossing PL929 & PL930 at ~KP129 (NTS)

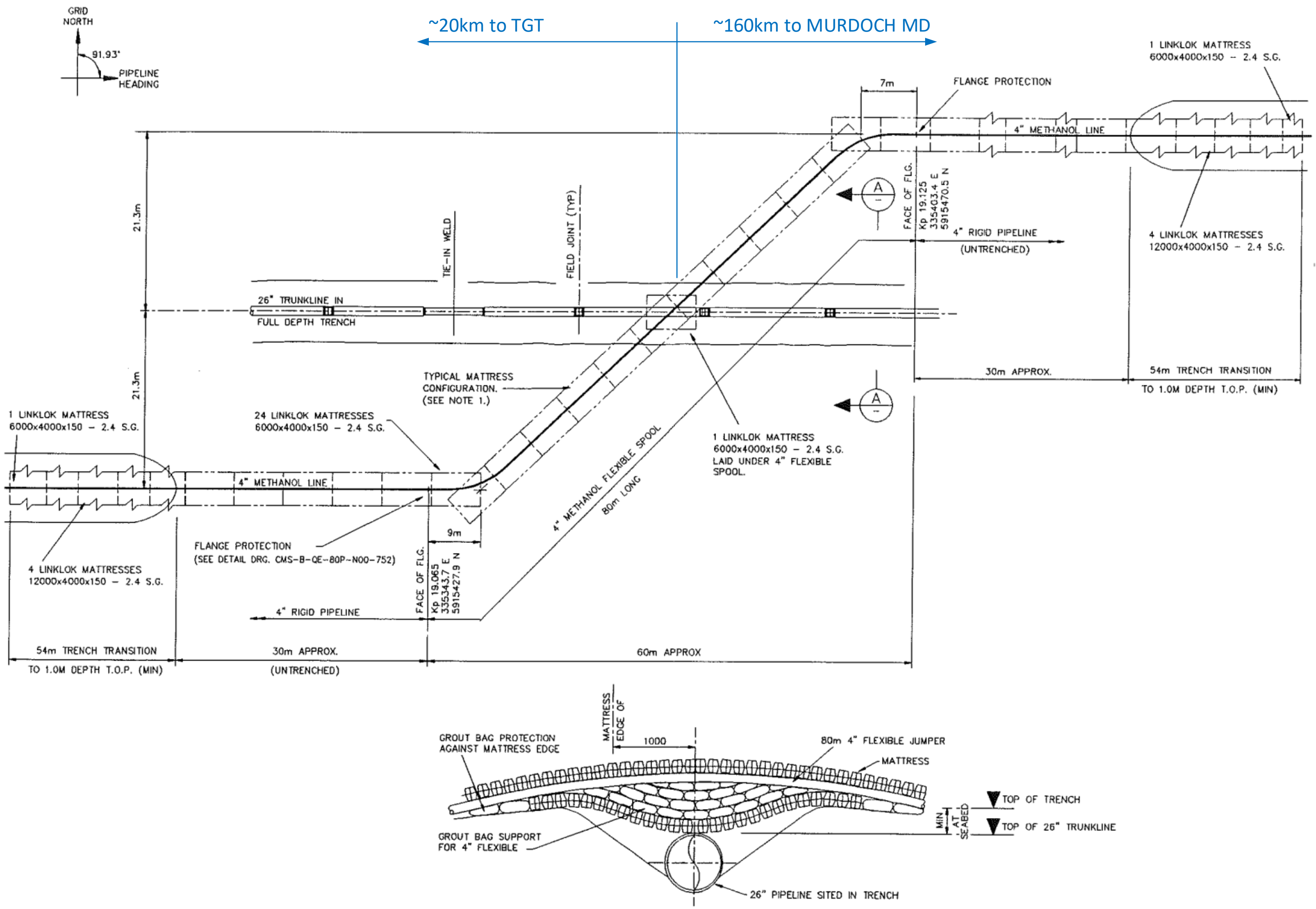


Figure 3.2.3: PL930 crosses over PL929 ~20km from MLWM (NTS)

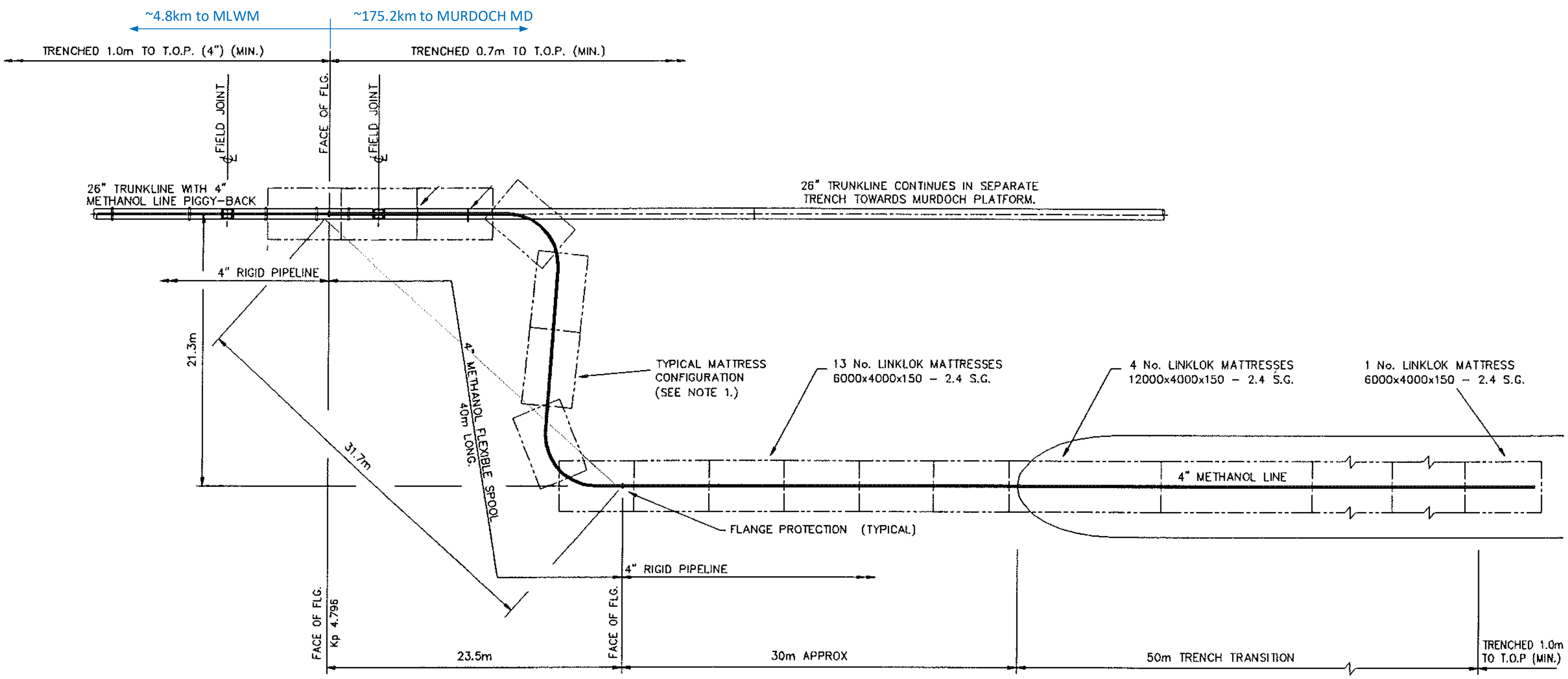


Figure 3.2.4: Separation of PL930 & PL929 ~4.8km from MLWM (NTS)

According to as-built data, excepting the transition areas and cross over points described earlier, PL929 was trenched to at least between 0.5m to 0.7m to top of pipe below seabed. PL930 was trenched to at least 1.0m to top of pipe below seabed. For the purposes of this assessment and given the bathymetry of the seabed it is assumed that PL930 would exhibit the same burial characteristics as PL929, but this will need to be confirmed by survey.

The most extensive survey of the ~180km pipeline was done in 2006 between ~KP15 and ~KP180 (Figure 3.2.5). A total of 115 exposures and 9 freespans were detected over a length of 5.994km, the longest of which was 805m between KP155.898 and KP156.703. Just one of the freespans - ~61m long at KP57.432 was recordable but more recently this span was not observed in 2017.

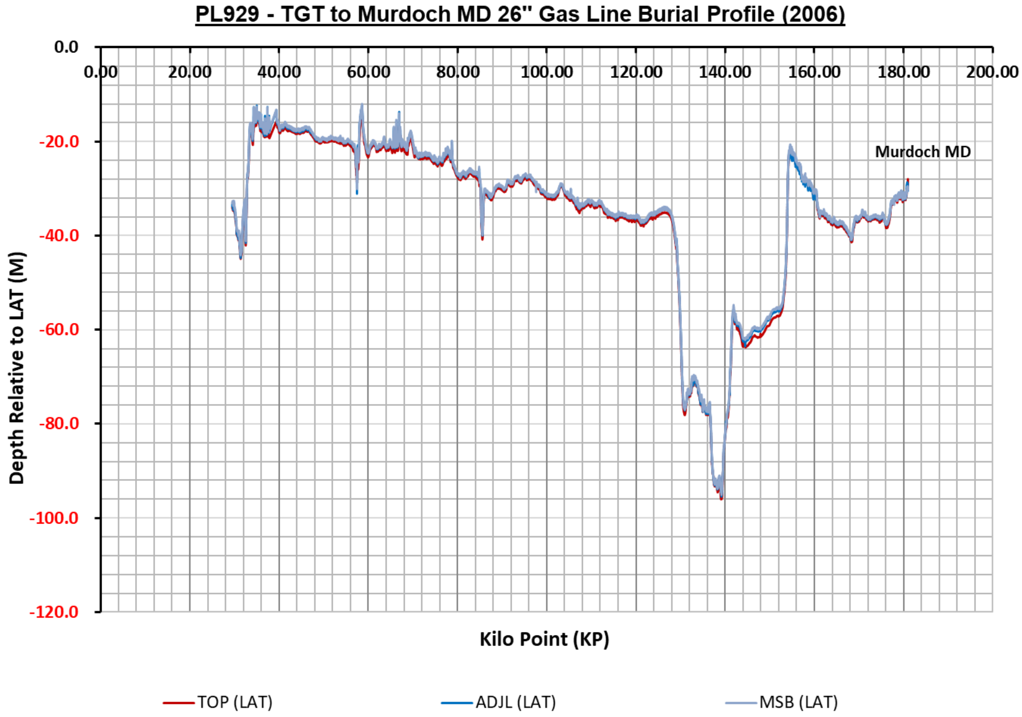


Figure 3.2.5: PL929 seabed & burial profile ~KP15 to ~KP181

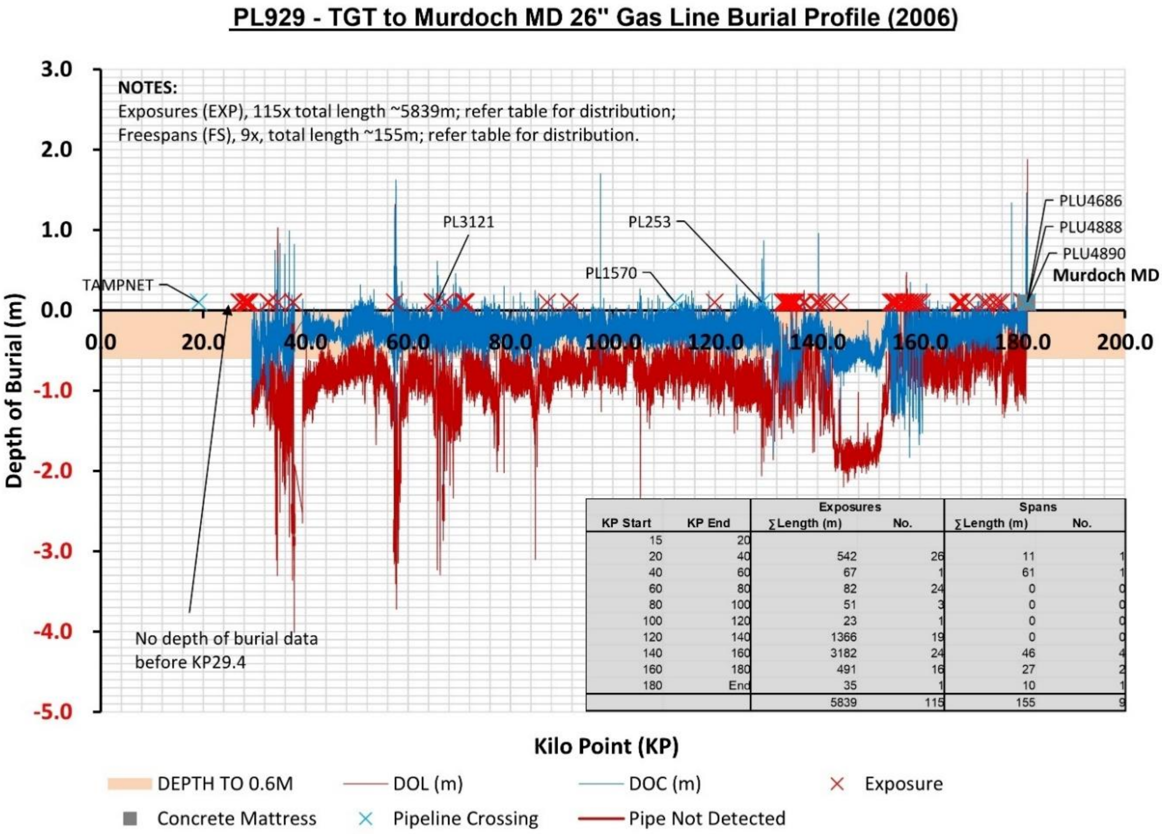


Figure 3.2.6: PL929 depth of cover profile ~KP15 to ~KP181

The results of the 2016 survey between KP97.6 and KP180.97 identified a total of 42 exposures and one freespan over a total length of 3.622km. Ten of the exposures exceeded 100m, the longest of which was 792m. Refer Figure A1.1.4 in Appendix 1.

An examination of the 2017 survey between ~KP16 and ~KP66.7 identified a total of 55 exposures over an overall length of 708m. Five of these exposures exceeded 50m, the longest of which was 99m. Refer Figure A1.1.2 in Appendix 1.

The exposures and freespans noted over the years outside of the approach to Murdoch are presented in Table A1.1.1 in Appendix 1. On the approach to Murdoch MD the only exposures and spans have been located at the platform itself. Regrettably, no survey data are available for PL930, although the results for the piggyback section are similar to those obtained for PL929. The pipelines encounter a few pipelines that cross over them, and these are detailed in Table 3.2.1. To summarise, for the survey data reviewed, PL929 generally exhibits good burial depth and good depth of cover albeit with several km of the pipeline (<5%) being exposed.

A summary of the pipeline and umbilical crossings for PL929 and PL930 is presented in Table 3.2.1 below.

Pipeline, umbilical or cable description	Location	Protection
OUTSIDE MURDOCH 500M ZONE:		
Tampnet Fibre-optic cable (over PL929 & PL930), indicative only, to be confirmed.	KP19.097	Picked up in survey as cable bridge over PL929 & PL930, no details available.
PL3121 Juliet to Pickerill A gas pipeline & PLU3122 Juliet to Pickerill umbilical.	KP65.7	Unknown. Expectation is that the crossing will be protected with concrete mattresses overlain with deposited rock.
PL2641 8in Seven Seas Newsham gas export & PLU2642 Seven Seas control umbilical.	KP90.8	Unknown. As above.
PL1570 Shearwater to Bacton 34in gas pipeline (SEAL).	KP112.1	Unknown. As above.

Pipeline, umbilical or cable description	Location	Protection
PL253 Esmond to Bacton 24in gas export pipeline.	KP129.1	12x 10m x 6m x 0.15m Linklok concrete mattresses overlain by deposited rock, ~200m long x ~55m wide.
INSIDE MURDOCH 500M ZONE:		
PLU4686 Murdoch MA to McAdam umbilical.	KP180.915	Refer Table 3.11.1, Table 3.12.1, Table 3.13.1, Figure A2.1.1.
PLU4888 Watt QM to Boulton HM umbilical.	KP180.915	
PLU4890 Murdoch MA to Murdoch K.KM umbilical.	KP180.915	
NOTE 1. Origin of pipeline KP taken at MLWM and ends at base of PL929 riser at Murdoch MD.		

Table 3.2.1: PL929 (& PL930) pipeline crossings

3.3 PL935 & PL936 Caister CM pipelines

PL935 is a ~11.2km long 16in carbon steel pipeline that is coated with an asphalt enamel overlain with a concrete weight coating (CWC) throughout its length except for the risers at Caister CM and Murdoch MD. PL936 is a 3in pipeline ~10.7km long, mostly constructed using carbon steel that is coated using fusion bonded epoxy. The length of PL936 is interspersed with four flexible transition spool pieces 65m, 40m, 40m and 85m long[13]. The 65m and 85m long flexible spools are connected to the risers at Murdoch MD and Caister CM respectively and the two 40m long flexibles are located at the separation points on the edge of the Caister CM and Murdoch 500m zones (Figure A2.2.1 and Figure A2.3.1 respectively). Apart from either end of the pipeline where PL935 is piggybacked by PL936, the pipelines lie in separate trenches. Regrettably, no survey data are available for PL936 outside of the 500m zones, where the results for the piggyback section replicate those obtained for PL935.

According to as-built data, excepting the transition areas and cross over points described earlier, PL935 was trenched to at least between 0.5m to top of pipe below seabed. PL936 was trenched to at least 1.0m to top of pipe below seabed. The survey data for PL935 has exhibited a good depth of burial and excellent depth of cover throughout its length. For the purposes of this assessment and given the bathymetry of the seabed it is assumed that PL936 would exhibit the same burial characteristics as PL935, but this will need to be confirmed by survey.

[13] The ‘as-built’ lengths and number of the flexible pipespools may differ from the PWA details.

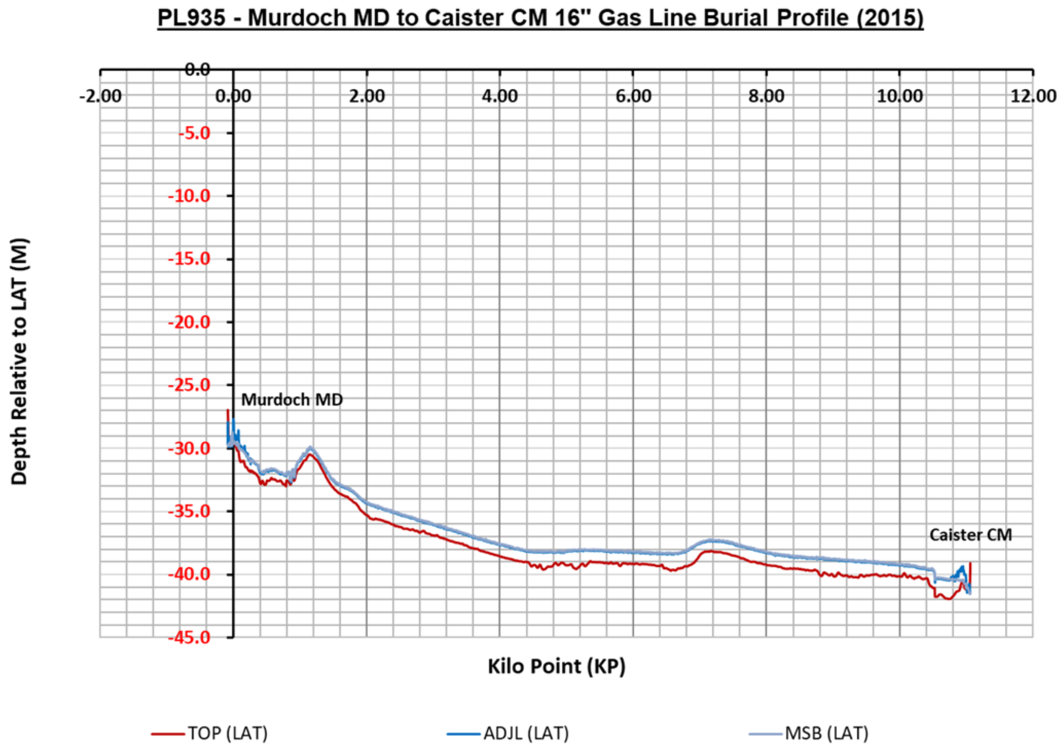


Figure 3.3.1: PL935 seabed & burial profile ~KP-0.1 to ~KP11.1

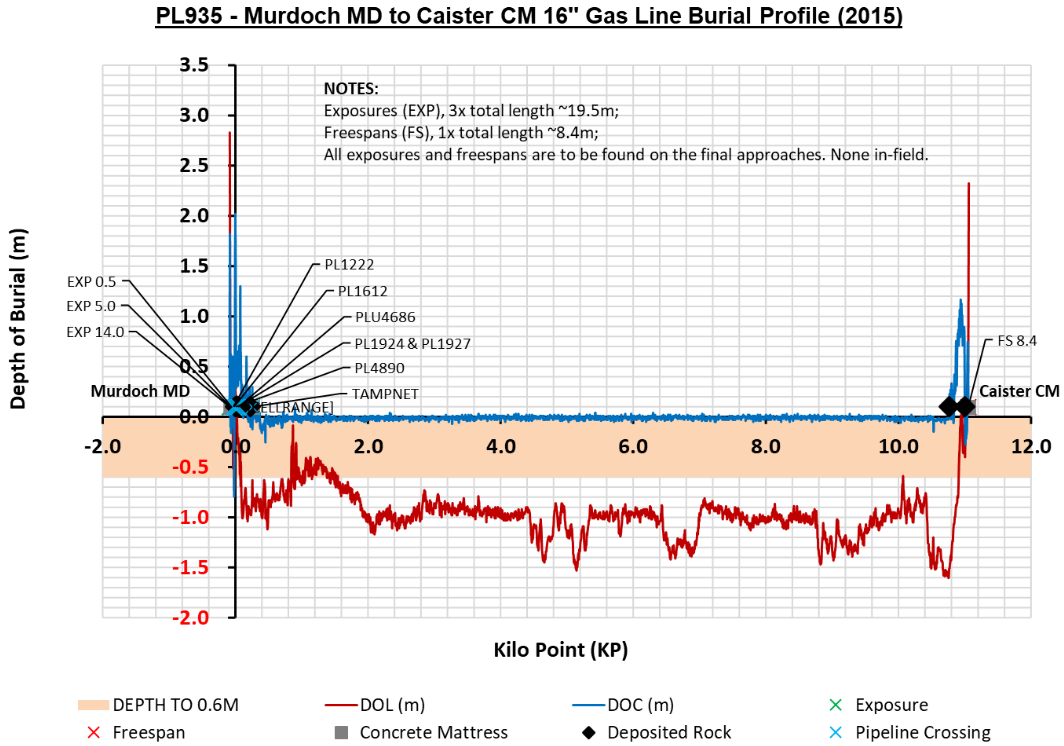


Figure 3.3.2: PL935 Depth of cover profile ~KP-0.1 to ~KP11.1

A summary of the pipeline and umbilical crossings for PL935 and PL936 is presented in Table 3.3.1 below.

Pipeline, umbilical or cable description	Location	Protection
INSIDE MURDOCH 500M ZONE:		
Tampnet fibre-optic cable crosses over PL935 & PL936.	KP0.258	The Tampnet cable will be protected using Uraduct 15m long and is buried to 400mm below seabed including where it crosses over PL935 & PL336.
PLU4890 Murdoch MA to Murdoch K.KM umbilical.	KP0.050	Refer Table 3.13.1.
PL1924 & PL1927 Boulton HM 10in & 3in pipelines.	KP0.037	Refer Table 3.7.1.
PLU4686 Murdoch MA to McAdam MM umbilical.	KP0.010	Refer Table 3.11.1.
PL1612 & PL1613 Ketch 18in & 3in pipelines.	KP -0.021	21x 6m x 3m x 0.3m concrete mattresses and several hundred grout bags forming a protective bridge over PL935; refer Ketch decommissioning programmes [11] which state that these will all be fully recovered to shore.
PL1222 & PL1223 Schooner 16in & 3in pipelines.	KP -0.032	13x 6m x 3m x 0.3m concrete mattresses and several hundred grout bags; refer Schooner decommissioning programmes [12] which state that these will all be fully recovered to shore.
NOTE 1. Origin of KP taken for PL935 (& PL936) at the base of the riser at Murdoch MD; 2. All pipeline crossings bar the Tampnet fibre-optic cable crossing are close to the Murdoch platform.		

Table 3.3.1: PL935 (& PL936) pipeline crossings

3.4 PL1436 & PL1437 Boulton BM pipelines

Boulton BM (Figure A2.4.1) comprises a single surface installation that is tied back to Murdoch MD via PL1436 and PL1437. PL1436 is a 10in carbon steel pipeline ~11.6km long coated with 3-layer polypropylene (3LPP) throughout its length except for the riser at Boulton BM which is protected using thermal sprayed aluminium (TSA) supplemented by an outer layer of neoprene in the splash zone. Throughout its length PL1436 is piggybacked by PL1437, which is a 3in carbon steel pipeline the same length as PL1436 and coated with 3LPP throughout except for the riser at Boulton BM which is protected using TSA. At Murdoch MD, PL1436 and PL1437 are connected to PL1311 and PL1312 at their respective riser tie-in flanges.

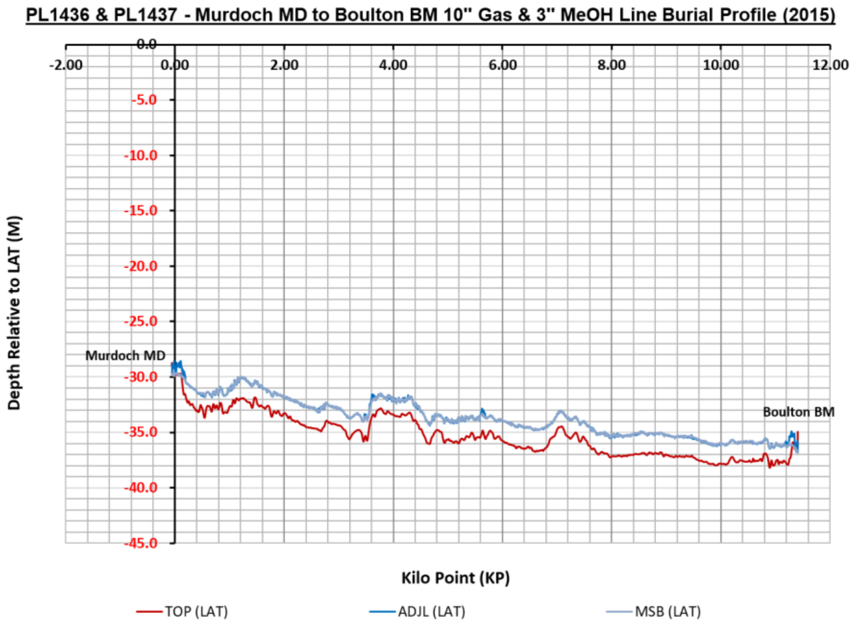


Figure 3.4.1: PL1436 & PL1437 seabed & burial profile ~KP-0.06 to ~KP11.41 (2015)

The survey data has indicated that both PL1435 & PL1436 have exhibited a good depth of burial and excellent depth of cover throughout their length. Any exposures occur locally to the end terminations and the expectation is that these would be removed along with the pipeline ends.

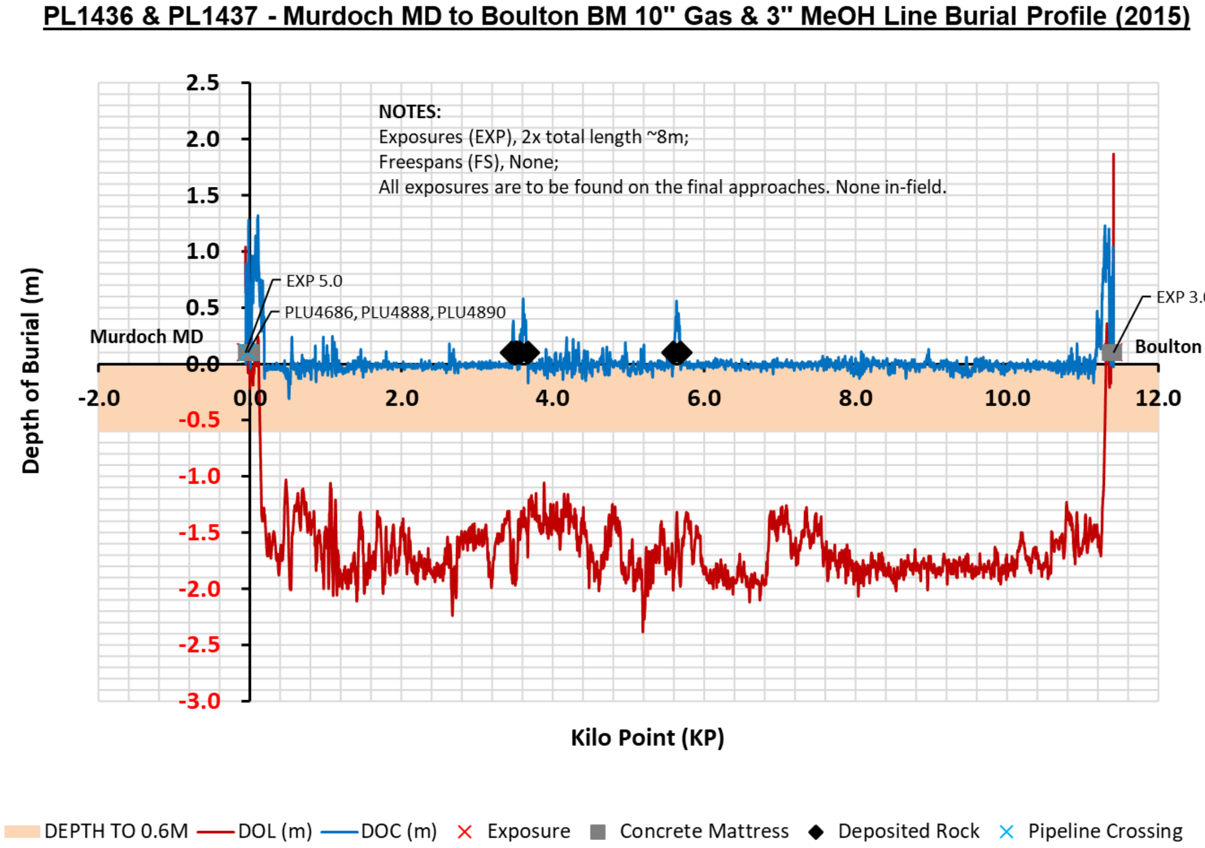


Figure 3.4.2: PL1436 & PL1437 depth of cover profile ~KP-0.06 to ~KP11.41 (2015)

Three umbilicals cross over PL1436 & PL1437 near Murdoch MD and these are summarised in Table 3.4.1 below.

Pipeline, umbilical or cable description	Location	Protection
INSIDE MURDOCH 500M ZONE:		
PLU4686 Murdoch MA to McAdam MM umbilical.	KP -0.027	Refer Table 3.11.1.
PLU4888 Watt QM to Boulton HM umbilical.	KP -0.027	Refer Table 3.12.1.
PLU4890 Murdoch MA to Murdoch K.KM umbilical.	KP -0.027	Refer Table 3.13.1.
NOTE 1. Origin of KP for PL1436 & PL1437 taken at the base of the riser at Murdoch MD.		

Table 3.4.1: PL1436 & PL1437 pipeline crossings

3.5 PL1922 & PL1925 Hawksley EM & McAdam MM pipelines

Hawksley EM (Figure A2.6.1) comprises a subsea installation that is tied back to Murdoch MD via the McAdam Tee and the Pigging Skid Northern Lobe (PSNL) using PL1922 and PL1925. PL1922 is a 12in/10in carbon steel pipeline and PL1925 is a 3in carbon steel pipeline. PL1922 and PL1925 are ~21.6km and ~21.5km long respectively, both coated with 2.3mm thick polypropylene (PP) throughout. The pipelines are both divided into two segments, being split at the McAdam Tee. PL1924 & PL1927 are laid in the same trench between Hawksley EM and McAdam MM. Between the McAdam Tee and Murdoch MD the pipelines are piggybacked. The pipelines are both connected to McAdam MM and McAdam Tee at about KP12 along the pipeline (Figure A2.7.1). Outside of the surface laid areas at Hawksley EM & McAdam MM survey data has indicated that both PL1922 & PL1925 exhibit a good depth of burial and excellent depth of cover throughout their length. Any exposures occur locally to the end terminations and the expectation is that these would be removed along with the pipeline ends.

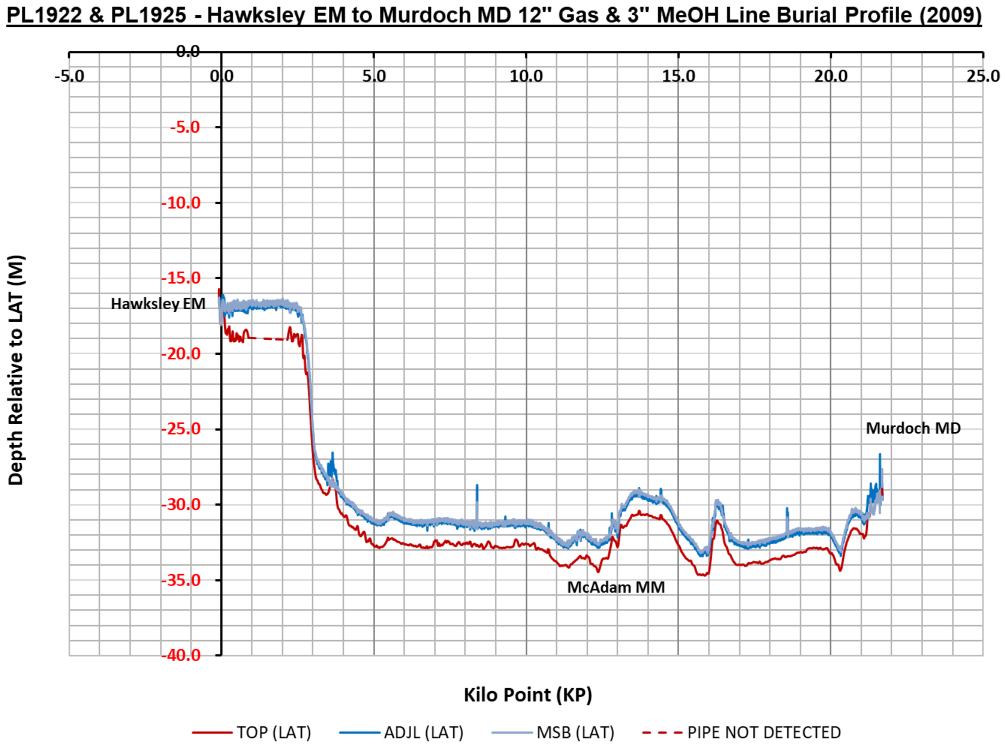


Figure 3.5.1: PL1922 & PL1925 seabed & burial profile ~KP-0.085 to ~KP21.75 (2009)

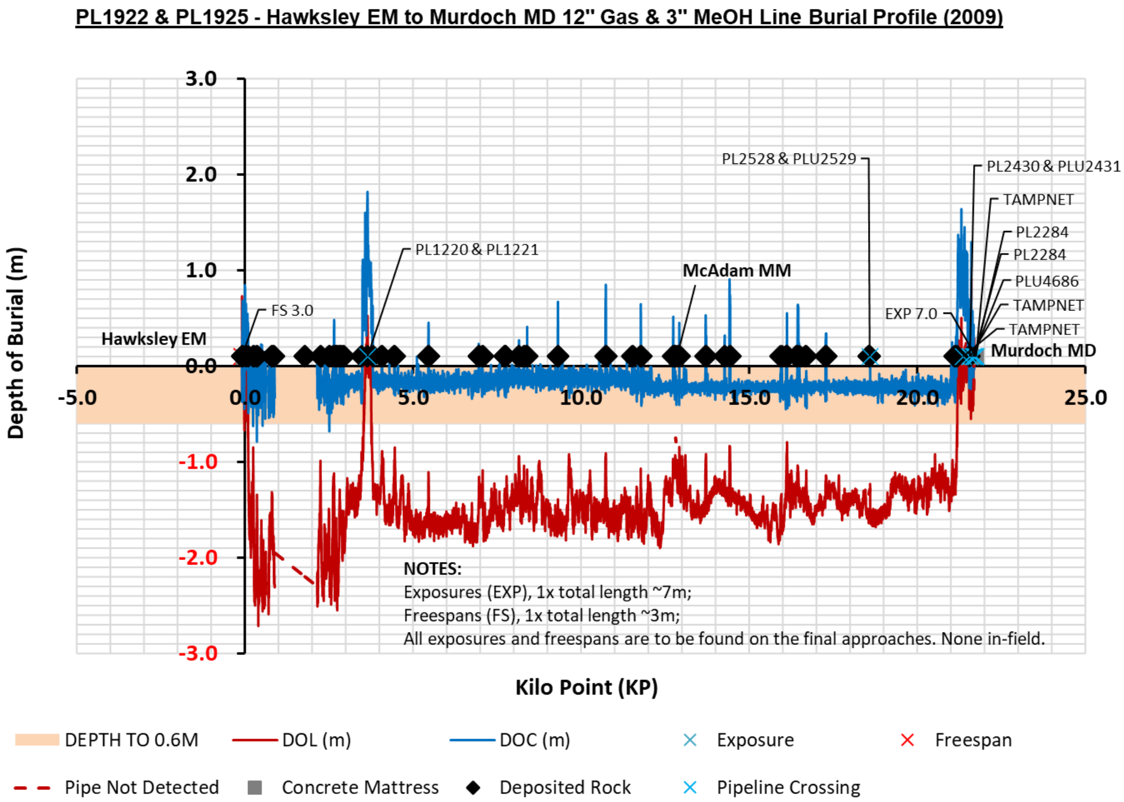


Figure 3.5.2: PL1922 & PL1925 depth of cover profile ~KP-0.08 to ~KP21.75 (2009)

The pipelines encounter a few pipeline and umbilical crossings en route, and these are described in Table 3.7.1 below.

Pipeline, umbilical or cable description	Location	Protection
OUTSIDE MURDOCH 500M ZONE:		
PL1220/PL1221 Tyne to Trent 20in gas pipeline (PL1922).	KP3.649	5x 6m x 3m x 0.3m concrete mattress, buried under deposited rock.
PL1220/PL1221 Tyne to Trent 20in gas pipeline (PL1925).	KP3.649	1x 6m x 3m x 0.3m concrete mattresses side by side, buried under deposited rock.
PL2528 & PLU2529 Rita to Hunter 8in gas pipeline and Hunter to Rita 100mm diameter umbilical.	KP18.7	Deposited rock; details not known.
INSIDE MURDOCH 500M ZONE:		
Tampnet fibre-optic cable underneath PL1922 & PL1925.	KP21.361	3x 6m x 3m x 0.3m concrete mattresses side by side; refer Figure A2.1.1.
PL2430 & PLU2431 Kelvin TM pipelines.	KP 21.565	Refer Table 3.9.1, Figure A2.1.1.
Tampnet fibre-optic cable underneath PL1922 & PL1925.	KP21.578	2x 6.6m x3m x 0.3m fronded mattresses; Figure A2.1.1.
PLU4686 Murdoch MA to McAdam MM umbilical.	KP21.613	Refer Table 3.11.1, Figure A2.1.1.
PL2284 Cavendish CM 10in & 2in pipelines.	KP21.687 & KP21.738	Not specified. Refer Cavendish decommissioning programmes [15] which states that these will be fully removed. Figure A2.1.1.
Tampnet fibre-optic cable underneath PL1922 & PL1925.	KP21.747	~2x 6m x 3m x 0.3m concrete mattresses; refer Figure A2.1.1.
NOTE 1. Origin of KP for PL1922 (& PL1925) taken at the end of the pipeline at Hawksley EM; 2. PL2528 & PLU2529 have not been identified in pipeline surveys. Data obtained from OGA National Data Repository (NDR).		

Table 3.5.1: PL1922 & PL1925 pipeline crossings

McAdam MM is provided with power from Murdoch MA using umbilical PLU4868 (~9.2km long), and Hawksley EM is provided with power via McAdam MM using umbilical PLU4685 (~13km long). Both of these umbilicals are discussed separately.

3.6 PL1923 & PL1926 Murdoch K.KM pipelines

Murdoch K.KM (Figure A2.9.1) comprises a subsea installation that is tied back to the Pigging Skid Northern Lobe (PSNL) using PL1923 and PL1926. PL1923 is a 10in carbon steel pipeline and PL1926 is a 3in carbon steel pipeline. PL1923 is piggybacked by PL1926 and both pipelines are ~5.25km long and coated with 2.3mm thick polypropylene (PP) throughout.

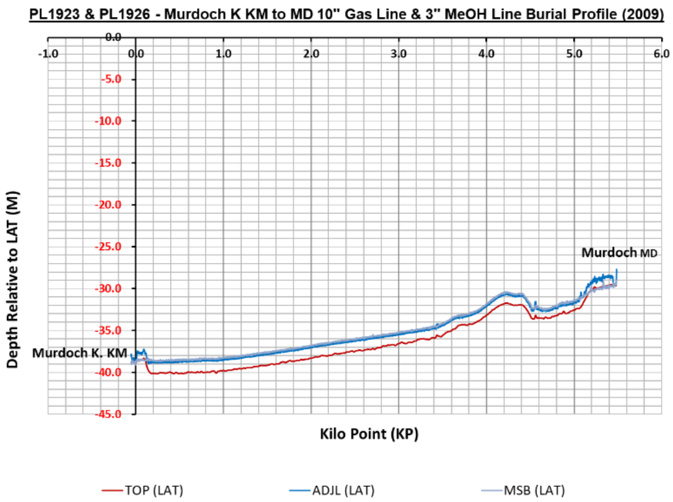


Figure 3.6.1: PL1923 & PL1926 seabed & burial profile ~KP-0.05 to ~KP5.49 (2009)

Outside of the surface laid areas at Murdoch K.KM and PSNL survey data has indicated that both PL1923 & PL1926 exhibit a good depth of burial and excellent depth of cover throughout their length. Any exposures occur locally to the end terminations and the expectation is that these would be removed along with the pipeline ends.

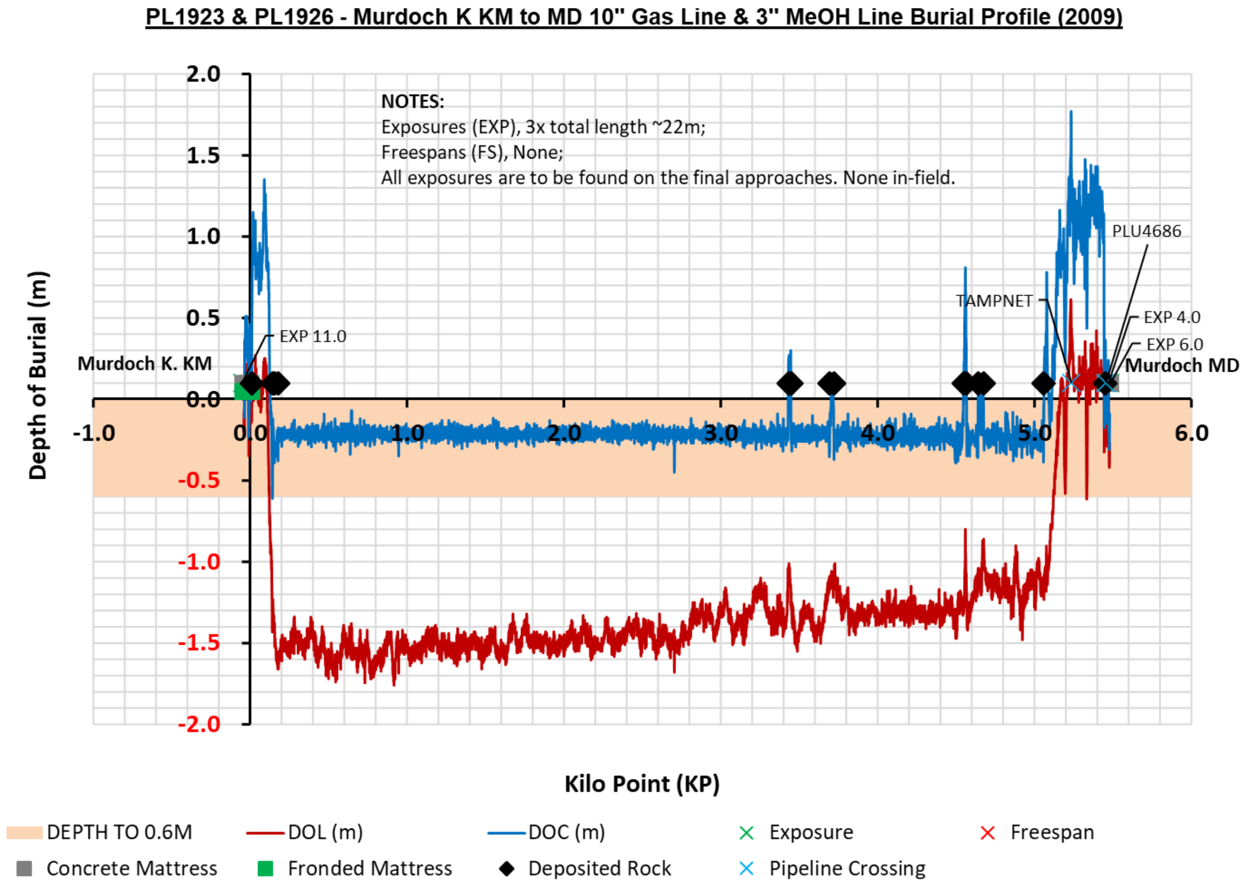


Figure 3.6.2: PL1923 & PL1926 depth of cover profile ~KP-0.05 to ~KP5.49 (2009)

The pipelines encounter just one umbilical crossing en route, and these are described in Table 3.6.1 below.

Pipeline, umbilical or cable description	Location	Protection
INSIDE MURDOCH 500M ZONE:		
Tampnet fibre-optic cable underneath PL1923 & PL1926.	KP5.236	Refer Table 3.13.1, Figure A2.1.1.
PLU4686 Murdoch MA to McAdam MM umbilical.	KP5.465	Refer Table 3.11.2, Figure A2.1.1.
NOTE 1. Origin of KP for PL1923 (& PL1926) taken at the end of the pipeline at Murdoch K.KM.		

Table 3.6.1: PL1923 & PL1926 pipeline crossings

Murdoch K.KM is provided with power from Murdoch MA using umbilical PLU4890 (~5.9km long), and this is discussed separately.

3.7 PL1924 & PL1927 Boulton HM pipelines

Boulton HM (refer Figure A2.5.1) comprises a subsea installation that is tied back to the Cavendish Subsea Pigging Skid otherwise known as the Pigging Skid Southern Lobe (PSSL) using PL1924 and PL1927. PL1924 is a 10in carbon steel pipeline and PL1927 is a 3in carbon steel pipeline. Each pipeline is ~16.8km and ~16.9km long respectively and coated with 2.3mm thick polypropylene (PP) throughout. PL1924 is piggybacked throughout by PL1927. Both pipelines are connected to Watt QM about half-way along. No exposures have been evident from the pipeline surveys; the survey data has indicated that both PL1924 & PL1927 exhibit a good depth of burial and excellent depth of cover throughout their length. Any exposures or spans occur locally at Watt QM or Murdoch MD. The expectation is that these would be removed along with the installations.

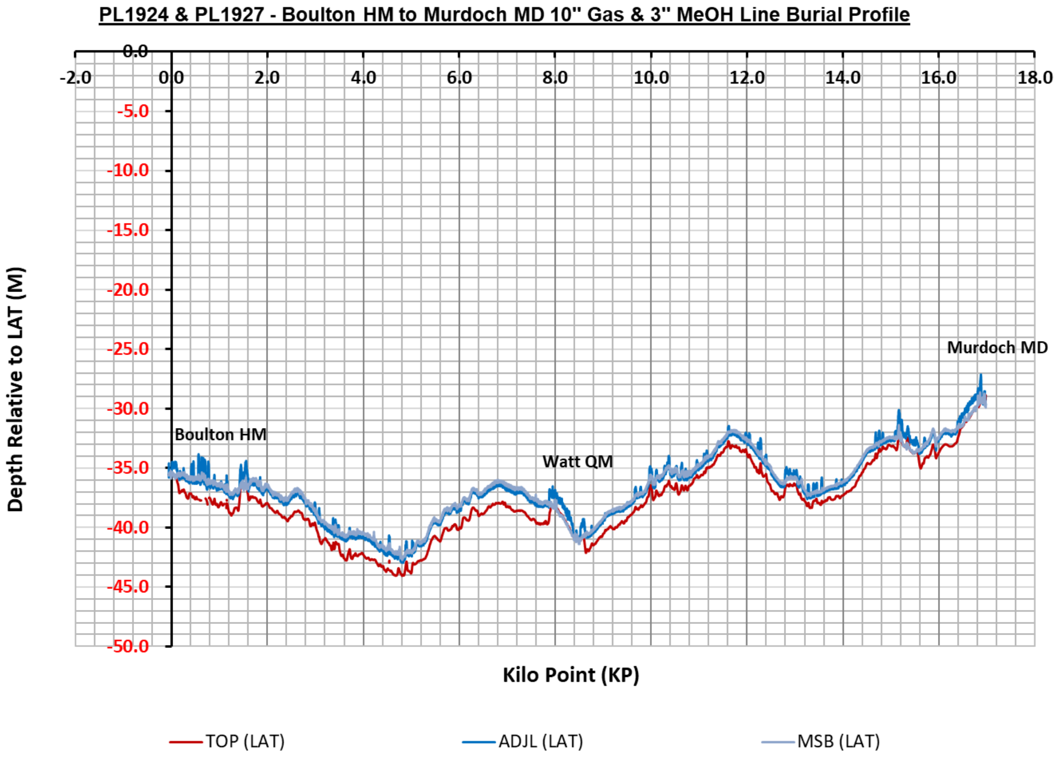


Figure 3.7.1: PL1924 & PL1927 seabed & burial profile ~KP-0.05 to ~KP16.98 (2009)

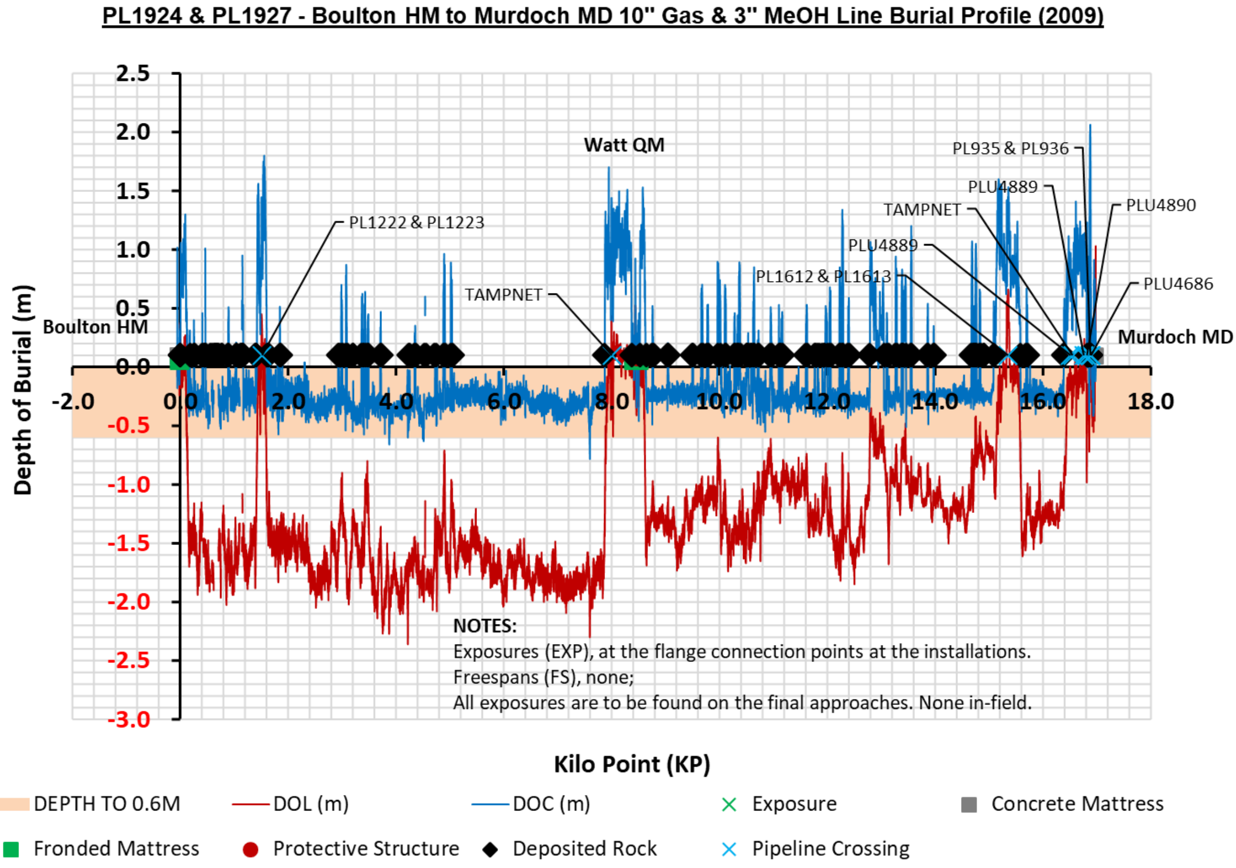


Figure 3.7.2: PL1924 & PL1927 depth of cover profile ~KP-0.05 to ~KP16.98 (2009)

They encounter several pipeline and umbilical crossings along their route, and these are described in Table 3.7.1 below.

Pipeline, umbilical or cable description	Location	Protection
OUTSIDE MURDOCH 500M ZONE:		
PL1222 & PL1223 Schooner 16in gas and 3in MeOH pipeline.	KP1.581	Shared with PLU4888. Refer Table 3.12.1.
Tampnet fibre-optic cable underneath both PL1924 & PL1927.	KP8.009	Shared with PLU4888. Refer Table 3.12.1.
PL1612 & PL1613 Ketch 18in gas and 3in MeOH pipelines.	KP15.351	29x 6m x 3m x 0.3m concrete mattresses buried under deposited rock.
INSIDE MURDOCH 500M ZONE:		
Tampnet cable under both PL1924 & PL1927.	KP16.548	3x 6m x 3m x 0.3m concrete mattresses buried under deposited rock.
PLU4890 Murdoch MA to Murdoch K.KM umbilical.	KP16.815	Refer Table 3.13.1.
PL935 & PL936 Caister CM pipelines.	KP16.879	8x fronded mattresses 6.6m x 3m x 0.3m.
PLU4686 Murdoch MA to McAdam MM umbilical.	KP16.892	2x 6m x 3m x fronded mattresses; refer Figure A2.1.1
NOTE 1. Origin of KP for PL1924 (& PL1927) taken at the end of the pipeline at Boulton HM.		

Table 3.7.1: PL1924 & PL1927 pipeline crossings

Boulton HM is provided with power from Watt QM using umbilical PLU4889 (~8.6km long), and this is discussed separately.

3.8 PL2109 & PL2110 Munro MH Pipelines

Munro MH (refer Figure A2.4.1) comprises a single surface installation that is tied back to Hawksley EM (Ref Figure A2.6.1) via PL2109 and PL2110. PL2109 is a 10in carbon steel pipeline ~5.0km long that is coated with an FBE coating, on top of which lies a concrete weight coating (CWC) throughout its length. The riser at Munro MH is protected using TSA supplemented with 12.5mm thick polychloroprene (PCP) in the splash zone. PL2110 is a 3in carbon steel pipeline that is also ~5.0km long coated with 3LPP throughout its length except for the riser at Munro MH which is protected using TSA. PL2109 is piggybacked by PL2110 throughout its length. There are no pipeline crossings associated with PL2109 or PL2110. In an attempt to minimise the environmental impact of excavation during installation the pipelines were furnished with ‘spoilers’ to promote self-burial. Survey data has indicated that after the first 1.5km both PL2109 & PL2110 exhibit a good depth of burial and excellent depth of cover throughout their length. A year-on-year comparison can be made for the surveys in 2009, 2012 and 2015 & 2017 combined, and the indications are that the number and length of exposures appears to fluctuate. Arguably given the bathymetry this to be expected. The exposures observed in the surveys over the years are presented in Appendix 1.2, Table A1.2.1; two of them appear to occur at dips in the seabed, possibly between sand waves or sand banks. No recordable spans have been noted.

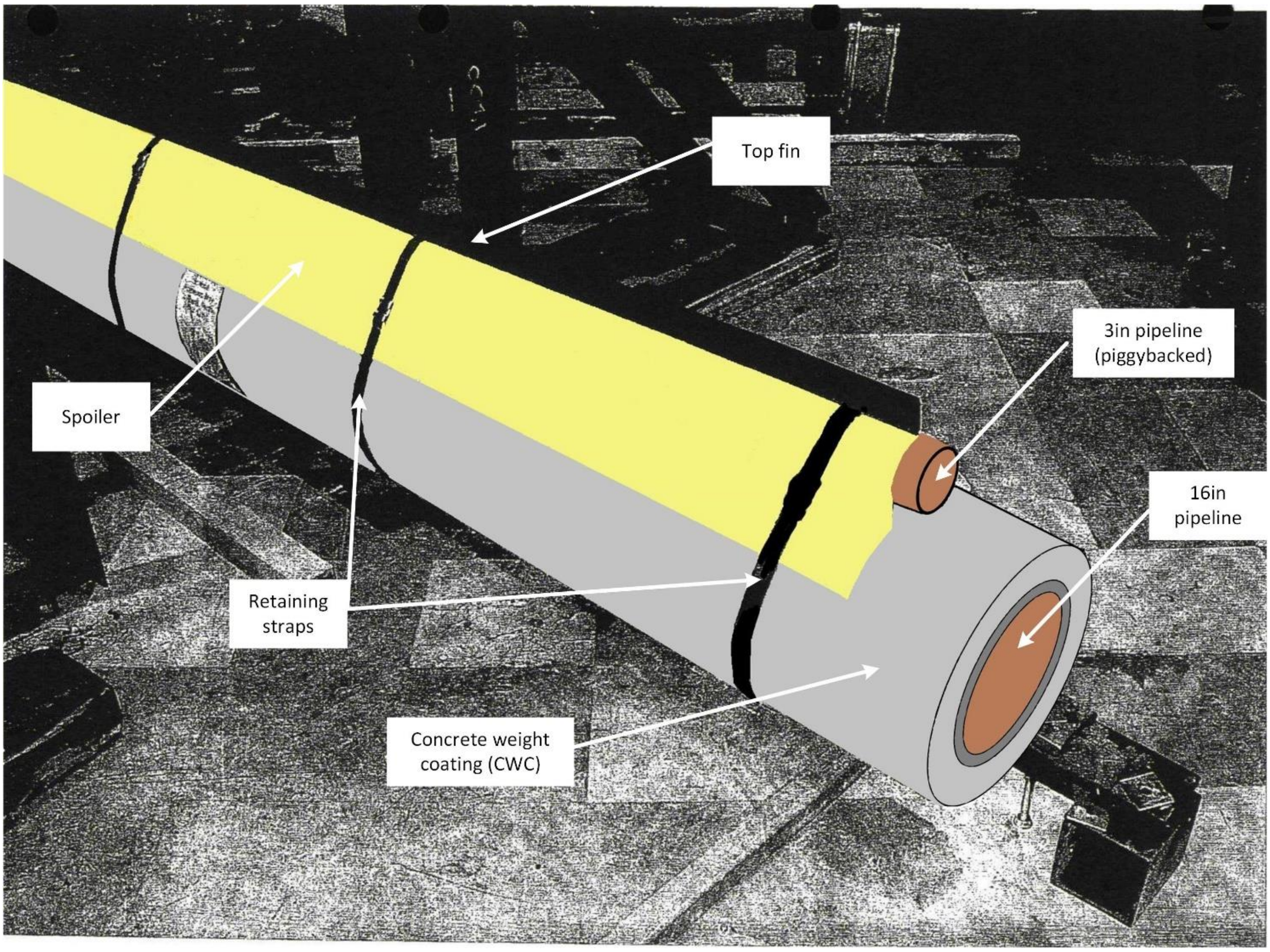


Figure 3.8.1: PL2109 & PL2110 pipeline spoilers

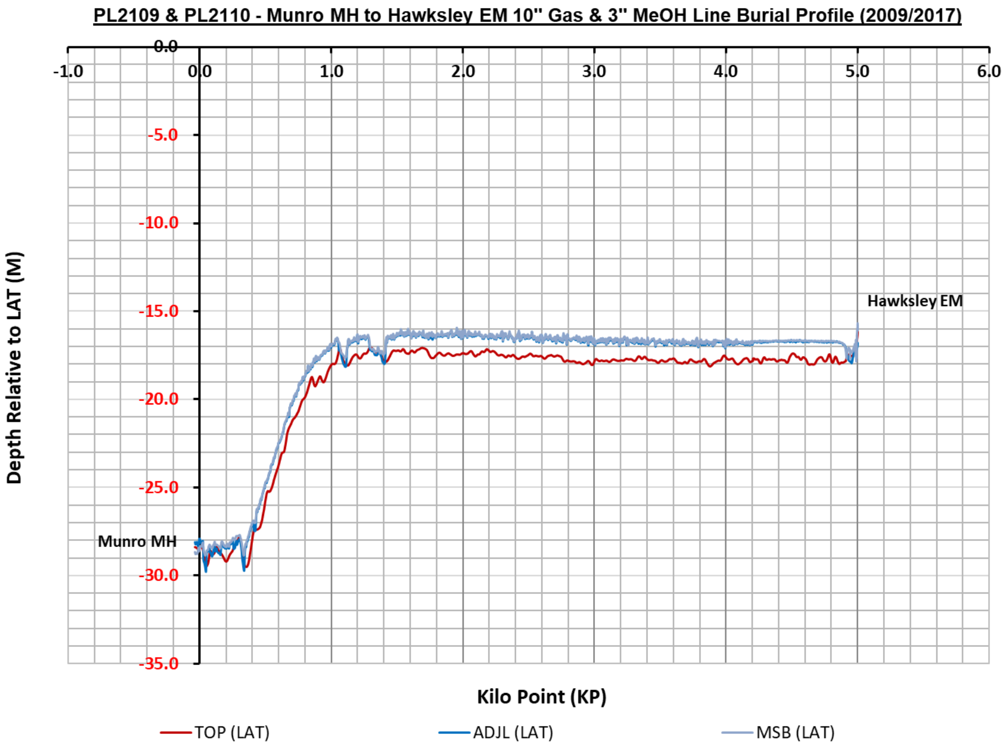


Figure 3.8.2: PL2109 & PL2110 seabed & burial profile ~KP-0.05 to ~KP16.98 (2009/17)

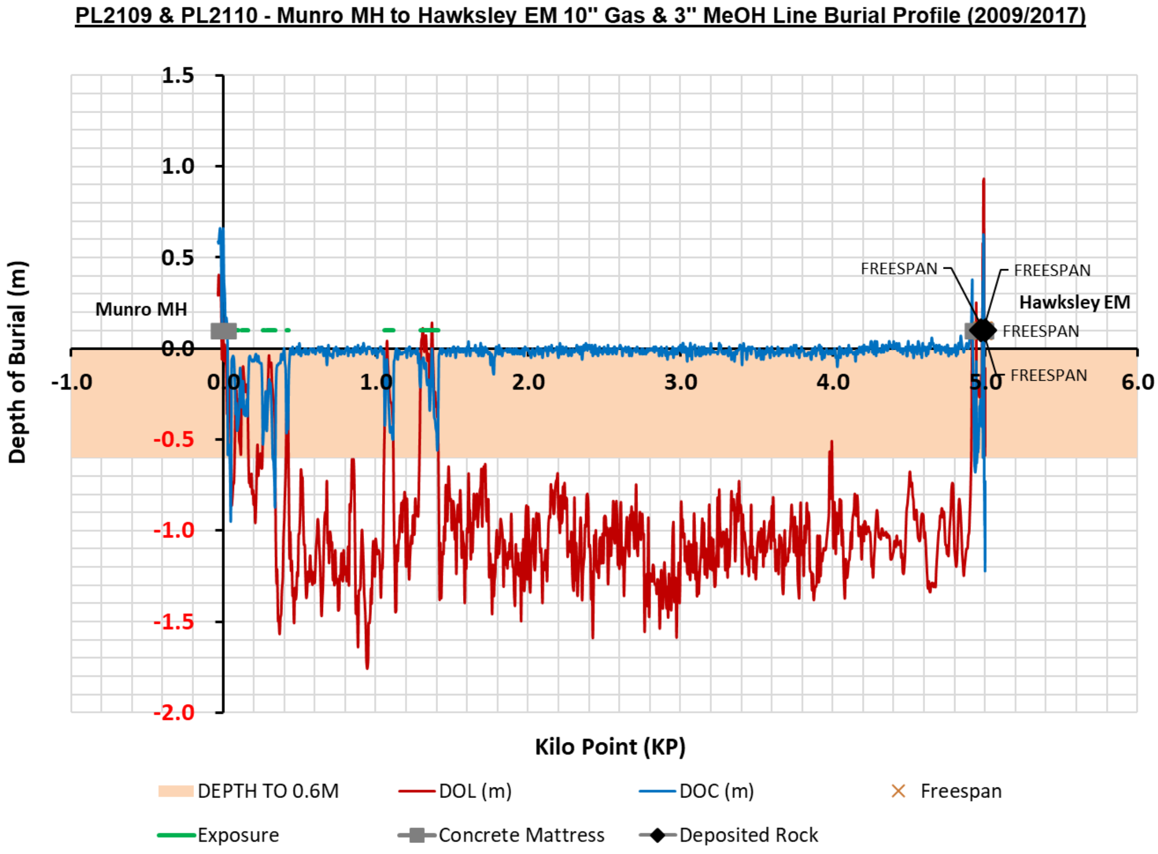


Figure 3.8.3: PL2109 & PL2110 depth of cover profile ~KP-0.05 to ~KP16.98 (2009/17)

No pipeline or umbilical crossings are encountered by PL2109 or PL2110.

3.9 PL2430 & PLU2431 Kelvin TM pipelines

Kelvin TM (Figure A2.10.1) comprises a single surface installation that is tied back via the Kelvin Subsea Tee Assembly and the Kelvin-Murdoch Subsea Pigging Skid to the PSSL using PL2430 and PLU2431. PL2430 is a 12in carbon steel pipeline ~12.7km long, coated with 2.5mm thick 3LPP throughout its length. It is piggybacked by PLU2431, a 3in carbon steel pipeline that is also coated with 2.5mm thick 3LPP. PLU2431 is ~12.7km long. Survey data indicates a good depth of burial and good depth of cover throughout the length of the pipelines except for surface laid sections and the pipeline crossings.

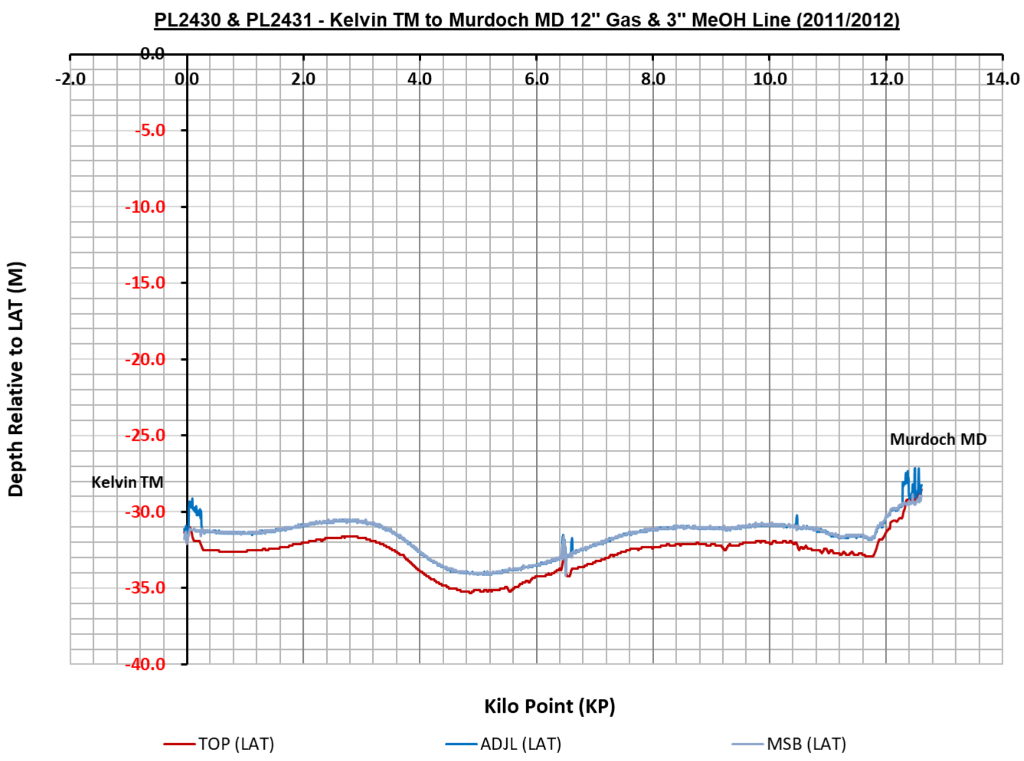


Figure 3.9.1: PL2430 & PLU2431 seabed & burial profile ~KP-0.05 to ~KP12.62 (2011/12)

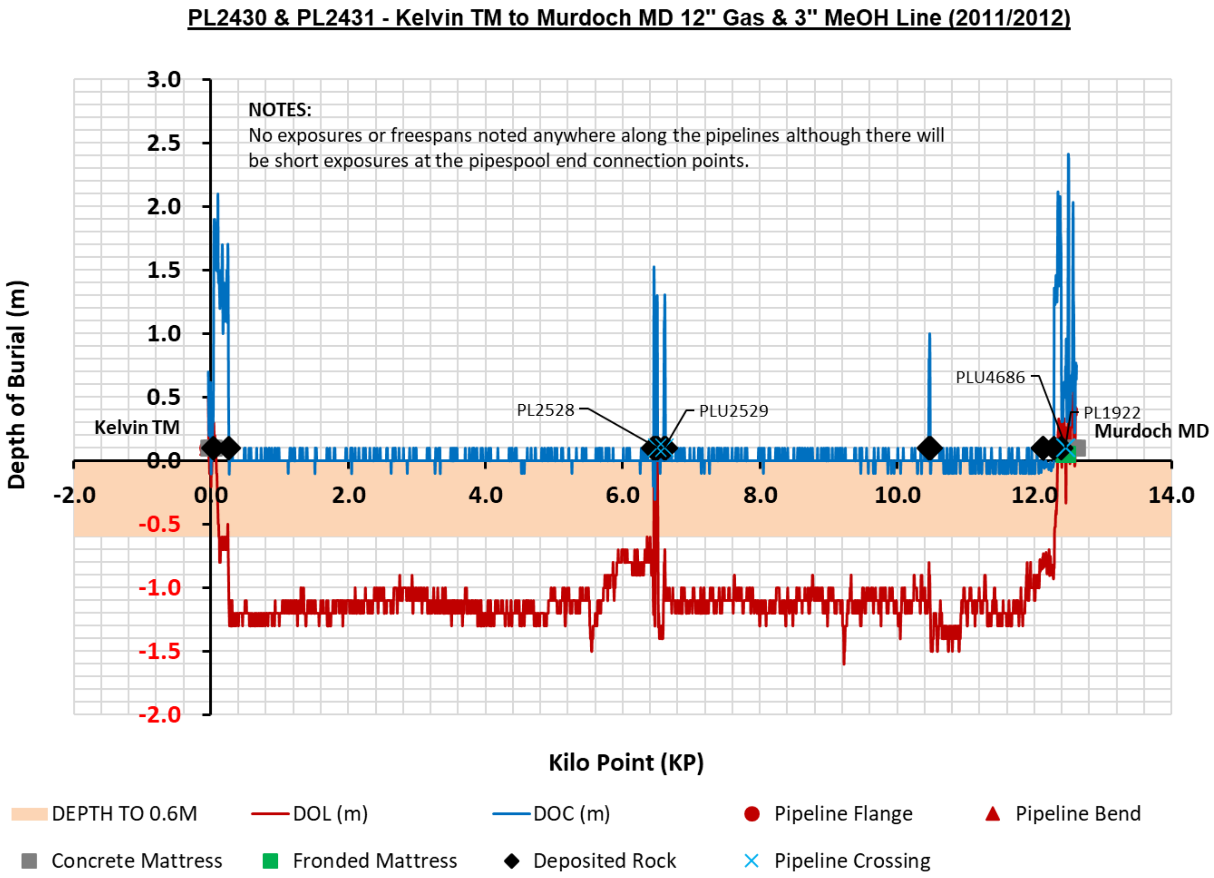


Figure 3.9.2: PL2430 & PLU2431 depth of cover profile ~KP-0.05 to ~KP12.62 (2011/12)

A couple of crossings are located midway along the pipelines while the remainder occur within the Murdoch 500m zone, and these are summarised in Table 3.9.1 below.

Pipeline, umbilical or cable description	Location	Protection
OUTSIDE MURDOCH 500M ZONE:		
PL2528 Rita to Hunter 8in gas pipeline	KP6.467	Deposited rock; details unknown.
PLU2529 Hunter to Rita 100mm umbilical	KP6.610	Deposited rock; details unknown.
INSIDE MURDOCH 500M ZONE:		
PL1922 & PL1925 Hawksley EM & McAdam MM 12in & 3in pipelines	KP12.457	5x 6m x 3m x 0.3m concrete mattresses; refer Figure A2.1.1.
PLU4686 Murdoch MA to McAdam MM umbilical	KP12.468	
NOTE 1. Origin of KP for PL2430 & PLU2431 taken at the end of the pipeline at Kelvin TM.		

Table 3.9.1: PL2430 & PLU2431 pipeline crossings

3.10 PL2894 & PL2895 Katy KT pipelines

Katy KT (refer Figure A2.11.1) comprises a single surface installation that is tied back via the Katy tee to the Kelvin Pigging Manifold Assembly (PMA) using PL2894 before commingling with the gas from Kelvin along PL2430. PL2894 is a 10in carbon steel pipeline ~14.1km long, coated with 3LPP throughout its length except for the riser at Katy KT which is protected using TSA supplemented with 12.5mm thick polychloroprene (PCP) in the splash zone. PL2894 is piggybacked by PL2895 which is a 2in carbon steel pipeline coated with 3-layer polyethylene (LPE) throughout its length. The PL2895 pipespools at each end are 3in nominal bore. Survey data indicates a good depth of burial and good depth of cover throughout the length of the pipelines except for surface laid sections at the approaches. Any exposures occur locally to Katy KT and the expectation is that these would be removed along with the pipeline ends.

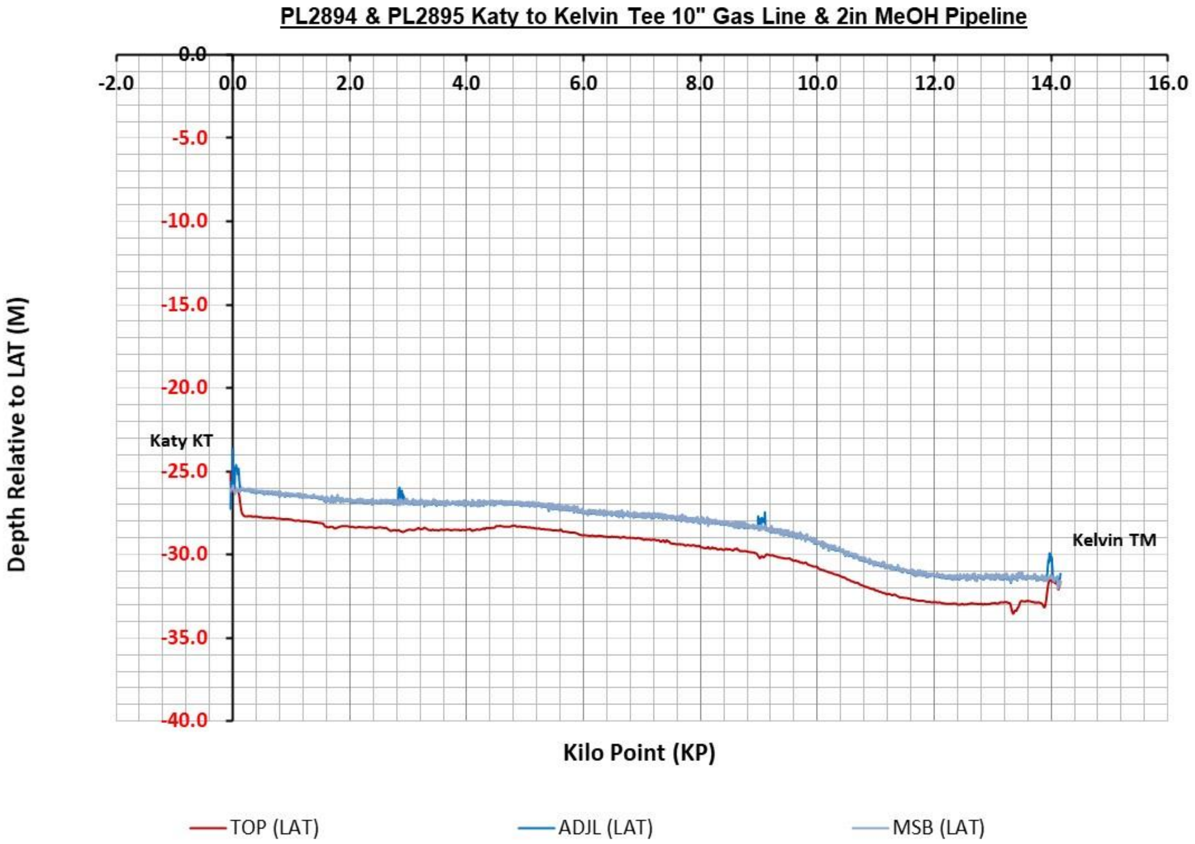


Figure 3.10.1: PL2894 & PLU2895 seabed & burial profile ~KP-0.04 to ~KP14.16 (2013)

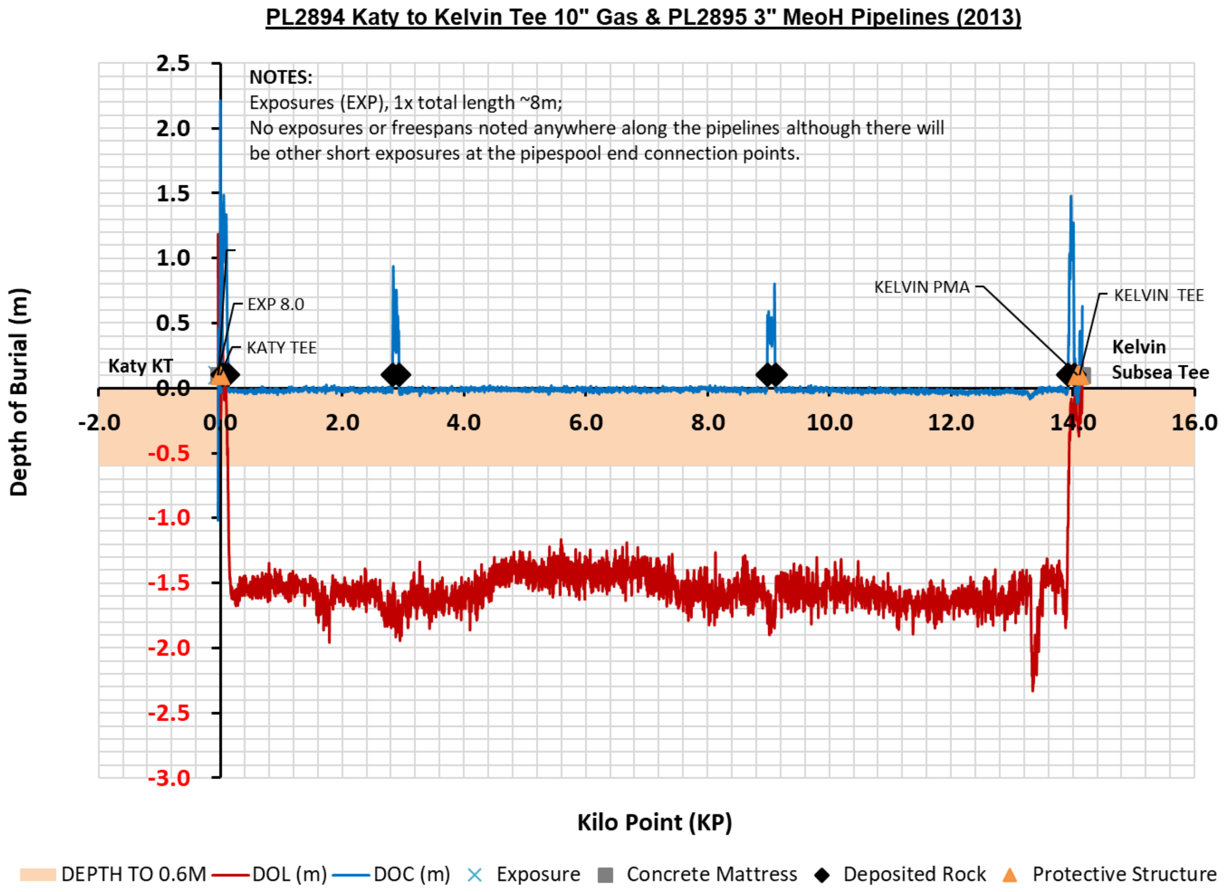
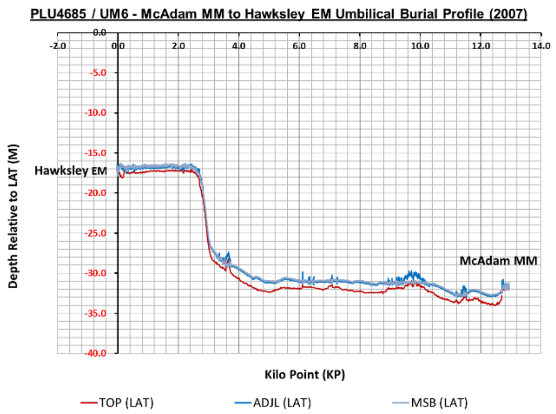


Figure 3.10.2: PL2894 & PL2895 depth of cover profile ~KP-0.04 to ~KP14.16 (2013)

There are no pipeline crossings associated with either PL2894 or PL2895.

3.11 PLU4686 & PLU4685 Murdoch MA to Hawksley EM via McAdam MM umbilicals

PLU4686 (108.5mm dia.) and PL4685 (108.5mm dia.) are umbilicals that provide electrohydraulic power from Murdoch MA to McAdam MM and then onto Hawksley EM. They are ~9.2km and ~13.0km long respectively. The survey data show that both umbilicals exhibit good depth of burial and depth of cover (Figure 3.11.2 & Figure 3.11.3). However, on two occasions PLU4685 has exhibited intermittent exposures or freespans. In 2007, 3x exposures (6m, 10m and 3m long – total length ~19m) were observed between KP0.047 and KP0.240 and 1x exposure ~2m long was observed on approach to McAdam MM (Figure 3.11.3). In 2011, 1x exposure ~8m long was found at KP0.028, and 3x freespans (3m, 4.5m, and 11.4m long – total length ~19m) and 1x exposure (33m long) were observed between KP0.222 and ~KP0.280 near Hawksley (Figure 3.11.5 & Figure 3.11.6).



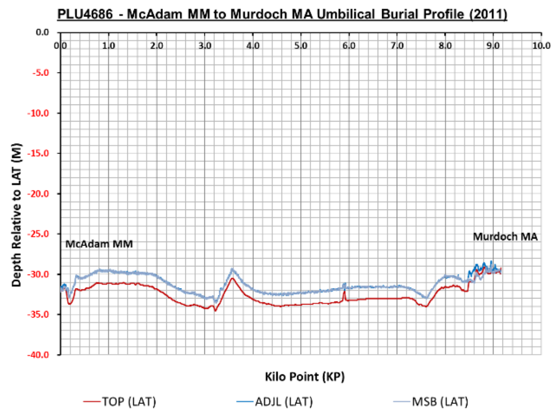


Figure 3.11.1: PLU4685 & PLU4686 seabed & burial profile (2007, 2011)

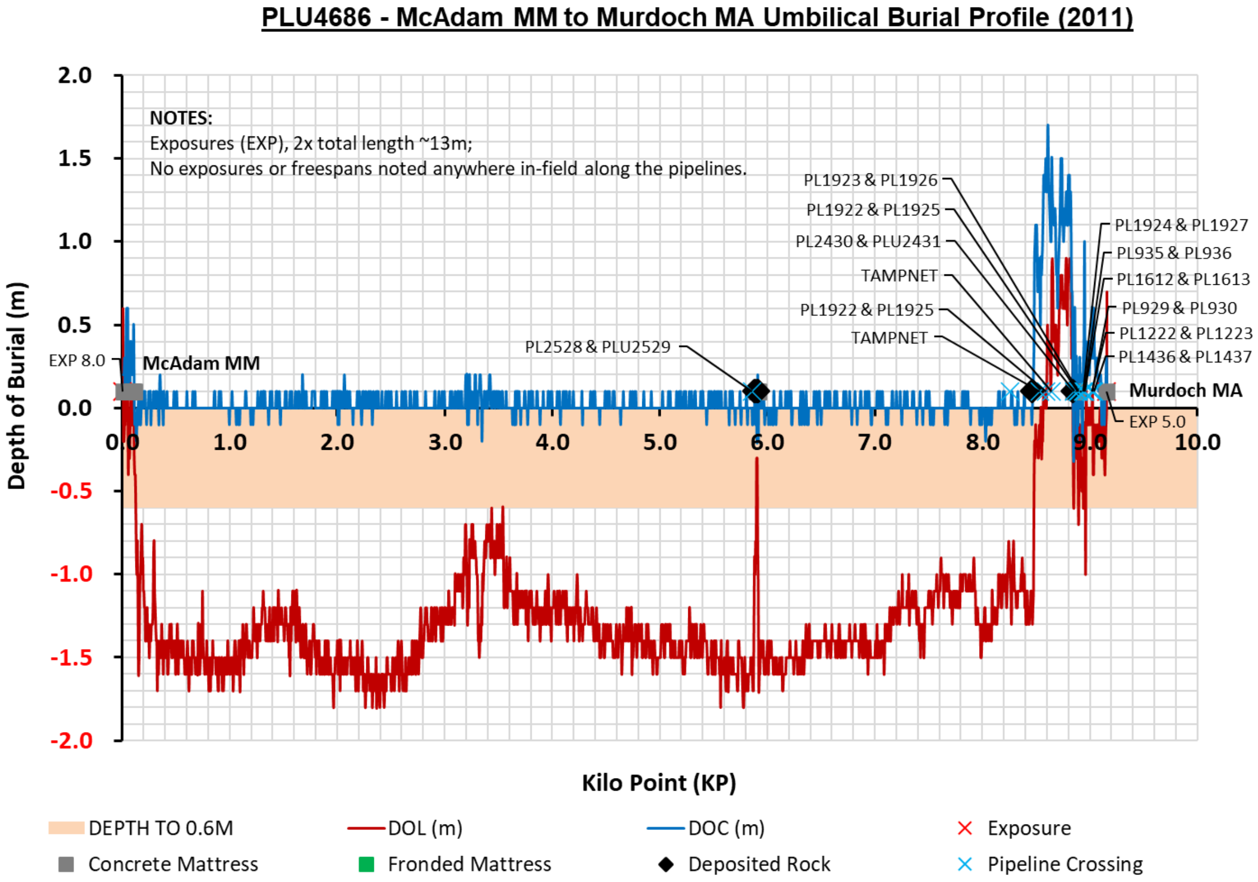


Figure 3.11.2: PLU4686 depth of cover profile ~KP0.0 to ~KP9.16 (2011)

PLU4686 encounters several pipeline and umbilical crossings along their route, and these are described in Table 3.11.1 below.

Pipeline, umbilical or cable description	Location	Protection
OUTSIDE MURDOCH 500M ZONE:		
PL2528 & PLU2529 PL2528 Rita to Hunter 8in gas pipeline Hunter to Rita 100mm umbilical.	KP5.858	Deposited rock. Details not known.
INSIDE MURDOCH 500M ZONE		
Tampnet fibre-optic cable underneath PL4686.	KP8.104	2x (total) 6.6m x 3m x 0.3m fronded mattresses buried under deposited rock; refer Figure A2.1.1.
Tampnet fibre-optic cable underneath PL4686.	KP8.260	3x (total) 6.6m x 3m x 0.3m fronded mattresses buried under deposited rock, shared with PL1922 & PL1925; refer Figure A2.1.1
Tampnet fibre-optic cable underneath PL4686.	KP8.572	1x 6m x 3m x 0.3m concrete mattress; refer Figure A2.1.1.
PL2430 & PLU2431 Kelvin TM 12in & 3in pipelines.	KP8.854	2x 6m x 3m x 0.3m concrete mattress; refer Figure A2.1.1.
PL1922 & PL1925 McAdam MM 10in & 3in pipelines.	KP8.884	1x 6.6m x 3m x 0.3m fronded mattress; refer Figure A2.1.1.
PL1923 & PL1926 Murdoch K.KM 10in & 3in pipelines.	KP8.893	1x 6.6m x 3m x 0.3m fronded mattress; refer Figure A2.1.1.
PL1924 & PL1927 Boulton HM 10in & 3in pipelines.	KP8.938	1x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1.

Pipeline, umbilical or cable description	Location	Protection
PL935 & PL936 Caister CM 16in & 3in pipelines.	KP8.941	2x 6m x 3m x 0.3m concrete mattresses laid end on end; refer Figure A2.1.1; crossing protection shared with PLU4890.
PL1612 & PL1613 Ketch 18in & 3in pipelines.	KP8.949	2x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1; protection shared with PLU4890.
PL1222 & PL1223 Schooner 16in & 3in pipelines.	KP9.023	2x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1; protection shared with PLU4890. Refer Table 3.13.1.
PL929 & PL930 Murdoch MD 26in & 4in trunklines.	KP9.034	2x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1. Crossing protection shared with PLU4889 & PLU4890. Refer Table 3.12.2 & Table 3.13.1.
PL1436 & PL1437 Boulton BM 10in & 3in pipelines.	KP9.112	2x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1. Crossing protection shared with PLU4889 & PLU4890. Refer Table 3.12.2 & Table 3.13.1
NOTE 1. Origin of KP for the umbilical taken at McAdam MM.		

Table 3.11.1: PLU4686 umbilical & pipeline crossings

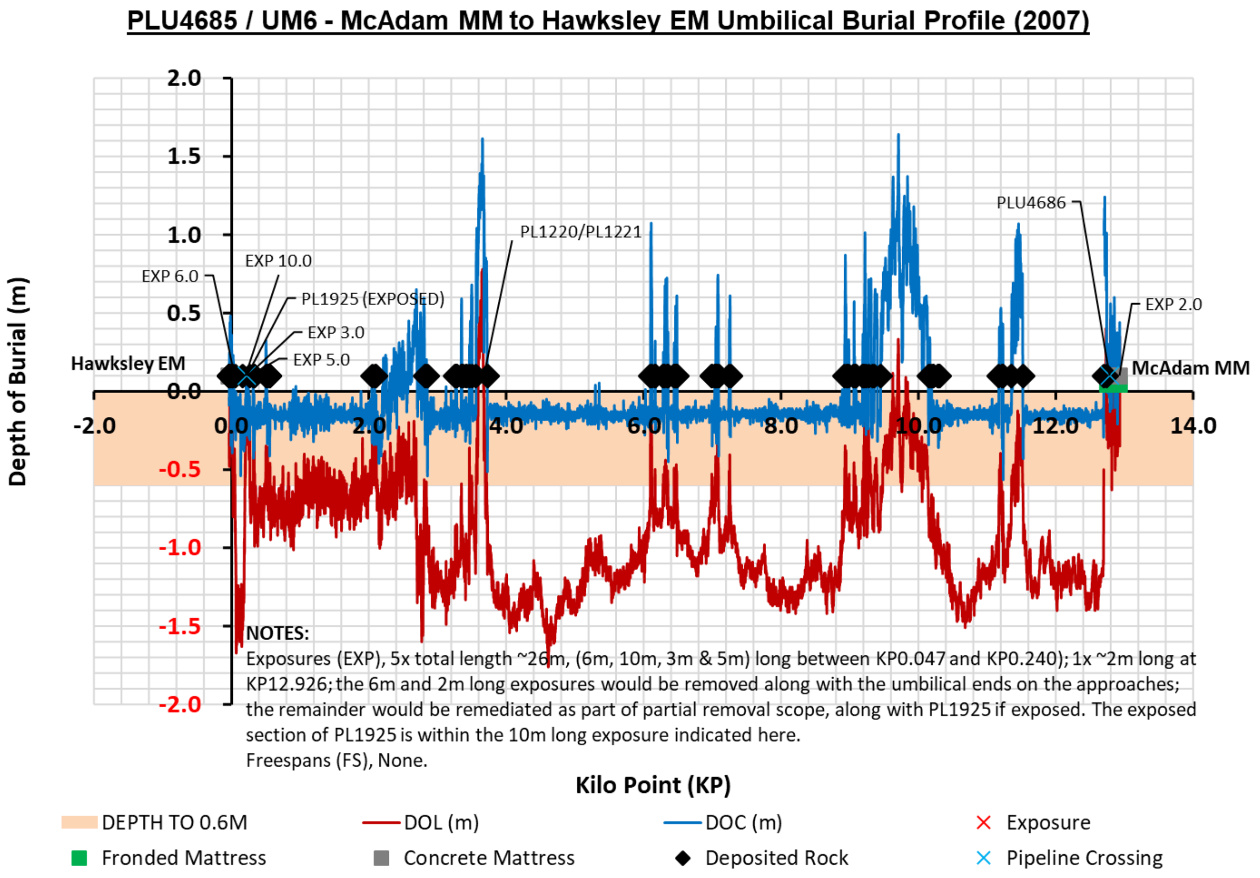


Figure 3.11.3: PLU4685 depth of cover profile ~KP-0.04 to ~KP13 (2007)[14]

[14] Although PL1925 is indicated here as exposed in the survey for PLU4685, it was not noted as being exposed in more recent surveys (section 3.5). The 3.0m freespan indicated in Figure 3.5.1 is at a different location and close to Hawksley EM.

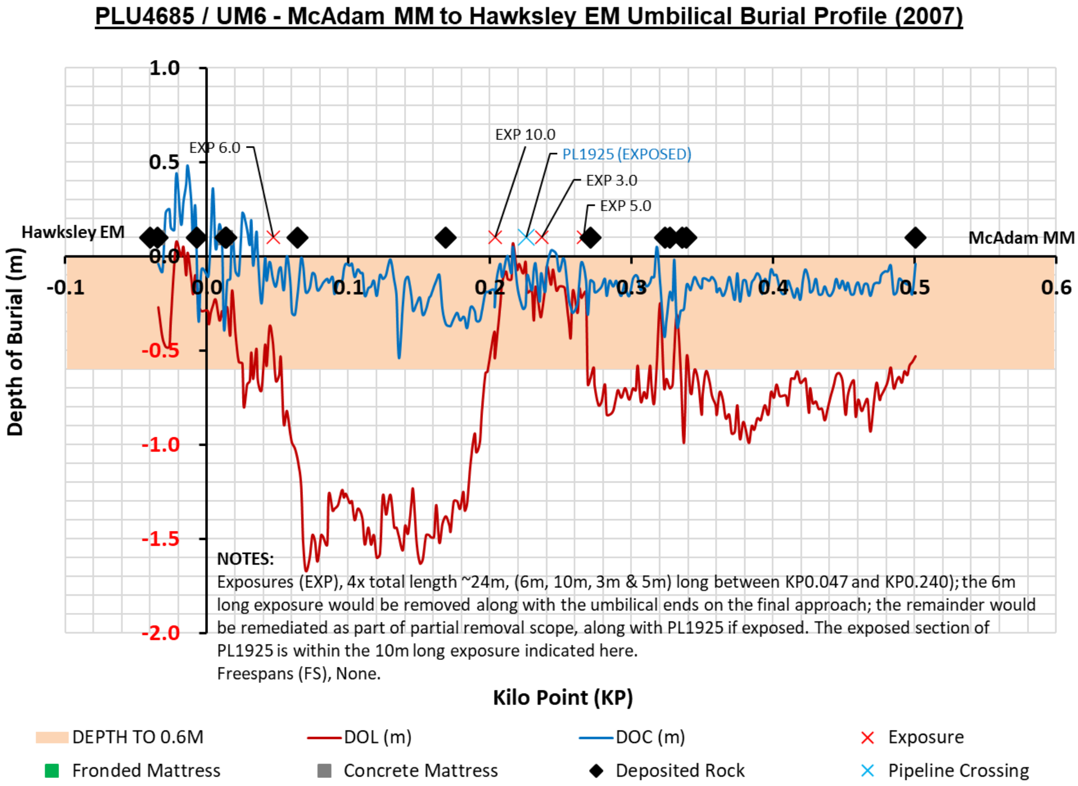


Figure 3.11.4: PLU4685 depth of cover profile ~KP-0.04 to ~KP0.50 (2007)

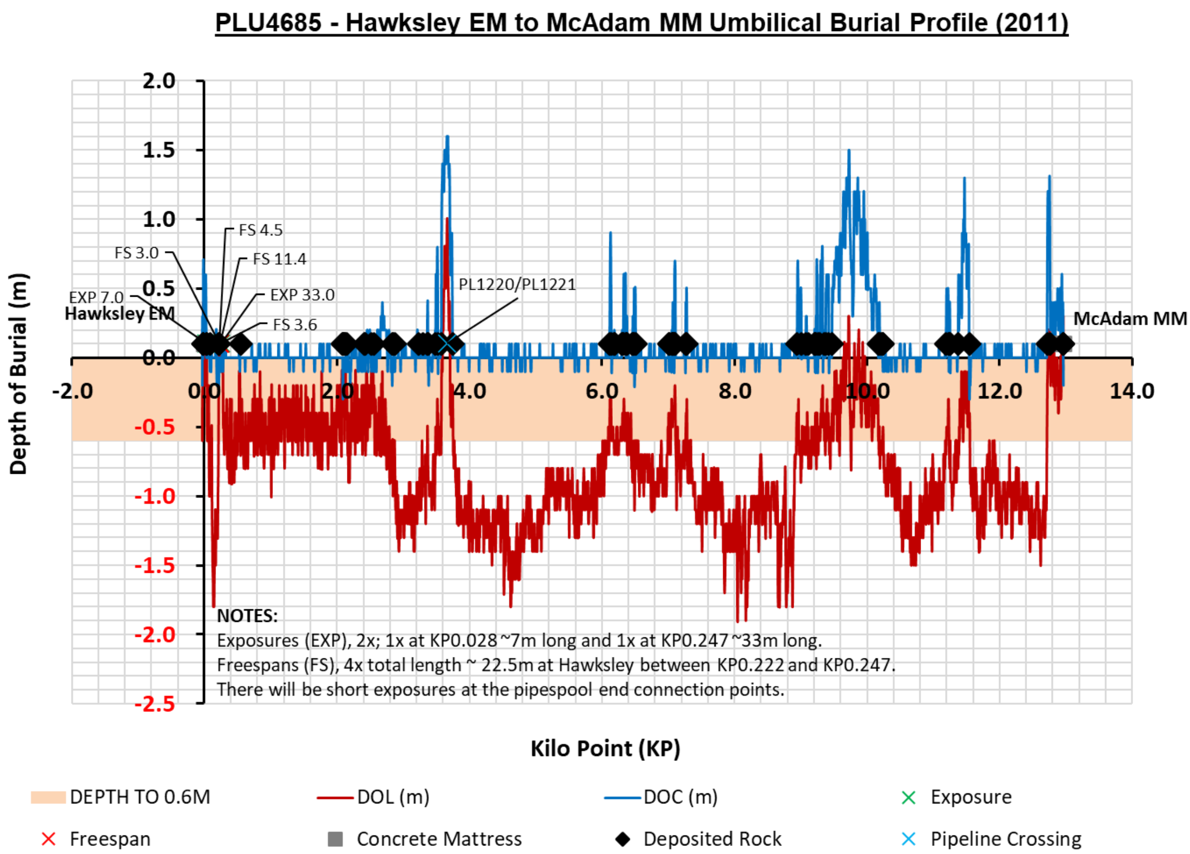


Figure 3.11.5: PLU4685 depth of cover profile ~KP-0.04 to ~KP13 (2011)

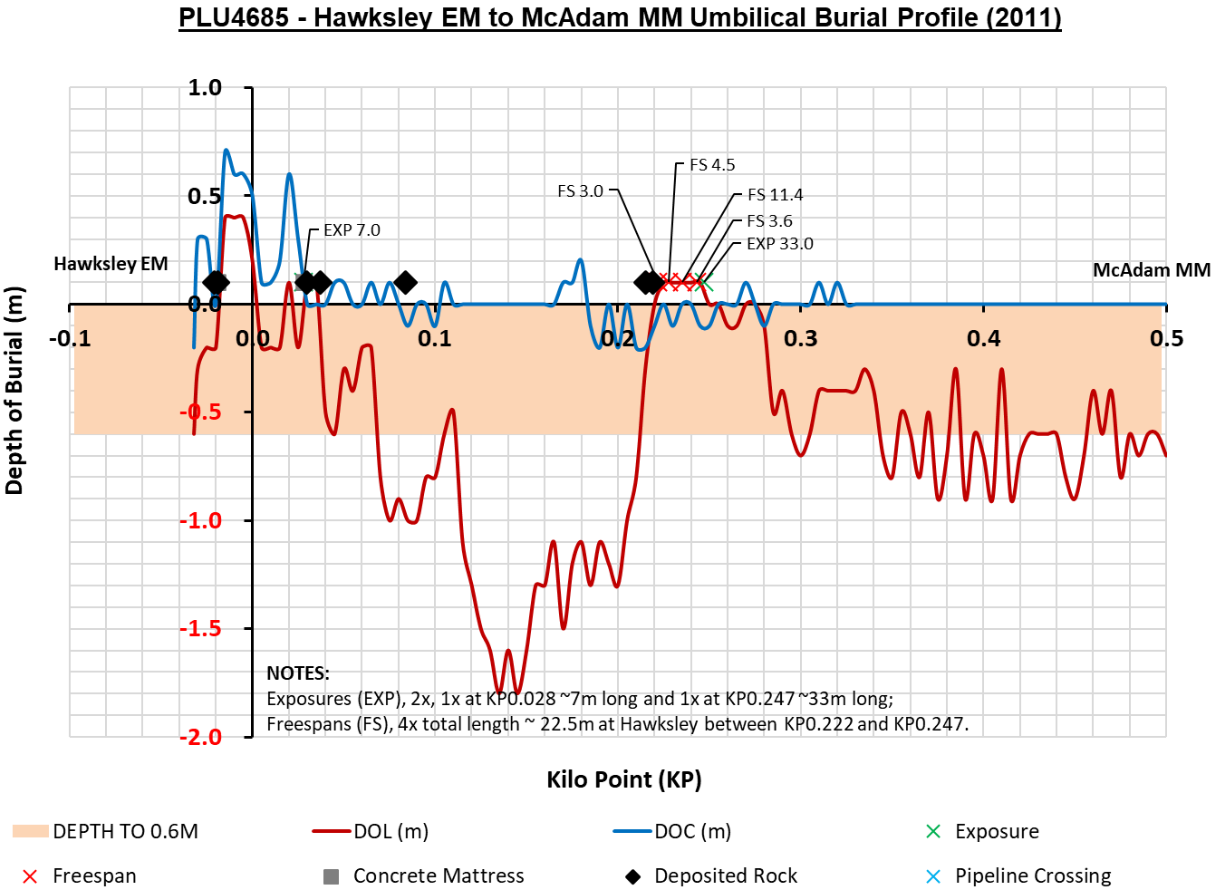


Figure 3.11.6: PLU4685 depth of cover profile ~KP-0.04 to ~KP0.50 (2011)[15]

PLU4685 encounters just one pipeline crossing along its route, and this is described in Table 3.11.2 below.

Pipeline, umbilical or cable description	Location	Protection
OUTSIDE OF MURDOCH 500M ZONE:		
PL1220/PL1221 Tyne to Trent 20in gas pipeline.	KP3.665	Assume ~1x 6m x 3m x 0.3m concrete mattress buried under deposited rock.
NOTE 1. Origin of KP for the umbilical taken at Hawksley EM.		

Table 3.11.2: PLU4685 umbilical & pipeline crossings

3.12 PLU4889 & PLU4888 Murdoch MA to Boulton HM via Watt QM umbilicals

PLU4889 (96mm dia.) and PL4888 (82mm dia.) are umbilicals that provide electrohydraulic power from Murdoch MA to Watt QM and then onto Boulton HM. They are ~8.7km and ~8.6km long respectively. The survey data show that both umbilicals exhibit good depth of burial and depth of cover (Figure 3.12.2 & Figure 3.12.3).

15 The exposure at KP0.028 would be removed along with the umbilical end on the final approach. The other exposures and spans lie within deposited rock.

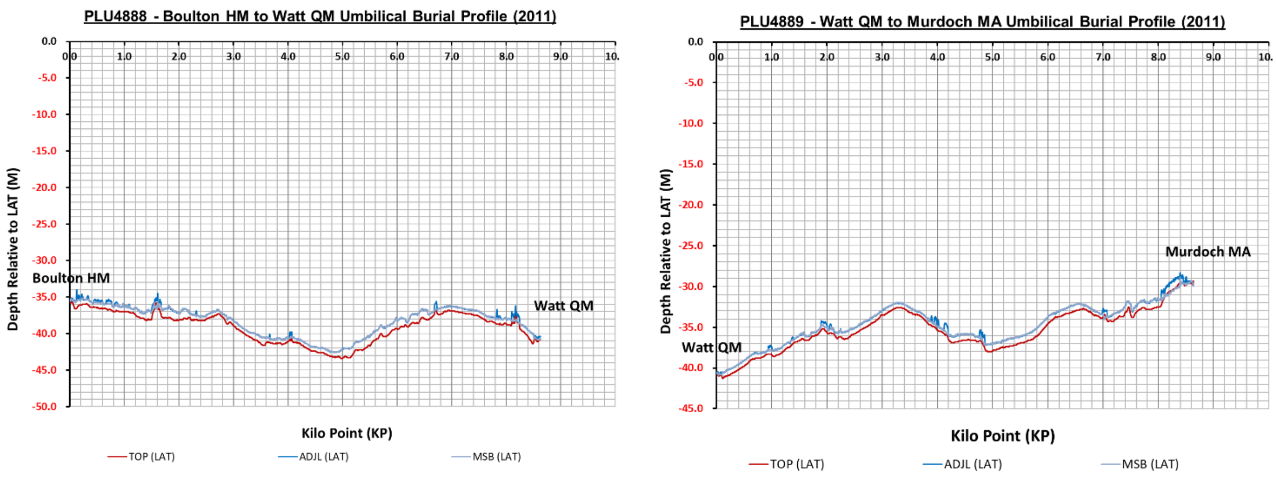


Figure 3.12.1: PLU4688 & PLU4889 seabed & burial profile (2011)

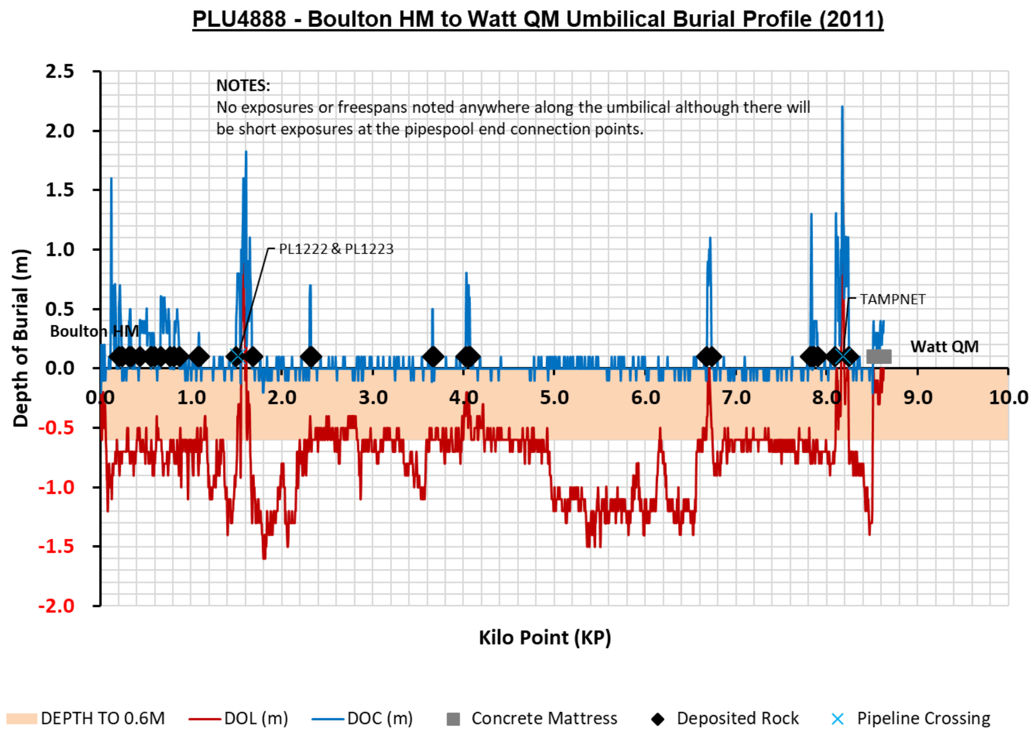


Figure 3.12.2: PLU4888 depth of cover profile ~KP-0.01 to ~KP8.64 (2011)

PLU4688 encounters two pipeline crossings along its route, and these are described in Table 3.12.1 below.

Pipeline, umbilical or cable description	Location	Protection
OUTSIDE MURDOCH 500M ZONE:		
PL1222 & PL1223 Schooner 16in gas and 3in MeOH pipelines.	KP1.581	3x concrete mattresses, 6m x 3m x 0.3m, buried under deposited rock. Shared with PL1924 & PL1927.
Tampnet fibre-optic cable underneath PLU4888	KP8.087	3x 6m x 3m x 0.3m concrete mattresses buried under deposited rock. Shared with PL1924 & PL1927.
NOTE 1. Origin of KP for the umbilical taken at Boulton HM.		

Table 3.12.1: PLU4888 umbilical & pipeline crossings

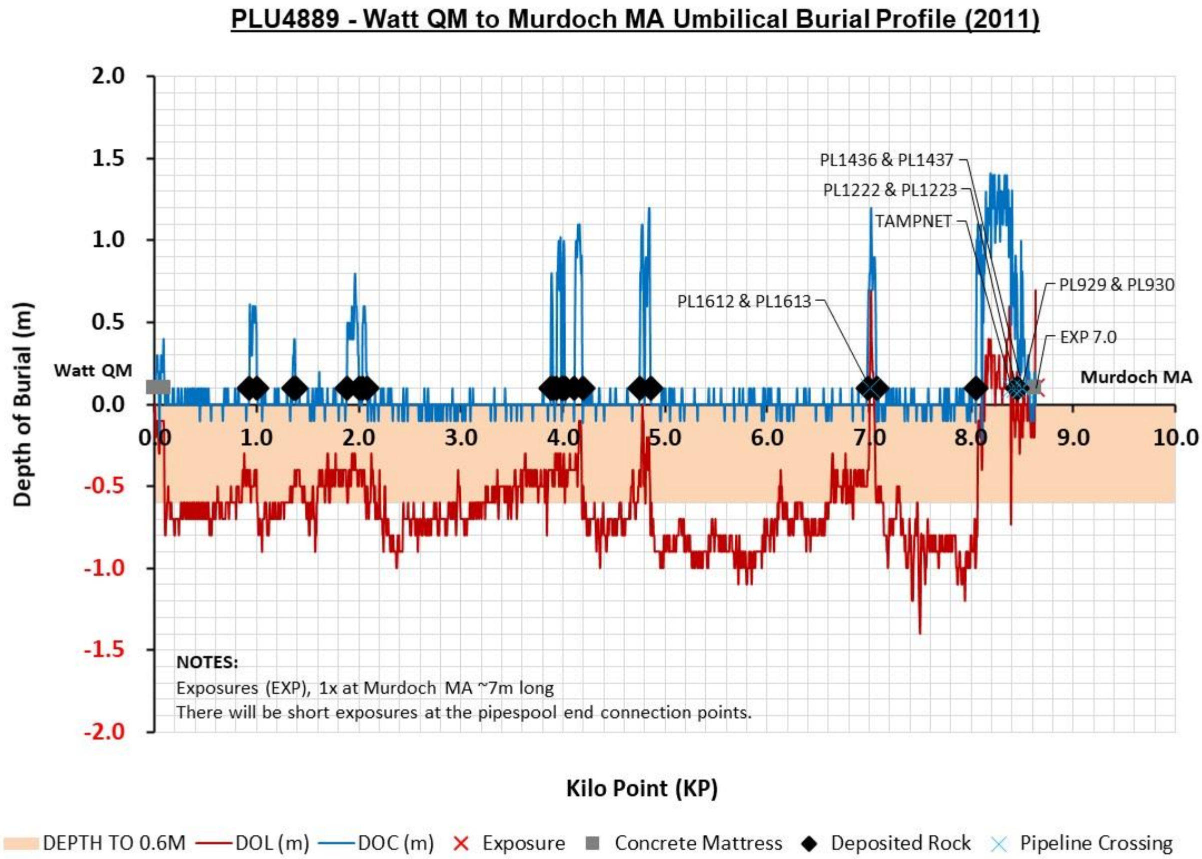


Figure 3.12.3: PLU4889 depth of cover profile ~KP-0.0 to ~KP8.64 (2011)

PLU4889 encounters several pipeline and umbilical crossings along its route, and these are described in Table 3.12.2 below.

Pipeline, umbilical or cable description	Location	Protection
OUTSIDE MURDOCH 500M ZONE:		
PL1612 & PL1613 Ketch 18in & 3in pipelines.	KP6.971	3x 6m x 3m x 0.3m concrete mattresses laid side by side buried under deposited rock.
INSIDE MURDOCH 500M ZONE:		
PL1612 & PL1613 Ketch 18in & 3in pipelines.	KP8.399	3x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1.
PL1222 & PL1223 Schooner 16in gas and 3in MeOH pipelines.	KP8.441	2x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1.
PL929 & PL930 26in & 4in trunklines.	KP8.492	2x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1. Crossing protection shared with PLU4686 & PLU4890.
PL1436 & PL1437 Boulton BM pipelines.	KP8.505	2x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1. Crossing protection shared with PLU4686 & PLU4890.
NOTE 1. Origin of KP for PLU4889 taken from the umbilical end at Watt QM.		

Table 3.12.2: PLU4889 umbilical & pipeline crossings

3.13 PLU4890 Murdoch MA to Murdoch K.KM umbilical

PLU4890 (82mm dia.) is an umbilical that provides electrohydraulic power from Murdoch MA to Murdoch K.KM. It is ~5.9km long. The survey data show that the umbilicals exhibit good depth of burial and depth of cover (Figure 3.13.2). The umbilical encounters several pipeline crossings on approach to the Murdoch installations.

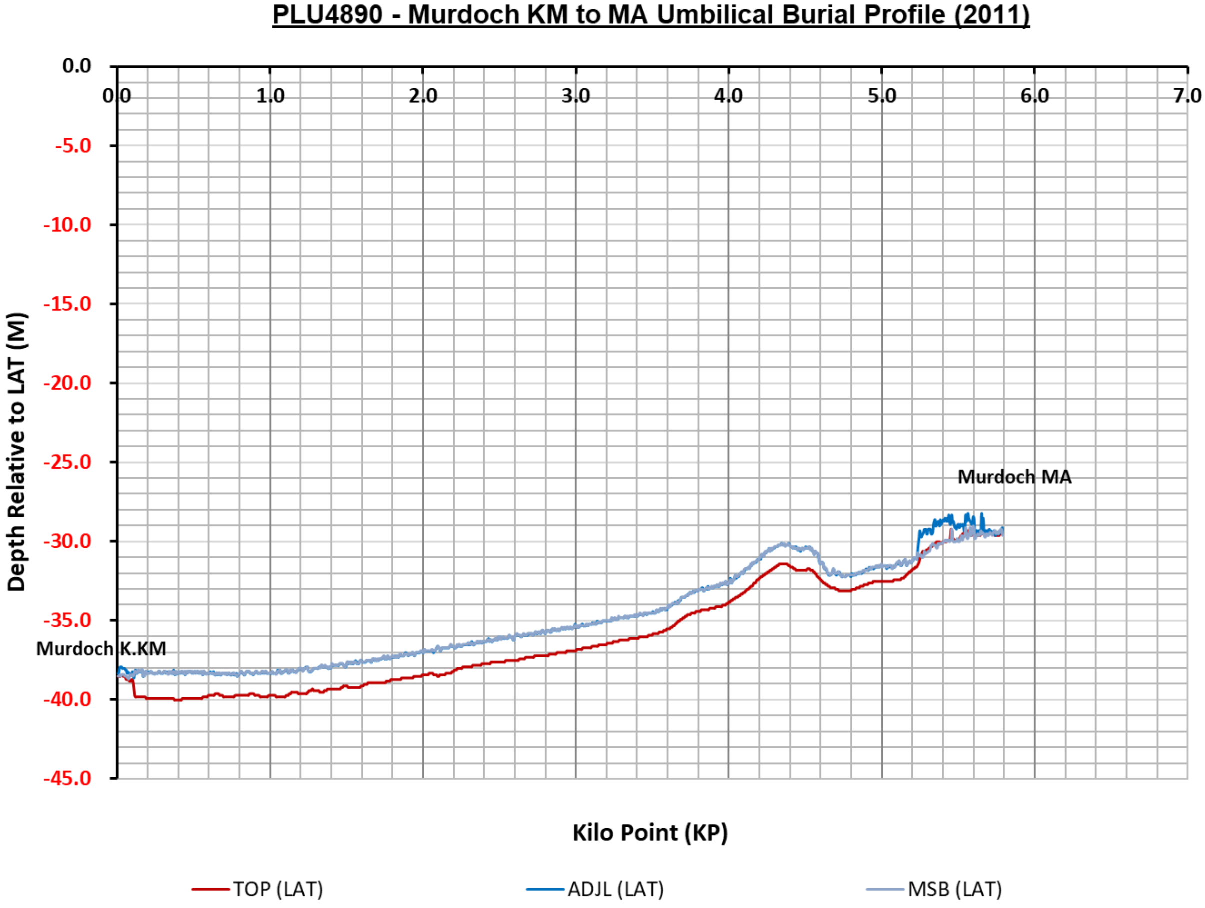


Figure 3.13.1: PLU4890 seabed & burial profile ~KP-0.00 to ~KP5.80 (2011)

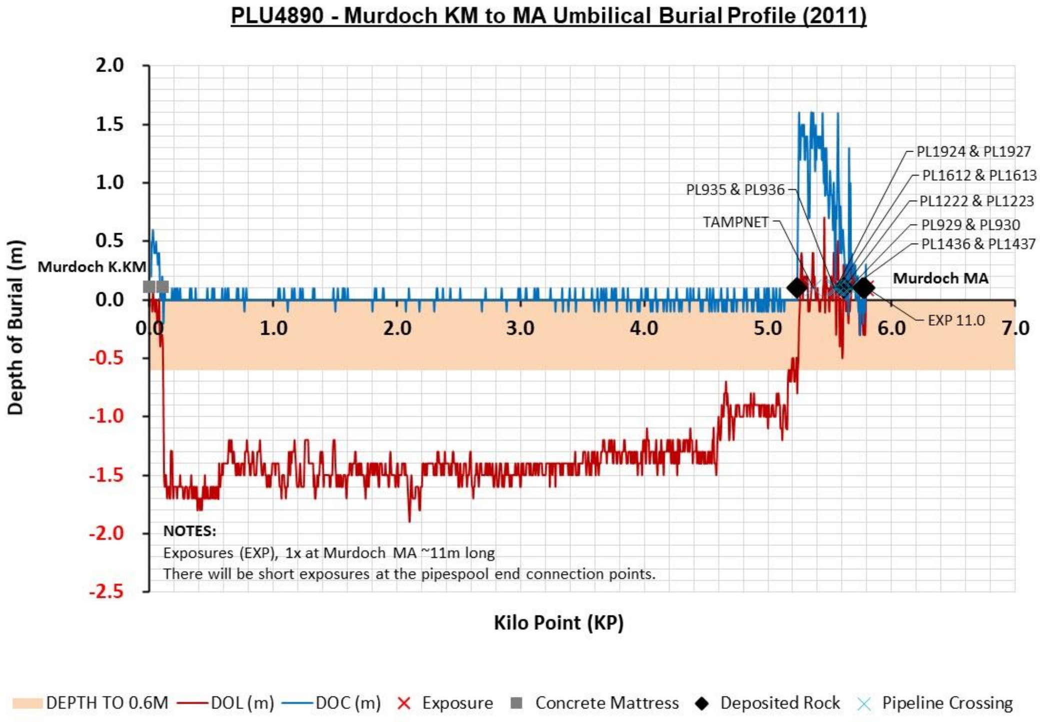


Figure 3.13.2: PLU4890 depth of cover profile ~KP-0.00 to ~KP5.80 (2011)

PLU4890 encounters several pipeline and umbilical crossings along its route, and these are described in Table 3.13.1 below.

Pipeline, umbilical or cable description	Location	Protection
INSIDE MURDOCH 500M ZONE:		
Tampnet fibre-optic cable underneath umbilical.	KP5.366	3x 6m x 3m x 0.3m concrete mattresses; refer Figure A2.1.1.
PL935 & PL936 Caister CM 16in & 3in pipelines.	KP5.532	2x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1; crossing protection shared with PLU4686.
PL1924 & PL1927 Boulton HM 10in & 3in pipelines.	KP5.549	2x 6m x 3m x 0.3m concrete mattresses buried under deposited rock; refer Figure A2.1.1
PL1612 & PL1613 Ketch 18in & 3in pipelines.	KP5.567	2x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1. Crossing protection shared with PLU4686 & PLU4889.
PL1222 & PL1223 Schooner 16in & 3in pipelines.	KP5.613	2x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1. Crossing protection shared with PLU4686 & PLU4889.
PL929 & PL930 Murdoch MD 26in gas & 4in MeOH trunklines.	KP5.657	2x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1. Crossing protection shared with PLU4686 & PLU4889.
PL1436 & PL1437 Boulton BM 10in &n 3in pipelines.	KP5.677	2x 6m x 3m x 0.3m concrete mattresses laid side by side; refer Figure A2.1.1. Crossing protection shared with PLU4686 & PLU4889.
NOTE 1. Origin of KP for PLU4890 is taken at Watt QM.		

Table 3.13.1: PLU4890 umbilical & pipeline crossings

3.14 Pipeline exposures & spans

It is useful to explain the difference between exposures and spans as illustrated in Figure 3.14.1. An exposure or span does not necessarily introduce a snagging hazard and is often preferable to the removal of the exposed section and leaving two cut ends, even though they would be remediated to remove exposure of the cut ends.

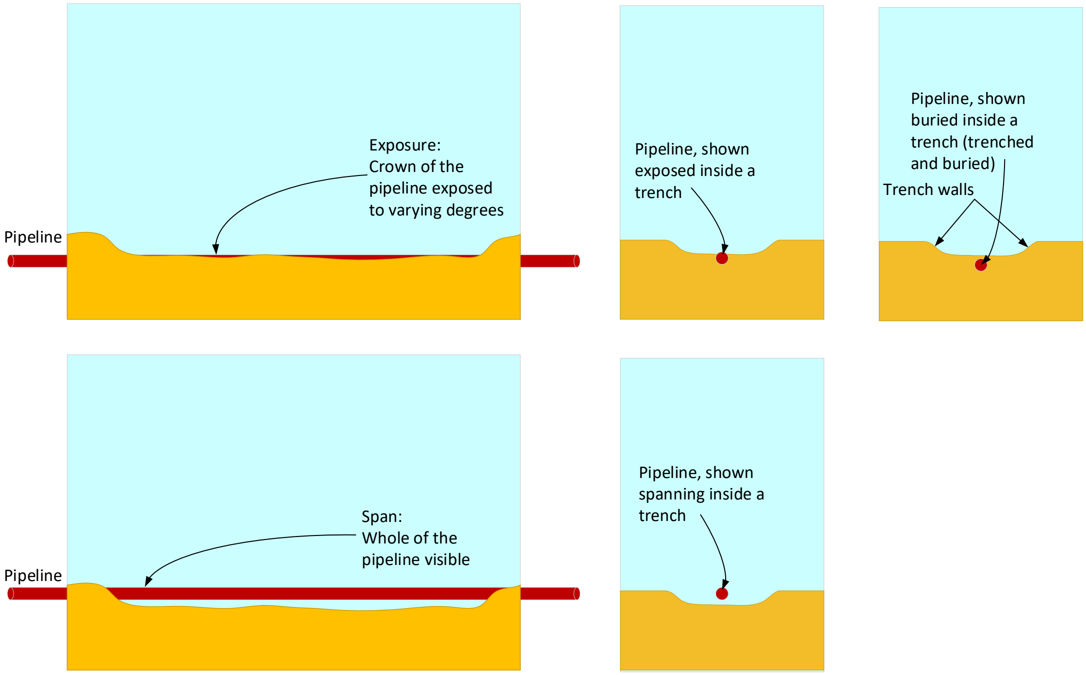


***Figure 3.14.1: The difference between pipeline exposures and spans*[16]**

3.15 Pipeline crossings

Several of the pipelines and umbilicals considered in this comparative assessment cross over other pipelines and umbilicals, as indicated in the figures in Appendix 2. For oil and gas related infrastructure, this can usually be determined by the pipeline number. The higher pipeline number will usually cross over the top of a pipeline with a lower identification number, so for example, PL2430 or PLU2431 would cross over PL935. This is illustrated in Figure 3.15.1.

[16] Trench walls may or may not be prominent.

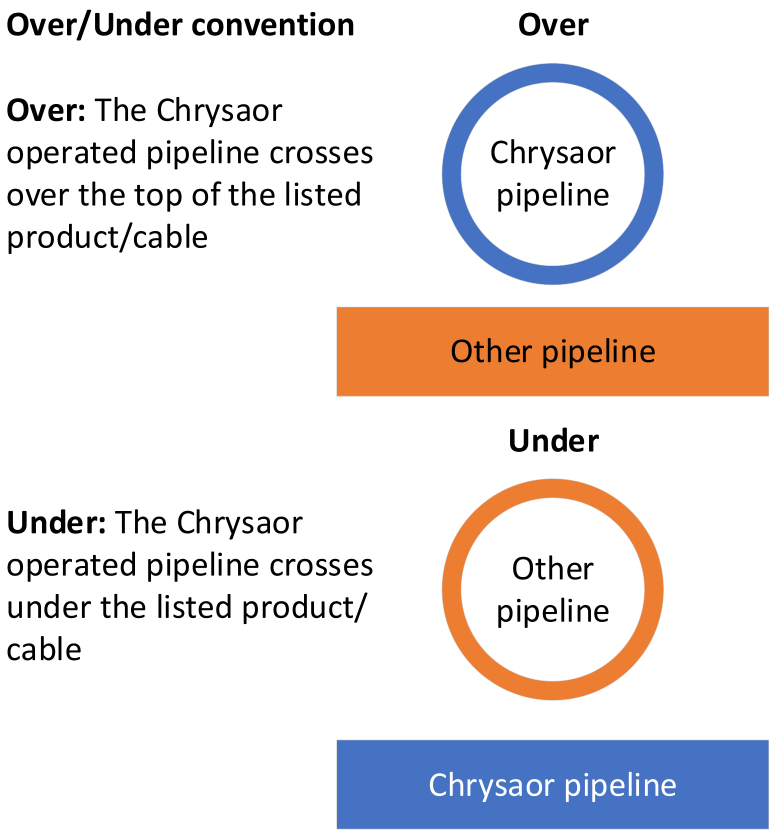


Figure 3.15.1: Over/under convention for pipeline crossings

A summary of the pipeline crossing locations is presented in Appendix 3, Figure A3.1.1, and Figure A3.2.1.

3.16 Dealing with pipeline crossings

The various pipeline and cable crossings will impact or be impacted by the decommissioning options described in section 4.2. The potential impacts are summarised in Table 3.16.1 and illustrated in Figure 3.16.1, although we have not considered this level of detail in the comparative assessment.

Decommissioning option	Newer infrastructure on top	Older infrastructure underneath[17]
Full removal	Cut Chrysaor pipeline either side of third-party pipeline crossing.	No impact on option but may impact decommissioning proposals for the underlying pipeline or cable.
Partial removal or remedial work	As per full removal, otherwise no impact on option as none of the partial removal options would involve removing pipelines from underneath; leave Chrysaor pipeline *in situ*.	
Leave *in situ*	No impact on option as none of the leave *in situ* options would involve removing a pipeline from underneath another pipeline; leave Chrysaor pipeline *in situ*.	

Table 3.16.1: Impact of pipeline crossings on pipeline decommissioning options

[17] Although it is noted here that there would be no discernible impact on the decommissioning option, permission would need to be granted from the owner of the older pipeline to carry out any works in the vicinity.

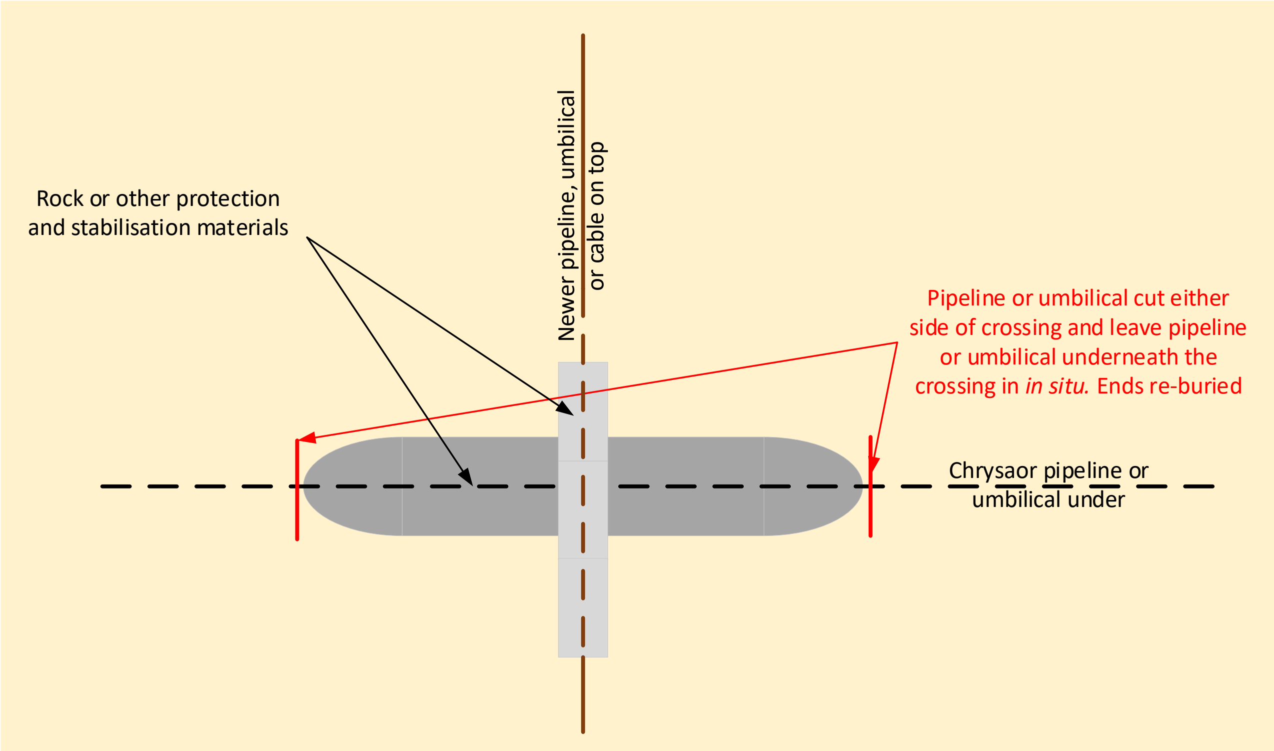


Figure 3.16.1: Pipeline or umbilical being removed from underneath

4 Decommissioning options

4.1 Mattress decommissioning

Two decommissioning options are considered for the removal of fronded and concrete mattresses. These are:

- **Complete removal** – This would involve the complete removal of the mattresses by whatever means would be most practicable and acceptable from a technical perspective;
- **Leave *in situ*** – This would involve leaving the mattresses *in situ* with no remedial works but carrying out a post-decommissioning survey possibly followed by future surveys using a risk-based approach.

As the pipelines and associated infrastructure were expected to experience scour, fronded mattresses were installed. Most of the mattresses are associated with the approaches, and if removed, it is assumed that any pipelines or umbilicals underneath them would also be removed. There are some that were installed to protect pipeline structures such as tees and pigging assemblies, and some were installed at pipeline crossings. A small number may be buried under deposited rock. An implicit assumption is that any mattresses buried under deposited rock will be left *in situ*.

Should the edges of the mattresses be buried (Figure 4.1.1) the expectation is that the associated snagging risk would be relatively benign and if undisturbed the mattresses could probably be left *in situ*.

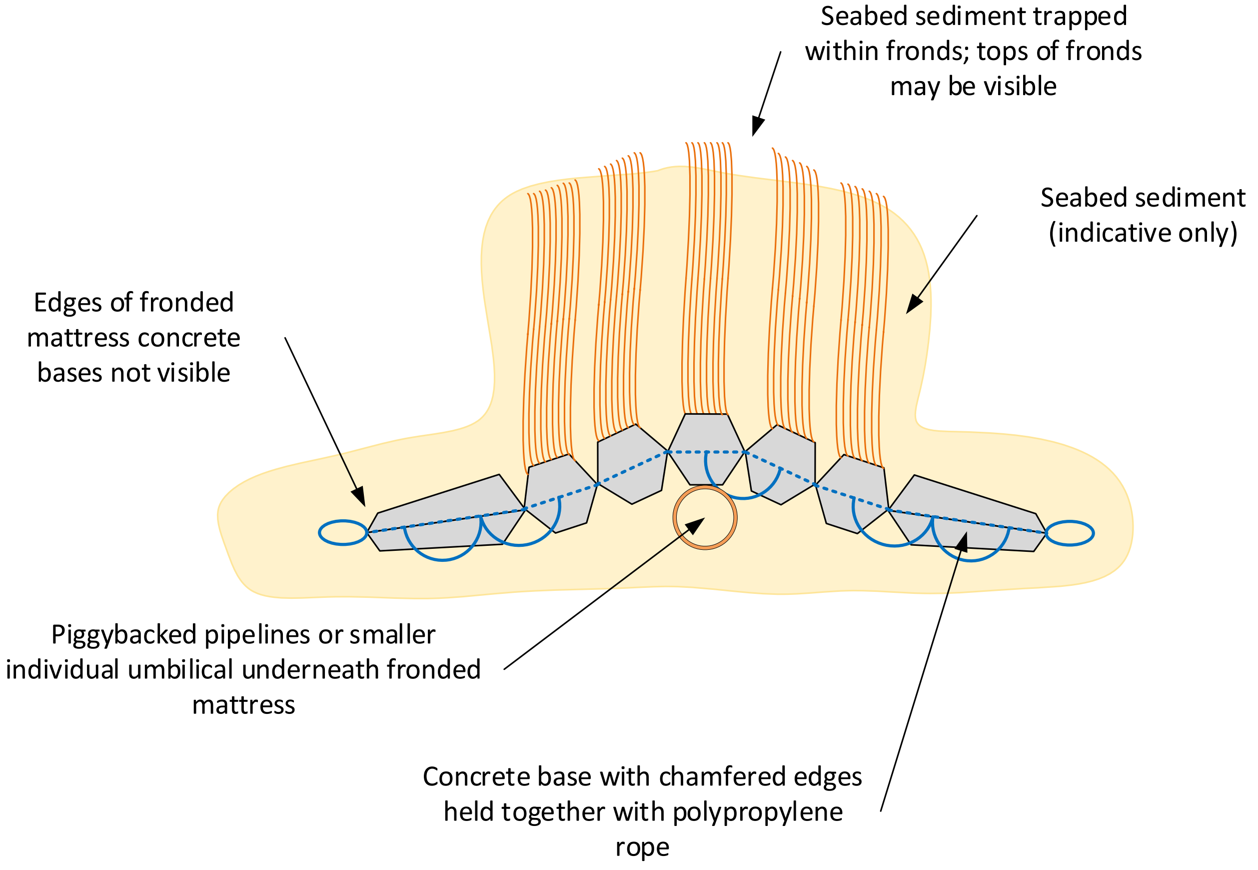


Figure 4.1.1: Fronded mattress with concrete base, edges buried

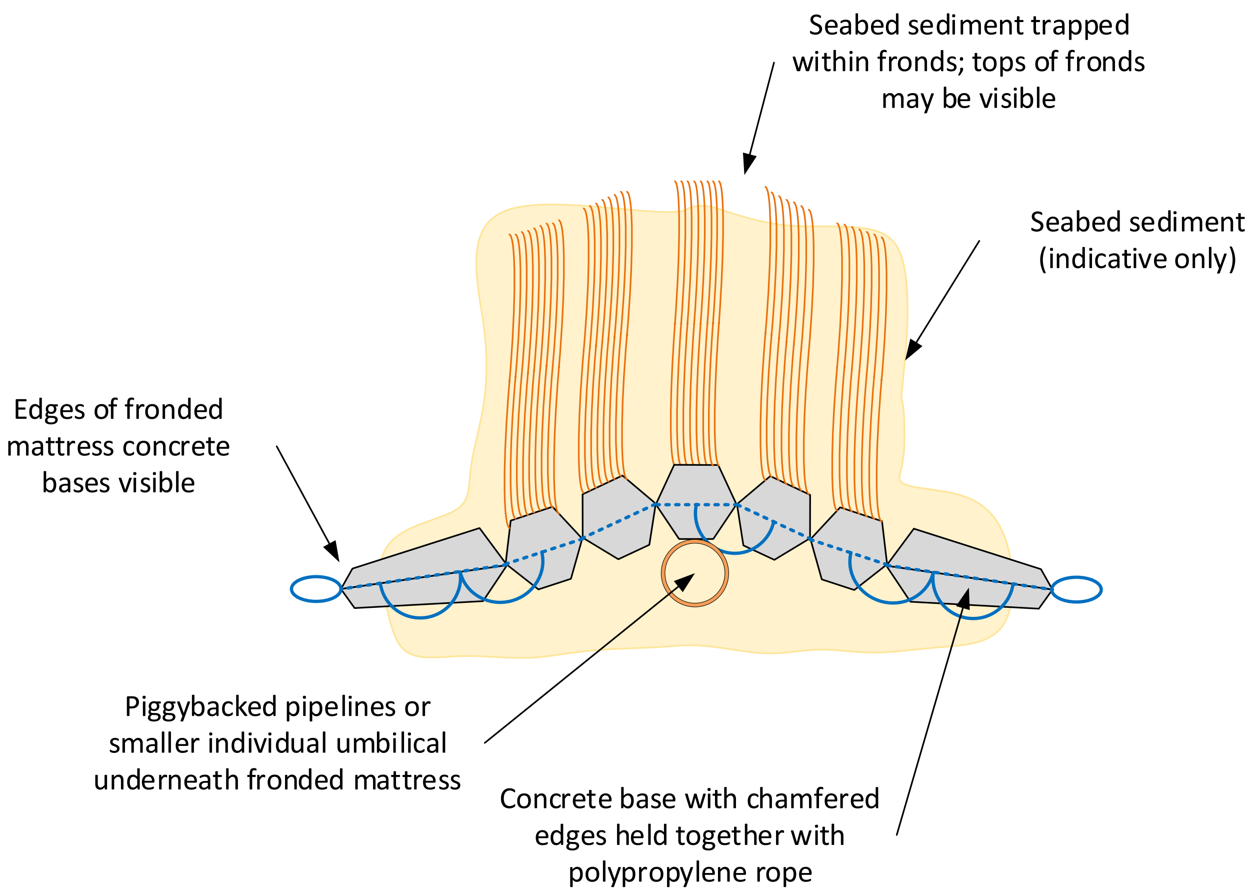


Figure 4.1.2: Fronded mattress with concrete base, edges exposed

4.2 Pipeline decommissioning

Although PL929 is a candidate for Carbon Capture, Usage and Storage (CCUS) [1] [2], there is an implicit assumption that options for re-use of the pipelines have been exhausted before facilities and infrastructure move into the decommissioning phase and associated comparative assessment. Therefore, the re-use option has been excluded from this assessment. The three decommissioning options considered are:

- **Complete removal** – This would involve the complete removal of the pipelines by whatever means most practicable and acceptable from a technical perspective;
- **Partial removal or remediation** – This would involve removing exposed or potentially unstable sections of pipelines or carrying out remedial work to make the remaining pipeline safe for leaving *in situ.* This option is relevant for those pipelines that have known exposures or spans. There will likely be a need to verify their status via future surveys;
- **Leave *in situ*** – This would involve leaving the pipeline(s) *in situ* with no remedial works but possibly verifying their status via future surveys.

For the purposes of the pipeline assessment the partial removal and leave *in situ* options assume that the pipeline and umbilical ends on the approaches would be fully recovered, although the recovery of overlying mattresses is also subject to a comparative assessment.

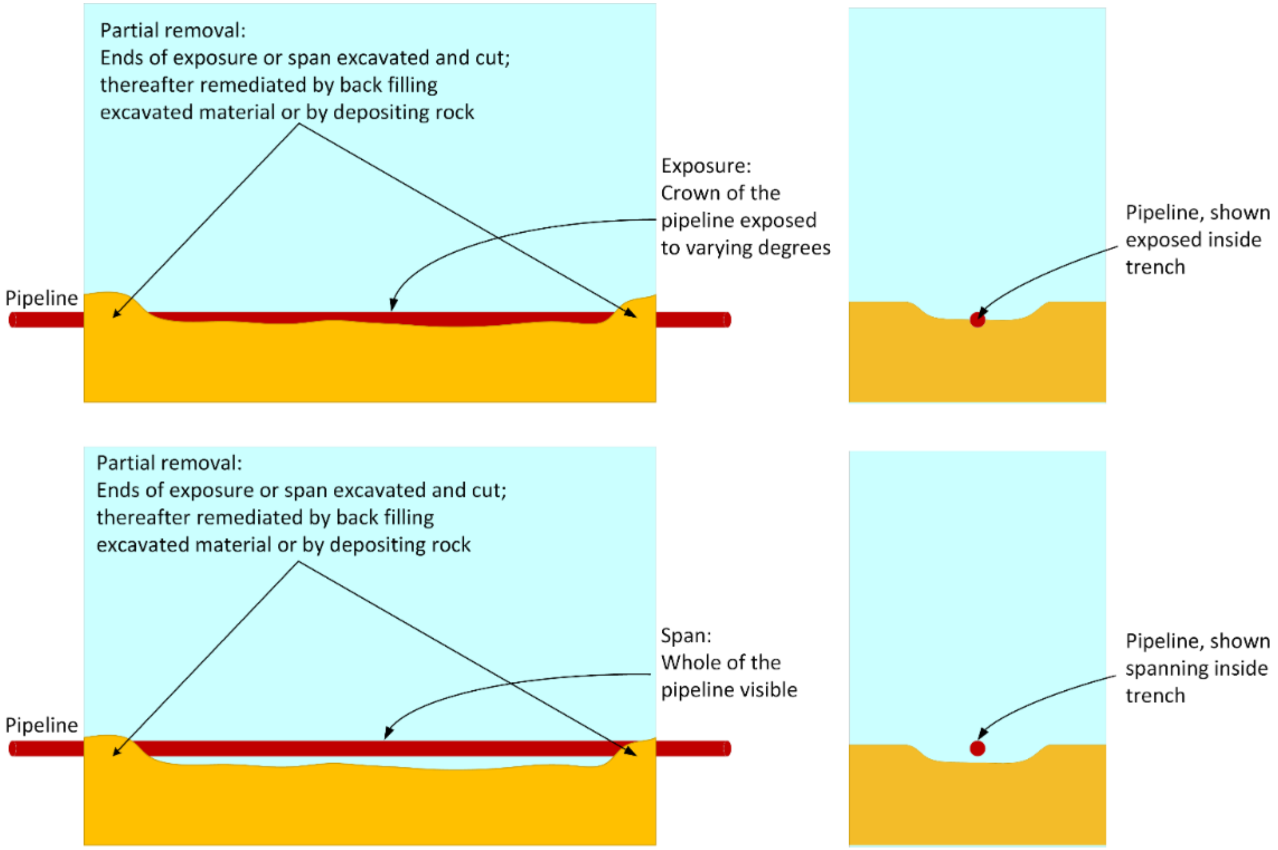


Figure 4.2.1: Exposures, spans & partial removal

The pipelines and umbilicals and associated decommissioning options and groupings are summarised in Table 4.2.1 below.

Asset	Pipeline ID	Complete removal	Partial removal	Leave *in situ*	Group	Comments
Murdoch MD	PL929	X	X	X	1	Reasonable depth of cover, several km of exposures, 8x crossings(7x over)
Murdoch MD	PL930	X	X	X	1	Unknown, assume as per PL929
Caister CM	PL935	X		X	1	Good burial, no exposures in-field, 6x crossings (6x over)
Caister CM	PL936	X		X	1	Unknown, assume as per PL935
Boulton BM	PL1436 & PL1437	X		X	2	Good burial, no exposures in-field, 3x crossings (3x over)
Hawksley EM & McAdam MM	PL1922 & PL1925	X		X	2	Good burial, no exposures in-field, 8x crossings(4x over)
Murdoch K.KM	PL1923 & PL1926	X		X	2	Good burial, no exposures in-field, 2x crossings (4x over)
Boulton HM & Watt QM	PL1924 & PL1927	X		X	2	Good burial, no exposures in-field, 7x crossings (2x over)
Munro MH	PL2109 & PL2110	X	X	X	2	Good burial but with several exposures in-field, 0x crossings
Kelvin TM	PL2430 & PLU2431	X		X	2	Good burial, no exposures in-field, 2x crossings (1x over)
Katy KT	PL2894 & PL2895	X		X	2	Good burial, no exposures in-field, 0x crossings
Hawksley EM	PLU4686	X		X	3	Good burial, no exposures in-field, crossings (13x crossings) (0x over)
McAdam MM	PLU4685	X	X	X	3	Good burial, a few exposures or freespans, 1x crossings (0x over)
Boulton HM	PLU4888	X		X	3	Good burial, no exposures in-field, 2x crossings (0x over)
Watt QM	PLU4889	X		X	3	Good burial, no exposures in-field, 5x crossings (0x over)
Murdoch K.KM	PLU4890	X		X	3	Good burial, no exposures in-field, 7x crossings (0x over)

NOTES:
1. Pipeline groups as follows: group 1 – individual pipelines in their own trench but piggybacked on the approaches; group 2: piggybacked pipelines; group 3: umbilicals in their own trenches;
2. PL930 is assumed to replicate the burial status of PL929 and PL936 is assumed to replicate the burial status of PL935;
3. For details of pipeline crossings - abbreviated to “crossings” here, refer section 3.

Table 4.2.1: Pipeline decommissioning options & group summary

For efficiency of analysis the options for decommissioning these pipelines will be assessed as three separate groups since many aspects of the assessment are common to all in a group. For example, the pipelines in group 2 are all piggybacked, and the depth of burial is good for most of them with no exposures. Any aspect pertinent to an individual pipeline is explained in the narrative.

Group 1: Individual pipelines such as PL929, PL930, PL935 and PL936 laid in their own trench but piggybacked on the approaches, possibly with multiple exposures (PL929 and possibly PL930 only);

Group 2: These include all the CMS pipelines referred to earlier except PL1311 & PL1312[18]. Excepting PL1311 and PL1312 that are platform risers, these are all piggybacked pipelines with good depth of cover although exposures have only been found along PL2109 & PL2110;

Group 3: These include all the umbilicals. Although PLU4685 has exhibited short exposures and freespans (total length ~60m)[19] and spans in historical surveys the umbilicals otherwise show good depth of cover, with no exposures.

Further details of the decommissioning options are described in sections 4.2.1, 4.2.2 and 4.2.3 below. For the purposes of the assessment in all cases it is assumed that on the final approaches the pipeline or umbilical ends would be removed along with the overlying mattresses, although the mattresses are subject to a comparative assessment in section 5.4.

The activities in these sections could be undertaken using a variety of vessels. Vessel type might include a subsea support vessel (SSV), construction support vessel (CSV), an ROV support vessel (ROVSV) or a pipelay vessel, or a rock discharge vessel or a mixture of them all, depending on the activities involved.

[18] PL1311 and PL1312 are platform risers and will be removed along with the Murdoch MD jacket;

[19] 1x exposure ~7m long was found at KP0.028, and 3x freespans (3m, 4.5m, and 11.4m long) and 1x exposure (33m long) were observed between KP0.222 and ~KP0.280 near Hawksley.

4.2.1 Decommissioning options and methods for pipelines in group 1

ID	Item Description[6]	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
1	Riser sections at Murdoch MD (PL929, PL930, PL935 & PL936).	Remove along with the Murdoch MD jacket.	Remove. As option 1.	Remove. As option 1.
2	Surface laid sections on approach to Murdoch MD (PL929 & PL930 piggybacked, PL935 & PL936 piggybacked).	Uncover any mattresses and underlying pipeline(s) to point of burial in seabed or deposited rock using a mass flow excavator (MFE). Completely remove mattresses and completely remove pipelines using 'cut and lift' method.	Remove. As option 1.	Remove. As option 1.
3	Trenched and buried section of pipelines (PL929, PL930, PL935 & PL936), separate trenches)	Completely remove 26in (PL929) and 16in (PL935) rigid and concrete coated pipelines using the 'cut and lift' method[1,2]. Complete remove 3in (PL936) & 4in (PL930) pipeline(s) using reverse reel method[1,3].	PL929 & PL930 only. Either remove exposed sections of pipelines or remediate the remaining pipeline ends.	Leave *in situ*.
4	Surface laid sections of PL929 & PL930 at separation point ~0.5km from Murdoch , at cross over point ~20km from MLWM & ~4.4km from MLWM. See note 6. Surface laid sections of PL936 at separation points between KP0.226 and KP0.493 and KP10.485 and KP10.760.	Uncover any mattresses and underlying flexible pipespool as far as connection points and burial using local excavation. Completely remove mattresses and underlying PL930 flexible pipespools by severing the ends and recovering.	PL929 & PL930 only. As option 3. Leave *in situ*.	Leave buried mattresses and underlying pipelines *in situ*. Otherwise fully recover all mattresses and underlying pipeline(s).
5	Surface laid sections on approach to Caister CM (PL935 & PL936), piggybacked.	Uncover any mattresses and underlying pipeline(s) using an MFE. Completely remove piggybacked pipelines using 'cut and lift' method.	PL935 and PL936 only. As option 3. Leave *in situ*.	Leave *in situ*.
6	Riser sections at Caister CM (PL935 & PL936) [5].	Removed along with the Caister CM jacket.	PL935 and PL936 only. As option 3. Leave *in situ*.	Remove. As option 1.

NOTES:

1. Leave sections buried under deposited rock undisturbed;
2. Only the 'cut and lift' method of removal is considered viable for these pipelines as they are both concrete coated;
3. Removal using reverse reel method of removal would only be considered viable if it could be determined that there are no integrity issues with the pipelines;
4. Assume any local excavations in the seabed would be mechanically backfilled to reduce snagging hazard;
5. Pipeline ends cut at rock will be buried by redistributing existing rock or by depositing a small quantity of additional rock;
6. Note that PL929 and PL930 beyond MLWM towards TGT is out of scope.

Table 4.2.2: Options for decommissioning pipelines in group 1

4.2.2 Decommissioning options and methods for pipelines in group 2

<table>
<tr><th>ID</th><th>Item Description</th><th>Option 1
Complete removal</th><th>Option 2
Partial removal</th><th>Option 3
Leave in situ</th></tr>
<tr><td>1</td><td>Riser sections at Murdoch MD (PL1436 & PL1437)</td><td>Remove along with the Murdoch MD jacket.</td><td rowspan="4">Remove. As option 1.</td><td>Remove. As option 1.</td></tr>
<tr><td>2.1</td><td>Surface laid tie-in pipespools on approach to pipeline structures:
• Katy Tee: PL2894 & PL2895;
• KSTA: PL2430 & PLU2431;
• KPMA: PL2894 & PL2895;
• McAdam Tee: PL1922 & PL1925;
• KMPS & CSPS/PSSL: PL2430 & PLU2431;
• PSNL: PL1922 & PL1925, PL1923 & PL1926, PL1924.</td><td>Uncover any buried mattresses and underlying pipeline(s) between structure and point of burial in seabed or under deposited rock transition using an MFE. Completely remove pipespools using ‘cut and lift’ method.</td><td>Remove. As option 1.</td></tr>
<tr><td>2.2</td><td>Surface laid tie-in spools on approach to subsea installations:
• Boulton HM: PL1924 & PL1927;
• Hawksley EM: PL1922 & PL1925, PL2109 & PL2110;
• McAdam MM: PL1922 & PL1925;
• Murdoch K.KM: PL1923 & PL1926;
• Watt QM: PL1923 & PL1926.</td><td>As above.</td><td>Remove. As option 1.</td></tr>
<tr><td>2.3</td><td>Surface laid tie-in spools on approach to surface installations:
• Boulton BM: PL1436 & PL1437; Katy KT: PL2894 & PL2895;
• Kelvin TM: PL2430 & PLU2431; Munro MH PL2109 & PL2110
• Murdoch MD: PL1436 & PL1437, PL1922 & PL1925, PL1927[2]</td><td>As above.</td><td>Remove. As option 1.</td></tr>
<tr><td>3</td><td>Trenched and buried section of all pipelines: PL1436 & PL1437, PL1922 & PL1925, PL1923 & PL1926, PL1924 & PL1927, PL2430 & PLU2431, PL2894 & PL2895.
Partial removal: PL2109 & PL2110.</td><td>Uncover the pipeline(s) using an MFE. Completely remove rigid pipelines using the ‘cut and lift’ method[1].</td><td>PL2109 & PL2110 only. As option 1 for exposed sections. N/A for all other pipelines.</td><td>Leave in situ.</td></tr>
<tr><td>4</td><td>Riser sections at Boulton BM (PL1436 & PL1437), Katy KT (PL2894 & PL2895), Kelvin TM (PL2430 & PLU2431) & Munro MH (PL2109 & PL2110).</td><td>Remove along with the associated jacket.</td><td>Remove. As option 1.</td><td>Remove. As option 1.</td></tr>
<tr><td colspan="5">NOTES:
1. Only the ‘cut and lift’ method of removal is considered viable for these pipelines as the larger gas pipelines are piggybacked.</td></tr>
</table>

Table 4.2.3: Options for decommissioning pipelines in group 2

4.2.3 Decommissioning options and methods for pipelines in group 3

ID	Item Description	Option 1 Complete removal	Option 2 Partial removal	Option 3 Leave *in situ*
1	Sections within J-Tube Murdoch MA: PLU4686, PLU4889 & PLU4890.	Remove along with the Murdoch MD jacket.	Remove. As option 1.	Remove. As option 1.
2	Surface laid sections on approach Murdoch MA: PLU4686, PLU4889 & PLU4890.	Uncover any buried mattresses and completely remove them. Completely remove umbilical(s) using 'reverse reel' method.		Remove. As option 1.
3	Surface laid sections on approach to subsea installations: • Boulton HM: PLU4888; • Hawksley EM: PLU4685; • McAdam MM: PLU4686 & PLU4685; Murdoch K.KM: PLU4890; • Watt QM: PLU4888 & PLU4889.	As above.	PLU4685. Remove short lengths of exposures (total length ~33m long) or spans (total length ~19m long) using cut and lift method.	Remove. As option 1.
4	Trenched and buried sections of all umbilicals: PLU4686 & PLU4685, PLU4889 & PLU4888 and PLU4890.	Uncover the pipeline(s) using an MFE. Completely remove umbilical(s) using reverse reel method.	Leave *in situ*. As option 3	Leave *in situ*.

NOTES:

1. PLU4685 buried in seabed at end of transition at Hawksley EM, PLU4686 buried in seabed at end of transition at McAdam MM, PLU4888 buried in seabed at end of transitions at either end, PLU4890 buried in seabed at end of transition at Murdoch K.KM. Otherwise the ends of the umbilicals are buried under deposited rock at the transitions;
2. PLU4685 suffers from short lengths of exposures (total length ~33m long) or spans (total length ~19m long) as well as a short 7m exposed length on the final approach to Hawksley EM. Once removed the exposed umbilical ends would be remediated by the deposition of additional rock. A total of 2x ends would require remediation, at KP0.222 and ~KP0.280;
3. Removal using reverse reel method of removal would be considered viable on the basis that these are umbilicals, and integrity issues are unlikely to impede this approach.

Table 4.2.4: Options for decommissioning pipelines in group 3

5 Comparative Assessment

5.1 Method

The comparative assessment is largely qualitative, carried out at a level that is sufficient to differentiate between the options. However, in some cases, for example such as cost, it can be necessary to examine the differences in more detail and quantitatively to provide clarity. The comparative assessment considers generic evaluation criteria and specific sub-criteria in line with OPRED guidance notes [18]. These elements are considered for short-term work as the assets are decommissioned as well as over the longer-term as 'legacy' impacts and risks. Please refer Table 5.2.1 and Table 5.3.1.

No scores have been determined and no weightings are used. 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. High costs also attract a less desirable outcome, but differences are compared relative to each other. A relatively high cost where the cost by difference would be an order of magnitude higher than the lowest cost option therefore would be coloured red, a less than order of magnitude higher cost would be coloured orange and the lowest cost option would be coloured green. It should be noted that societal assessment examined at beneficial outcomes as well as detrimental outcomes. Where comparison of options varies by shades of green rather than by red or orange it means there is little to choose between the options.

The assessment has been split into two parts:

- Decommissioning of the mattresses, and by implication removal of any underlying pipelines and umbilicals;
- Decommissioning of the pipelines.

The first part considers whether there would be merit in fully recovering mattresses and by implication the underlying pipelines and umbilicals or whether it would be appropriate to leave undisturbed mattresses, etc. *in situ*. Refer section 5.4. This is considered a binary comparison for complete removal versus leave *in situ* but seeks to offer criteria that may be useful in the decision-making process (refer section 4.1). This is carried out to assist with the decision-making for the approaches.

The second part explores the decommissioning of the pipelines. Refer sections 5.5, 5.6, 5.7 and this is carried out to assist with the decision-making for the pipelines and umbilicals.

The cost assessment explores decommissioning of the mattresses and any underlying pipelines and umbilicals at the approaches as well as in combination with the pipeline and umbilical ends. When comparing cost by difference for the complete and partial removal options versus leave *in situ*, the assumption used is that the pipeline and umbilical ends on the approaches would be removed. When decommissioning pipelines or umbilicals *in situ*, it is quite common for the surface laid pipeline and umbilical ends to be removed. For the purposes of the assessment this is conservative. It means that should the mattresses, pipelines and umbilicals at the approaches be lift *in situ*, the cost by difference would increase. Refer Appendix 9, particularly for what is meant by an 'order of magnitude' difference in cost.

5.2 Criteria and sub-criteria for mattresses

CRITERIA	DEFINITION	SUB-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.	Risk of project failure concerns the possibility of significant unplanned delays not dealt with by contingency planning or having to go back to the drawing board. It assesses the chances of failure, whether equipment is available, maturity of the technology, any integrity concerns, and would contingency planning be needed?
		Technological challenge.	The technological challenge concerns the availability of specific technologies to perform a task and the extent of research & development that may be required.
		Technical challenge.	The technical challenge considers the viability of a task should the technology be available.
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.	Assesses typical offshore and onshore hazards. Offshore hazards include loss of dynamic positioning, sudden movements during mattress recovery works, dropped objects, collision between vessels. Typically, these would increase with the quantity of material being recovered. After decommissioning has been completed typical hazards could relate to exposed mattresses, leading to possibility of snagging of fishing nets. Onshore hazards might include dealing with large quantities of bulk items, onshore cutting, or crushing, sudden movements or dropped objects and these would increase with the quantity of material being handled.
		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 threat and or impacts to the environmental receptors because of operational activities or the legacy aspects.	Energy and emissions to atmosphere.	The mattresses and any pipelines and umbilicals underneath are mostly located inside the Dogger Bank which is an environmentally sensitive area. Assesses the effect on the seabed, the effect on the conservation objectives, extent of temporary and permanent disturbance in comparison to the overall area of the Dogger Bank SAC (12,331km^2), SNS SAC (36,950 km^2), type of material being left *in situ*, fate of materials, requirement for materials needing to be manufactured to compensate for materials left *in situ*.
		Effect on seabed: Seabed disturbance and area affected.	
		Disturbance to protected areas & impact on conservation objectives of the area (e.g., SAC, SPA, SSSI).	
		Effect on water column: • Liquid discharges to sea; • Liquid discharges to surface water; • Noise.	

CRITERIA	DEFINITION	SUB-CRITERIA (Short-term & Legacy, UNO)	COMMENTS
		Waste creation and use of resources such as landfill. Recycling and replacement of materials.	
Socio-economic	An assessment of the significance of the impacts on societal activities, including offshore and onshore activities associated with the complete programme of work for each option and the associated legacy impact. This includes all the “direct” societal effects (e.g., employment on vessels undertaking the work) as well as “indirect” societal effects (e.g., employment associated with services in the locality to onshore work scope, accommodation, etc.).	Effects on commercial activities e.g., fishing Employment. Communities or impact on amenities.	Decommissioning of mattresses generally involves work that is temporary. Assesses impact on commercial activities and job creation.
Cost	Difference in cost.	Difference in cost compared for like-for-like activities; normalised to demonstrate a sense of scale.	Examines cost by difference for the compete removal and leave *in situ* options. That is common activities such as engineering and management costs, mobilisation and demobilisation of vessels are ignored. Where appropriate the cost of dealing with the mattresses is combined with decommissioning of the underlying pipelines and umbilicals. Note that the mattresses around pipeline structures and subsea installations do not always lie over pipelines and umbilicals and this is accounted for in the assessment. All other criteria and sub-criteria being equal, cost would be the final differentiator.

Table 5.2.1:Mattress comparative assessment method – criteria & sub-criteria

5.3 Criteria and sub-criteria for pipelines and umbilicals

CRITERIA	DEFINITION	SUB-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.	Assesses the chances of failure, whether equipment is available, maturity of the technology, any integrity concerns, and would contingency planning be needed?
		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.	Assesses typical offshore and onshore hazards. Offshore hazards include loss of dynamic positioning, sudden movements during mattress recovery works, dropped objects, collision between vessels. This would with the quantity of material being recovered. After decommissioning has been completed typical hazards could relate to exposed mattresses, leading to possibility of snagging of fishing nets. Onshore hazards might include dealing with large quantities of bulk items, onshore cutting, or crushing, sudden movements or dropped objects and these would increase with the quantity of material being handled.
		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 threats or impacts to the environmental receptors because of operational activities or the legacy aspects.	Energy and emissions to atmosphere.	With the exception of most of PL929 and PL930, the pipelines and umbilicals are located inside the Dogger Bank SAC which is an environmentally sensitive area. Parts of PL929 and PL930 are routed through the SNS SAC SNS SAC (36,950 km^2), which is an environmentally sensitive areas for the habitat for the Harbour Porpoise (*Phocoena phocoena*). Assesses the effect on the seabed, the effect on the conservation objectives, extent of temporary and permanent disturbance in comparison to the overall area of the Dogger Bank SAC (12,331km^2), type of material being left *in situ*, compares fate of materials, requirement for materials needing to be manufactured to compensate for materials left *in situ*.
		Effect on seabed: Seabed disturbance and area affected.	
		Disturbance to protected areas & impact on conservation objectives of the area (e.g., SAC, SPA, SSSI).	
		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.	
Socio-economic	An assessment of the significance of the impacts on societal activities, including offshore and onshore activities associated with	Effects on commercial activities e.g., fishing	Decommissioning of infrastructure involves work that is temporary. Assesses impact on commercial activities and job creation.
		Employment.	

CRITERIA	DEFINITION	SUB-CRITERIA (Short-term & Legacy, UNO)	COMMENTS
	the complete programme of work for each option and the associated legacy impact. This includes all the "direct" societal effects (e.g., employment on vessels undertaking the work) as well as "indirect" societal effects (e.g., employment associated with services in the locality to onshore work scope, accommodation, etc.).	Communities or impact on amenities.	
Cost	Difference in cost.	Difference in cost compared for like-for-like activities. Normalised to demonstrate a sense of scale.	Examines cost by difference for the complete removal and leave *in situ* options. Where applicable the partial removal option is also examined. That is common activities such as engineering and management costs, mobilisation and demobilisation of vessels are ignored in the assessment. All other criteria and sub-criteria being equal, cost would be the final differentiator.

Table 5.3.1: Pipeline comparative assessment method – criteria & sub-criteria

5.4 Comparative assessment for mattresses

The complete removal and leave *in situ* decommissioning options are compared for fronded mattresses that are anchored, fronded mattresses with concrete bases and concrete mattresses. Most of the mattresses were installed to protect and stabilise the pipelines or umbilicals as they exit burial from deposited rock on the seabed. Some mattresses were used to provide protection to the installations, pipeline tees, and pigging manifold protection structures. As mentioned previously, one fronded mattress in the Murdoch 500m zone was installed as protection over an initiation pile[20] adjacent to the PL2430 and PLU2431 bend. Please refer Appendix 2 for schematics. Please refer Appendix 5 for summary comparison assessment tables and for more details.

5.4.1 Technical considerations

In general terms, there are at least five methods that have been used to recover mattresses with concrete bases, and historically most of them give reliable results:

- 'Curtain' lift;
- 'Pancake' lift;
- Lift and transfer to a purpose-built lifting frame placed temporarily on the seabed;
- Removal using a variety of hydraulically operated clamshell grabs, orange peel grabs or grapples;
- Use purpose-built equipment.

Other methods of recovery are described by IMCA [13] and Jee Limited [16] but they are not discussed here.

To maximise the chances of success an MFE may need to be deployed to remove any overlying sediment. Experience has shown that it should be possible to carry out the mattress removal operations without deploying divers, although allowance would need to be made for tides, currents, and poor visibility in the SNS.

The fronded mattresses that are anchored would likely be more problematic to remove due to how they are constructed and how they are fixed to the seabed. Most of the removal methods described here may not be as suitable for the fronded mattresses that are anchored, but nevertheless the brute force of a grapple or clamshell would be expected to work. Purpose-built equipment might also be suitable.

Curtain lift

Removal of a mattress using a 'curtain' lift could be achieved by connecting a lifting beam and rigging to all the loops on one side of the mattress should they remain intact and lifting it vertically through the water column and splash zone. Assuming the integrity of the mattress is assured the advantage of this approach is that the pressure on the mattresses is minimised as it is recovered though the splash zone and less time is taken to connect rigging compared to the 'pancake' lift.

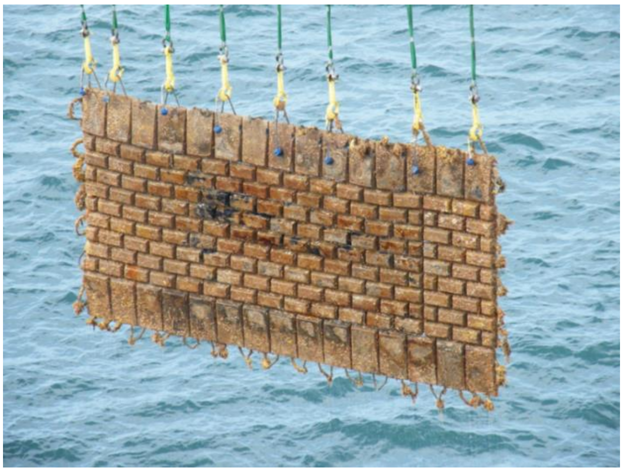


Figure 5.4.1: Removal of a mattress using a 'curtain' lift

[20] A single pile that was installed for a particular purpose but no longer used.

Pancake lift

Removal of a mattress using a 'pancake' lift could be achieved by connecting a lifting frame and rigging to all the loops on all sides of the mattress should they remain intact and lifting the mattress horizontally through the water column and splash zone. The advantage of this approach is the mattress is carried by a larger number of lift points. The disadvantages are that the mattress will experience more pressure as it is lifted through the water column. There have been several instances of failure as the mattresses are lifted through the splash zone. Refer Figure 2.4.7, central picture.

Lift and transfer

This method of removal would involve the transfer of mattresses to a purpose-built mattress handling frame such as a Speedloader or basket placed nearby on the seabed. Ideally a mattress would be lifted into the receptacle whole and with its integrity intact. Typically, four or five mattresses would then be recovered to deck at any one time.

Figure 5.4.2: Speedloader lifting frame[21]

Removal using a grab or grapple

Assuming that a commitment had been made to fully remove the mattresses this method of removal is often a last resort and typically deployed as a contingency measure for instances where the structural integrity of a mattress cannot be assured. Arguably this method of removal would disrupt the seabed more than others described here. This method or use of purpose-built equipment would likely be a candidate for removing the fronded mattresses that are anchored.

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[21] Photo courtesy of Subsea Protection Systems Ltd. https://www.subseaprotectionsystems.co.uk/

Purpose-built equipment

Purpose built equipment is available to remove mattresses and can currently be deployed very efficiently for all but perhaps the largest mattresses. Technology is also available that can facilitate debris clearance and provide data that could be used to support verification of a clear seabed once decommissioning activities have been completed. This method of removal or use of a grab or grapple would likely be a candidate for removing the fronded mattresses that are anchored.

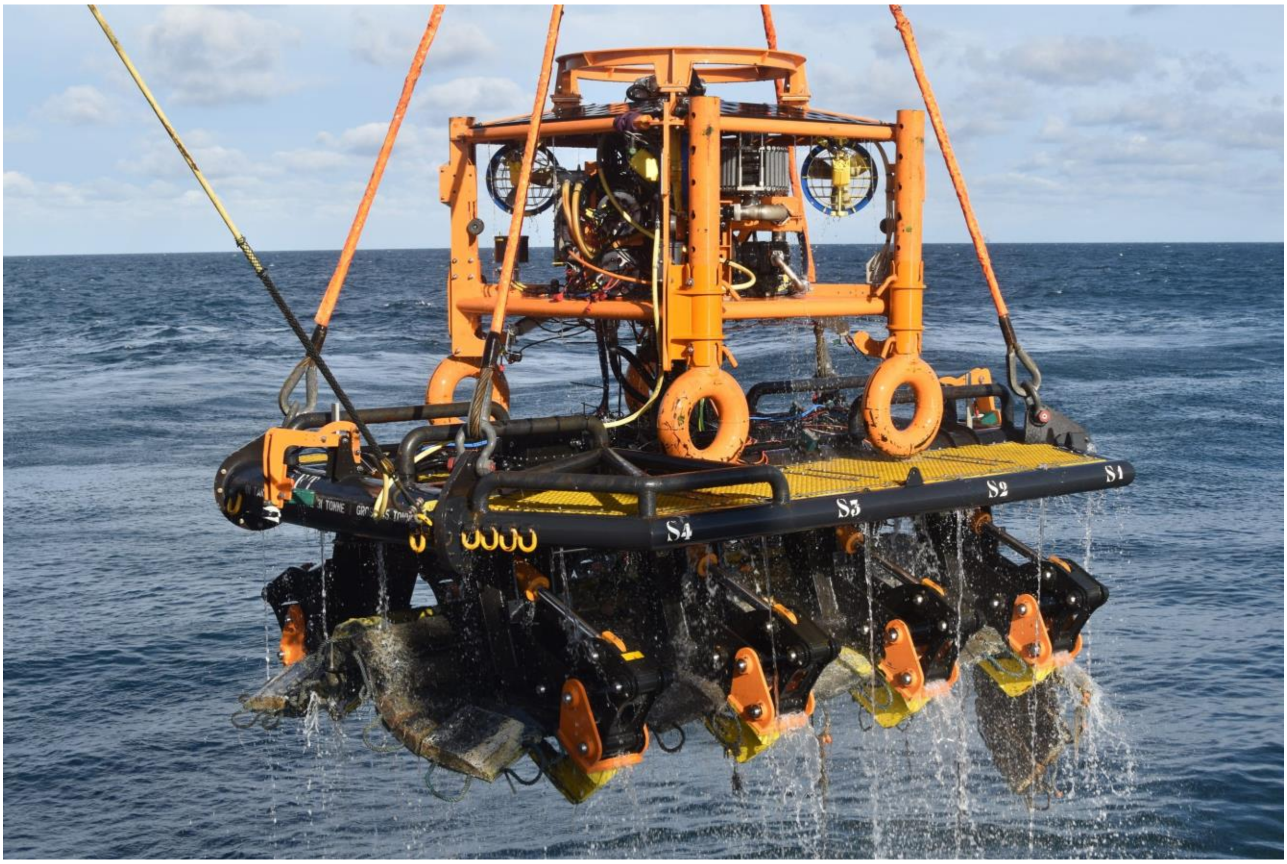

Figure 5.4.3: The UTROV® Solution[22]

In summary, it would be feasible to fully recover the mattresses although contingency planning would be required for mattress disintegration during recovery.

5.4.2 Safety considerations

The difference in potential safety risk between the options is sufficiently large that a HAZID was not considered necessary at this stage. A HAZID would ordinarily be carried out as part of the preparatory activities.

Safety Risk to Offshore Project Personnel

The key differences between the options are as follows.

- Risk to divers and personnel on the vessel – divers if used, and personnel on the vessel from dealing with bulky items would be greater for the complete removal option than for leave *in situ* due to the larger quantity of material recovered. However, mitigations such as remote operations are available that would avoid use of divers and that would minimise interactions between personnel and bulk items being moved around deck;
- Increased risk to all activities due to adverse weather would be greater for the complete removal option than for leave *in situ* as the vessels would be in the field for longer;
- Risk associated with legacy survey activities that is, the risks associated with vessels being used are greater for the leave *in situ* option than for complete removal. Typically, in the UK a minimum of three legacy surveys would be required to confirm the condition of subsea equipment left *in situ* but the requirement would likely depend on the degree of exposure. However, as most of the operations are

[22] Photo courtesy of Utility ROV Services, https://www.utrov.com

carried out using remotely operated trackers and ROVs the risk from this type of operation can be considered low.

Given that the activities and techniques are frequently used in the North Sea it is presumed that the risks from all hazards would be broadly acceptable. The repetitive nature of the recovery work could lead to complacency or loss of concentration, but this is a procedural issue that could be managed.

In summary, with planning the recovery of mattresses could be achieved using remote operations, thereby minimising the health and safety risk to project personnel. However, that the mattresses would be recovered at all would pose a greater HSE risk to project personnel than leaving them *in situ*.

Short-term Safety Risk to Fishermen and Other Marine Users

The risk to mariners in the short-term is aligned with the duration the activities would be undertaken in the field. While decommissioning operations are underway the duration of vessels in the field would be longer for any removal operations than for leave *in situ*. The nature of the recovery work is such that once a mattress is lifted the operation would need to be completed before the vessel could move from its location. Depending on the method being used the lifting operation for a single mattress would typically take between 20 minutes to perhaps an hour for more problematic mattresses for which contingency operations are needed.

Theoretically, for the leave *in situ* option vessels would be required in the field only to follow the decommissioning philosophy for those mattresses being left behind. Most of the mattresses are located in the installation 500m zones. Should the mattress decommissioning works be completed before the 500m zones have been deemed safe and relinquished, the only interaction with marine traffic would be during transits outside of the 500m zones.

While decommissioning activities are occurring, the risk to fishermen and other marine users would be least for the leave *in situ* option.

Residual Safety Risk to Fishermen and Other Marine Users

The greatest risk relating to marine users was likely to be concerned with snagging of fishing gear. The type of fishing in the area is predominantly beam trawler activity, targeting demersal fish. Therefore, for demersal fishing activities there is a potential for snagging on equipment left on the seabed, including spoil mounds and exposed mattresses.

From this it can be reasoned that decommissioning activities that minimise the disturbance to the seabed, reduce the likelihood of creating snag hazards or spoil mounds and that leave the seabed free of equipment would minimise the impact on local fishing activities; this would be different from the current situation in areas outside of the 500m safety zones, although it is worth noting that most of the mattresses are located *within* the existing 500m safety zones.

Should the mattresses be buried[23], both complete removal and leave *in situ* options would leave the seabed free of snagging hazards. However, by completely removing the mattresses the risk of snagging is removed in perpetuity so the complete removal option would result in lower residual risks to mariners and other users of the sea. The inference here is that as long as the mattresses remain *in situ* there would be the possibility of them becoming exposed. The cut pipeline ends would likely be remediated with additional rock. Should the mattresses be left *in situ* additional rock would be deposited at a cut pipe end next to a mattress rather than on or near point of burial in existing rock. The deposition of additional rock at cut pipeline ends could play a part in creating unpredictable local scour patterns and so the requirement should be minimised where possible. Should the mattresses be left *in situ*, surveys would need to be done in future in order to verify that the risk of snagging would remain low.

Health & Safety Risk to Onshore Project Personnel

The key differences between the options are as followed:

- Risks associated with cutting the mattresses or crushing resulting in injury would increase with the quantity of material being returned to shore and so would be greatest for the complete removal option. This risk could be mitigated by using remotely operated plant and mechanised;
- Risks associated with lifting and handling mattresses would also increase with the quantity of material being returned to shore.

[23] Burial assumes that the edges of the mattresses and most of the fronds are buried under sediment, although the tops of the fronds may be visible.

Based on the differences, the leave *in situ* option gives rise to lower risks to onshore personnel for the following reasons:

- Less offshore work;
- Less onshore handling;

Unloading mattresses from a vessel has been done before, but to do this at all would increase the risk to onshore personnel compared to the leave *in situ* option.

5.4.3 Environmental considerations

Planned and unplanned energy use, emissions, and discharges

The duration that vessels would be required in the field for the complete removal option would be longer than required for leave *in situ*; This would be reflected in the liquid discharges to sea, noise, energy requirements and emissions to air both offshore and onshore. Conversely, the legacy survey requirements for leave *in situ* would be greater than for complete removal.

The amount of lifting and disposal requirements are related to the number of mattresses being recovered. Therefore, the discharges to sea, discharges to surface water, noise in water and seabed disturbance from excavation and lifting activities, would all be greater for the complete removal option than for leave *in situ*.

Energy requirements and emissions to air would be such that there would be a significant difference between the options. However, the gap between complete removal and leave *in situ* would reduce when indirect energy requirements and resulting emissions for replacement of unrecovered material are accounted for.

Planned and unplanned impacts on the seabed sediments

While the complete removal option would result in no materials being left on the seabed, the leave *in situ* option would result in materials being left to degrade naturally. As the mattresses are predominantly manufactured from concrete this would not be detrimental to the local environment, although the fronds and the polypropylene rope[24] used to hold the concrete blocks together are made from synthetic materials. Particularly, should these be exposed to sunlight they can also be expected to degrade, resulting in synthetic material being released into the water column. Given their location, however, the process can be expected to be slow. As the deposition of degraded materials would likely occur very gradually over tens or hundreds of years, this would not be detrimental to the local marine environment.

Conservatively if it could be assumed that the removal of each mattress would affect a 5m wide perimeter around each of them, the overall area of seabed affected would equate to 0.197km^2. Remembering that the seabed area of the Dogger Bank SAC is 12,331km^2, this would mean that 0.0016% of the Dogger Bank SAC seabed area would be directly impacted by the disturbance created by the mattress removal activities. That is, the area affected would be negligible.

Impact on the conservation objectives of the Dogger Bank and Southern North Sea SACs

At the time of writing (2020) the conservation objective for the management of Dogger Bank is to restore the sandbank to favourable condition rather than to maintain the features in favourable condition. In their report [3] BEIS describe the Dogger Bank and associated biological communities are ‘vulnerable’ to physical disturbance or abrasion associated with activities that involve *disturbance* of seabed.

The conservation objectives of relevance here for the management of Southern North Sea SAC is to avoid significantly damaging the habitat for the Harbour Porpoise and thereby significantly reducing the availability of prey.

Although complete removal of the mattresses would involve disruption to the seabed sediment, it is arguable whether this option would be non-preferred compared to leave *in situ*, because the seabed would be expected to make a full recovery from such activities. Alternatively, the presence of hard strata such as concrete can be considered alien to the local environment, so for this to continue would be non-preferred, but this would be mitigated slightly should the mattresses remain buried.

As a percentage of the area covered by the Dogger Bank SAC, the area impacted by leaving the mattresses *in situ* would be ~0.018km^2. This equates to ~0.00015% of the Dogger bank SAC for all of the fronded and concrete mattresses considered here. The area disturbed would be an order of magnitude smaller than that

[24] Details have not been obtained for all the mattresses, but their vintage suggests that polypropylene rope would most likely have been used rather than steel rope which was used for much older mattresses.

disturbed by removal activities, albeit permanently. In percentage terms neither the temporary nor permanently affected areas would be significant.

By inspection, the majority if not all of the existing mattresses on PL929 and PL930 are located outside of the SNS, and the removal or otherwise of the mattresses for these pipelines would not affect the conservation objectives of the SNS SAC.

Waste management

The amount of material made available for reuse, recycling or destined for landfill would be directly related to the quantity recovered. However, experience would suggest that all the recovered materials (~7,060Te) would be recycled either as base material or in the case of the synthetic materials of the fronds, anchored frond bases and polypropylene rope the materials could be used for recovery as energy. This has been done before. Conversely, any material left *in situ* would need to be replaced by the manufacture of new material.

5.4.4 Societal considerations

Commercial

The main commercial activity in the area is demersal fishing. The potential effects could be loss of fishing revenue due to exclusion from fishing grounds, disturbance of the seabed or loss or damage of fishing equipment.

While the vessels are present in the field and activities are being undertaken the area would not be accessible for fishing and the magnitude of impact on commercial activities would be related to the number and duration of vessels. Activities which involve removal would implicitly disturb the seabed, and since complete removal would require more activities on the seabed it would also have a higher short-term impact on commercial fishing. However, since most of the mattresses are located with the 500m safety zones of the installations should the mattresses be removed before the 500m safety zones are relinquished there would be little to no impact on fishing or other marine related activities in the area with any impact being limited to movements between locations and transits to and from port.

The leave *in situ* would involve leaving infrastructure behind, presenting a potential snag hazard. In this situation there would be a greater chance that fishing gear could be lost or damaged, and this would have an impact on commercial fishing. However, if it could be demonstrated that the mattresses that remain *in situ* are buried it is unlikely that the leave *in situ* option would be detrimental to commercial fishing activities.

For all the decommissioning options seabed clearance activities and risk assessments would be done to verify that residual snagging hazards remain low and unlikely to occur.

Therefore, during decommissioning activities, in the short-term the complete removal option can be expected to have a greater impact on fishing activities as they would have the longest duration and the greatest amount of activity disturbing the seabed. The leave *in situ* option would involve leaving mattresses where they are, and this could result in residual snag hazards. Surveys would likely need to be undertaken to confirm that the mattresses remain buried. While these surveys are being undertaken fishing activity may be disrupted for a short time, but the impact can be expected to be minimal. Typically, one post-decommissioning survey would be required followed by legacy surveys; the exact magnitude of impact will be dependent on the type, frequency and duration of the surveys needed.

Employment

The complete removal option would use more vessel time and activities, and more waste management requirements and so would impact more positively on employment than leave *in situ*. However, the effect on employment would likely result in the continuation of existing jobs, rather than lead to the creation of new ones although the collective recovery of all the mattresses in the CMS area could result in creation of new jobs but perhaps only short-term. The significance of the positive impact can be assessed as low.

Communities

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 hold the required permits for waste management. The communities around the port and the waste disposal sites could therefore be expected to 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 the options.

5.4.5 Cost considerations

As discussed in section 2.4.6, there are 97 fronded mattresses that are anchored, 448 fronded mattresses with concreted bases and 372 concrete mattresses - a total of 917 mattresses. If it could be assumed that each mattress would take ~30 minutes to recover, this amounts to 458 hours or 19 days of vessel time excluding mobilisation and demobilisation costs, port calls and down time due to currents, tides, and non-productive time in general. This does not include additional time required to recover the underlying pipelines and umbilicals. The cost assessment examines cost by difference. That is, common activities such as engineering and management costs, mobilisation and demobilisation of vessels are ignored for the compete removal and leave *in situ* options.

The cost of dealing with the mattresses is combined with the removal of the underlying pipelines and umbilicals although mattresses around pipeline tee and pigging manifold assembly protection structures and subsea installations do not always lie over pipelines and umbilicals and are therefore treated differently.

The cost of this activity is assessed and the difference in cost compared with leave *in situ* is presented in Appendix 9, Table A9.4.1 and Table A9.5.1. Several concrete mattresses (~51x) associated with the CMS pipelines need to be removed anyway due to commitments in third party decommissioning programmes for Ketch [11] and Schooner [12]. The pipelines affected are PL1436 & PL1437, PL1924 & PL1927, PLU4686, PLU4888, PLU47889 and PLU4890. That they would be removed is accounted for in the leave *in situ* costs.

In the short-term and for pipeline and umbilical ends only, mattress removal operations for PL929, PL930, PL935 and PL936 and for all piggybacked pipelines and all umbilicals including the underlying pipelines, pipespools and umbilicals on the approaches would cost an order of magnitude more than to leave them *in situ*.

These differences may be partly offset by the need to recover those mattresses that would have been disturbed anyway as a result of the removal of installations, tee protection structures and pigging manifold structures, as it is likely that an MFE would be used to clear away local sediment. This means that the difference may not be as great as portrayed here.

The expectation is that the following mattresses and underlying infrastructure could be candidates for full removal anyway on the assumption that they would be disturbed when the installations, pigging structures and local third-party infrastructure are removed:

- PL1922 & PL1925, mattresses and underlying pipespools between McAdam MM and McAdam Tee;
- PL1923 & PL1926 mattresses and underlying pipespools between deposited rock and PSNL;
- PL1924 & PL1927, mattresses and underlying pipespools between Watt QM and deposited rock both upstream and downstream of Watt QM;
- PL1924 & PL1927, mattresses and underlying pipespools between end of ~18m long deposited rock and PSSL;
- PL1924 & PL1927 mattresses and pipespools between PSSL and riser on Murdoch MD;
- PL2109 & PL2110 between Kelvin TM and deposited rock;
- PL2894 & PL2895 mattresses and pipespool between Katy KT and deposited rock;
- PL2894 & PL2895 mattresses and pipespools between deposited rock and Kelvin TM subsea tee assembly;
- PLU4888 & PLU4889 mattresses and underlying pipespools between Watt QM and burial at trench depth in the seabed either side of Watt QM;
- Mattresses and underlying pipespools between PSNL, PSSL and Murdoch MD, noting that the Ketch [11], and Schooner [12] pipespools, mattresses and any grout bags are being recovered as part of separate decommissioning proposals. The Cavendish mattresses and any grout bags are also being fully recovered [15] while the pipeline ends are being reburied.

Complete removal of the mattresses associated with most of the pipeline structures and subsea installations would cost an order of magnitude more than leave *in situ* in the short-term although longer-term the cost difference would be offset by the need to legacy surveys sometime in future.

Leave *in situ* costs include incremental costs for carrying out 1x post decommissioning survey and 3x legacy surveys of the short sections of mattresses and any underlying pipelines and umbilicals left *in situ*. Ordinarily these costs would be borne as part of the pipeline surveys. There could be a scenario however, where mattress status surveys are required, but the burial status of the pipelines no longer warrants any future surveys. Assuming a total mattress length of ~3km, any mattresses would likely be surveyed in the same campaign as the pipelines, and they might be expected to account for ~1% of the surveying effort.

For context, the total length of pipelines in the CMS area is ~513km, or 154km if the two trunklines PL929 and PL930 are ignored. Excluding mobilisation and demobilisation, transit times and downtime due to currents, tides, and non-productive time in general, pipeline surveys for the whole region would take ~50 days or ~15 days excluding the trunklines; most of the mattresses are to be found on the CMS infrastructure rather than on the trunklines. This is simplistic, but compares with 16.5 days for removing the mattresses, excluding the underlying pipelines and umbilicals.

5.5 Comparative Assessment for pipelines in group 1

The ‘complete removal’, and ‘leave *in situ*’ decommissioning options are compared for all the pipelines in group 1 with the partial removal option also being considered for the two trunklines PL929 and PL930. The pipelines considered here are PL929 (26in, CWC), PL930 (4in), PL935 (16in, CWC) and PL936 (3in). Survey data for PL929 would suggest that they are likely to be buried with extensive exposures. Given the bathymetry (sand waves, sand banks, megaripples, etc) it is assumed likely that this would be replicated for PL930. PL935 has shown good depth of burial and it is likely that this would be replicated for PL936. Please refer Appendix 6 for summary comparison assessment tables and more details.

Several of the pipelines have pipeline crossings along their length. Although this is a consideration the effect of pipeline crossings is not discussed here. Please refer section 3.15, section 3.16 and section 3.

5.5.1 Technical considerations

The larger 26in (PL929) and 16in (PL935) pipelines are both concrete weight coated and were most likely installed using the S-lay technique, so they would not be candidates for reverse reeling. Reverse reeling is not generally considered a viable for concrete coated pipelines since the concrete coating cannot be reeled onto the reel without the coating cracking and falling off the pipeline. The concrete coated pipe is not designed to develop the bending stresses expected with reverse reeling when taking account of the weight of concrete coating. Reverse S-lay is unlikely to be feasible for concrete coated pipelines so these pipelines would need to be recovered in sections using ‘cut and lift’. There are also potential issues with the deterioration of the concrete coating over time which would hinder recovery of the pipe and may result in sections falling off during recovery. Given the age of the pipelines there would also be uncertainties over the condition and structural integrity of the pipeline which could fail during recovery. To the author’s knowledge reverse S-lay has not been used for recovering pipelines in the industry.

Although repetitive, the ‘cut and lift’ method would be feasible but would take a significant amount of time to achieve. Should the pipelines be recovered in road transportable lengths between 10m and 12m long this would mean between 80 and 100 sections being recovered per km of pipeline. For pipelines almost 190km long and 10.5km long for PL929 and PL935 respectively, recovery using the ‘cut and lift’ method would be an unrealistic prospect.

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

Partial removal – that is, removal of the exposed sections of PL929 (total up to ~6km long) would not find favour. Primarily this is because of the resources and inefficiencies that would be involved in finding and locally excavating the exposed pipelines to reveal the appropriate cut locations. The removal activities would likely involve piece-meal excavation and ‘cut and lift’ activities, with the effort required increasing for an increasing number of exposures or spans being remediated.

For the smaller 3in and 4in pipelines reverse reel method would likely be the method of choice for removal although any concerns about pipeline integrity would need to be addressed beforehand. That the pipelines are suitable for service does not necessarily mean that they would be suitable for recovery using reverse reel, especially if they have been in service for almost three decades or more. Given their burial depth it is likely that they would need to be excavated prior to being removed, but this could be determined by analysis. Any technical uncertainty over the integrity of the pipelines would have an adverse effect on technical feasibility.

Although all the pipelines could be completely or partially removed in road transportable lengths using the 'cut and lift' method, the length of pipeline(s) would probably render the 'cut and lift' approach impractical for the complete removal option. Nevertheless, feasible.

From a technical perspective deposition of additional rock or post-trenching would both be feasible for dealing with exposures and the leave *in situ* decommissioning option would also be feasible.

5.5.2 Safety considerations

The difference in potential safety risk between the options is sufficiently large that a HAZID was not considered necessary at this stage. A HAZID would ordinarily be carried out as part of the preparatory activities.

Safety Risk to Offshore Project Personnel

The key differences between the options are as follows.

- Risk to divers and personnel on the vessel – divers if used, and risk to personnel on the vessel from hydrocarbon or hazardous substance releases from recovered pipelines would be greater for complete and partial removal options than for leave *in situ* due to the larger volumes of material recovered;
- Risk associated with 'cut and lift' operations. Assuming the pipelines could successfully be excavated from a technical perspective the operation should be relatively straightforward. However, to ensure road transportable lengths of between 10m and 12m, the 'cut and lift'; operations would require between ~80 to ~100 sections of pipe to be removed *per km* of pipeline. Arguably, from a safety perspective this would likely be manageable, but the associated risks would increase with the number of operations needing to be performed and the amount of material being transferred and handled on the vessel; no such risks would be incurred for the leave *in situ* option;
- Risk associated with reverse reeling operations and risks associated with the vessel being attached to the pipelines. The risk to personnel and assets would therefore be greater for complete removal option and possibly for the partial removal option - should this method be used, than for leave *in situ*;
- Increased risk to all activities due to adverse weather would be greater for the complete and partial removal options than for leave *in situ* as the vessels would be in the field for longer;
- Risk associated with deposition of rock either along part or all of the pipelines. The operational risks would increase with the amount of material involved but can be expected to be low. To have to carry out the operation at all would present more of a risk than doing nothing at all;
- Risk associated with post-trenching along part or all of the pipelines. The operational risks are such that any safety concerns would be low, but to have to carry out the operation at all would present more of a risk than doing nothing at all;
- Risk associated with legacy survey activities that is, the risks associated with vessels being used would be greater for the leave *in situ* option than for complete removal. The partial removal option would likely take a similar amount of time as the leave *in situ* option. Typically, in the UK a minimum of three legacy surveys would be required to confirm the condition of subsea pipelines left *in situ*.

Given that the activities and techniques are frequently used in the North Sea and manageable, and most of not all of the work would likely be conducted using remote operations, it is assumed that the health and safety risks from all hazards would be broadly acceptable.

Short-term Safety Risk to Fishermen and Other Marine Users

The risk to mariners in the short-term is aligned with the duration the activities would be undertaken in the field. While decommissioning operations are underway the duration of vessels in the field would be longer for either the complete removal or partial removal options than for leave *in situ*. Reverse reel and to an extent 'cut and lift' would mean that the vessel is attached to a pipeline and could not move out of the way quickly.

Deposition of rock could be aborted relatively quickly although post-trenching operations using tethered equipment would take more time to abort and make safe.

For the leave *in situ* option at most only the pipeline ends would be dealt with and the duration of the vessels in the field would be much shorter for this option.

Therefore, while decommissioning activities are occurring, the risk to fishermen and other marine users would be least for the leave *in situ* option. However, fishing activity in the CMS area is low in frequency and principally by large vessels operating towed gear such as those from the UK demersal trawl fleet. It could be expected that interference would take the form of minor alterations to normal operating practices. Such deviations would be so small as to be insignificant. On this basis the potential impact associated with any of the three decommissioning activities can be considered low.

Residual Safety Risk to Fishermen and Other Marine Users

The greatest risk relating to marine users was likely to be concerned with snagging of fishing gear. The type of fishing in the area is predominantly trawler activity, targeting demersal fish. Some scallop dredging and static potting has been recorded in discrete areas about half-way along the export pipelines [5]. For demersal and scallop dredging activities, therefore, there is a potential for snagging on equipment left on the seabed, including spoil mounds. In this instance, the pipelines being considered here remain largely buried although PL929 has several exposures and PL930 might be expected to, given the location.

From this it can be reasoned that decommissioning activities that minimise the disturbance to the seabed, reduce the likelihood of creating snag hazards or spoil mounds and that leave the seabed free of equipment will minimise the impact on local fishing activities; this will be no different from the current situation in areas outside of the 500m safety zones. In the short-term both complete removal and leave *in situ* options would leave the seabed free of potential snagging hazards unless any spans are reportable to FishSAFE. Over time, however, the degradation of the pipelines would lead to additional snagging hazards, but this might be expected to take tens to over a hundred years, especially for the concrete coated pipelines [13].

The partial removal option may leave the seabed free of snag hazards in the short-term, but as the seabed in this area is mobile the situation could change. The cut ends of multiple exposures remediated today could become snag hazards in the future even though the exposed cut ends would be remediated. Remediation such as addition of deposited rock could lead to a change in topography, movement of the sediment and unpredictable scour patterns.

Post-trenching may work in the short-term, but it would not be certain that the cut pipeline ends would not reappear. Arguably, that cut pipeline ends would exist at all would be worse than exposed pipelines.

Although the complete and partial removal options have the potential to leave spoil mounds that present snagging hazards, it is possible that with extra effort these could be dispersed or given the location would disappear over time.

By completely removing the pipelines the risk of snagging would be removed in perpetuity. Therefore, the complete removal option results in lower residual risks to mariners and other users of the sea. The partial removal option could result in more snagging hazards being left behind – those associated with each section of pipeline that is removed, even though they would be remediated.

There would likely be no increased snagging risk associated with the leave *in situ* option even for those pipelines with known exposures - PL929 and probably PL930. Arguably, leave *in situ* would be preferred to the partial removal option and the situation would be no different to what it is now. This could change, however, with the occurrence of any pipeline spans with reportable dimensions. Surveys will need to be done in future in order to verify that the risk of snagging would remain low for the foreseeable future. The risk of snagging would already seem low for PL935 although the burial status and stability of PL936 will need to be confirmed by survey and risk assessed.

Health & Safety Risk to Onshore Project Personnel

The key differences between the options are as follows:

- Should deposition of rock be required instead of partial removal for example, there would be threats associated with the quarrying of rock, its transportation, and transfer to a rock discharge vessel at quayside, although the risks might be expected to be well managed, and so would be low;
- Risks associated with cutting the pipeline resulting in injury would increase with the quantity of material being returned to shore and so would be greatest for the complete removal option followed by the partial removal option compared with the leave *in situ* option;
- Risks associated with lifting and handling pipeline sections would also increase with the quantity of material being returned to shore.

Based on the differences, the leave *in situ* option gives rise to lower risks to onshore personnel for the following reasons:

- Less offshore work;
- Less onshore handling;
- Unloading pipespools from a vessel has been done before, but to do this at all for either the complete or partial removal options would increase the risk to onshore personnel compared to the leave *in situ* option;

- Unspooling of pipelines from a reel has been done before, but to have to do this at all for either the complete or partial removal options would increase the risk for onshore personnel compared to the leave *in situ* option.

5.5.3 Environmental considerations

Planned and unplanned energy use, emissions, and discharges

The vessels would be required in the field longer for complete removal and partial removal than for leave *in situ* option. Despite the piece-meal nature of partial removal activities for PL929 or possibly PL930 (subject to survey), the activities would still take less time to complete than complete removal. This would be reflected in the liquid discharges to sea, noise, energy requirements and resulting missions to air. Conversely, the legacy survey requirements for partial removal and leave *in situ* would be greater than for complete removal, and in the case of partial removal, the possibility of remedial works some time in future could increase with the number of cut pipeline ends.

The amount of cutting, lifting and disposal requirements are related to the length of pipeline being recovered. Therefore, the discharges to sea, discharges to surface water, noise in water from cutting, seabed disturbance from excavation and lifting, would all be greater for the complete removal and partial removal options than for leave *in situ*. From this perspective the impact of the partial removal option would be less than for complete removal but much more than for the leave *in situ* option.

Energy requirements and emissions to air would be such that there would be a difference between options. However, the gap between complete removal, partial removal and leave *in situ* would narrow when indirect emissions and energy requirements – such as that required for replacement of unrecovered material – are accounted for.

Planned and unplanned impacts on the seabed sediments

The complete removal option would result in no materials left in the seabed. During removal of concrete coated pipelines the likelihood of concrete spalling or breaking off during cutting and lifting operations would be greatest. The partial removal and leave *in situ* options would result in most or all of the pipeline materials being left to degrade naturally. As the pipelines are predominantly manufactured from steel and – for the two larger pipelines, concrete this would not be detrimental to the local environment as the deposition of degraded concrete and steel materials would likely occur very gradually over tens if not hundreds of years.

If it can be assumed that the removal of each pipeline would affect a 10m wide corridor along the length of the pipelines and remembering that the seabed area of the Dogger Bank SAC is 12,331km^2, for each of the trunk lines alone, this would mean that 1.8km^2 or 0.015% of the Dogger Bank SAC seabed area would be directly impacted by the disturbance created by the complete removal activities. A much smaller proportion of area would be affected should PL935 and PL936 each be completely removed because the length of the pipelines is much less than the length of the trunklines. That is, the percentage of area affected would be negligible.

Similarly, should the deposition of rock be the decommissioning option of choice for dealing with exposures, the amount of seabed sediment affected would be proportional to the lengths of pipeline being remediated. Clearly the area impacted would be much less than that effected by complete removal but the deposition of hard strata such as rock would have a permanent effect on the seabed and would likely alter the topography, movement of the sediment and cause unpredictable scour patterns. This also means that any pursuit of the partial removal option should aim to minimise the number of cut pipeline ends needing to be remediated.

Post-trenching may work in the short-term, but with the movement of the sediment it would not be certain that the cut pipeline ends would not reappear.

Impact on the conservation objectives of the Dogger Bank and Southern North Sea SACs

At the time of writing (2020) the conservation objective for the management of Dogger Bank is to restore the sandbank to favourable condition rather than to maintain the features in favourable condition. In their report [3] BEIS describe the Dogger Bank and associated biological communities are 'highly vulnerable' to physical disturbance or abrasion associated with activities that involve excavation of the seabed sediment.

The conservation objectives of relevance here for the management of Southern North Sea SAC is to avoid significantly damaging the habitat for the Harbour Porpoise and thereby significantly reducing the availability of prey.

As complete removal or partial removal of the pipelines would involve disruption and excavation of the seabed, these options would be non-preferred compared to leave *in situ*, although it should be recognised that the area of seabed affected as a percentage of the area covered by the Dogger Bank SAC would be extremely small (max. ~0.015%) for any of the four individual pipelines considered here.

For PL929 and PL935, any removal activities would likely result in dust and fragments of concrete weight coating being permanently lost on the seabed as sections of the pipelines are cut and recovered.

By inspection, the area affected by the decommissioning of the PL929 and PL930 in the SNS SAC would have a negligible effect on the conservation objectives of the SNS SAC.

The deposition of hard strata such as rock would be permanent and alien to the local environment while post-trenching would penetrate the substrata of the seabed resulting in permanent damage. On this basis both methods of remediation for the partial removal option would be non-preferred, although as described earlier the percentage of the Dogger Bank SAC affected would not be significant. This should also be taken in the context of the area impacted when the infrastructure was originally installed; the deposition of additional rock or post trenching activity would be along existing pipeline routes and so any additional impact would not be considered as significant as excavating a pristine seabed.

Waste management

The amount of material made available for reuse , recycling or destined for landfill would be directly related to the quantity recovered. However, experience would suggest that very little material would be destined for landfill once recovered. The concrete weight coating would likely be crushed and recycled as would the steel material. Any plastics recovered would be recycled as recovered energy. Conversely, any material left *in situ* would need to be replaced by the manufacture of new material.

5.5.4 Societal considerations

Commercial

The main commercial activity in the area is demersal fishing and some scallop dredging and potting [5]. The potential effects could be loss of fishing revenue due to exclusion from fishing grounds, disturbance of the seabed or loss or damage of fishing equipment.

While the vessels are present in the field and activities are being undertaken the area would not be accessible for fishing. Therefore, the magnitude of the impact on commercial activities is related to the number and duration of vessels and type of damage, for example, to static equipment used for lobster pots, etc.

Activities which involve removal or reburial would implicitly disturb the seabed. Therefore, since complete removal – and to a lesser extent, partial removal, would require more activities on the seabed they would have a higher short-term impact on commercial fishing.

Both the leave *in situ* and partial removal options would involve leaving infrastructure behind, presenting a potential snag hazard. In either situation there would be a greater chance that fishing gear could be lost or damaged, and this would have an impact on commercial fishing. The partial removal option could be regarded the worst of these two options because more cut pipeline ends would be left behind, even though they would likely be remediated. However, the intensity of fishing activity in the area is relatively low, and in this instance the pipelines are mostly buried, although PL929 has been found with exposures and PL930 might be expected to, subject to survey. The surveys have indicated that no reportable spans are present, and there have been no reports of snagging, so it is unlikely that the leave *in situ* option would be detrimental to commercial fishing activities.

As an alternative to partial removal, either deposited rock or post-trenching could be used to bury the exposures. Assuming that rock would be profiled adequately and graded appropriately this should not result in new snagging hazards being introduced. As the seabed is relatively mobile the seabed could possibly be left to back fill naturally, but to minimise uncertainty the post-trenching activities could be completed by backfilling the trench as part of the same operation.

For all the decommissioning options seabed surveys and risk assessments would be done to verify that the threat of residual snagging hazards would remain low. Over the longer term, however, should they be exposed as they degrade, the pipelines could pose more of a snag hazard, although this can be expected to occur over a period of tens if not over a hundred years [13], especially for the concrete coated pipelines.

Therefore, during decommissioning activities, in the short-term the complete and partial removal options can be expected to have a greater impact on fishing activities as they would have the longest duration and the greatest amount of activity disturbing the seabed. The partial removal and leave *in situ* options would involve leaving most of the pipelines where they are, resulting in potential residual snag hazards. Pipeline surveys would need to be undertaken to confirm that the pipelines remain buried. While these surveys are being undertaken fishing activity may be disrupted for a short time, but the impact can be expected to be minimal. Typically, one post-decommissioning survey would be required followed by legacy surveys; the exact magnitude of impact will be dependent on the type, frequency and duration of the surveys needed.

Employment

The complete removal and partial removal options would require a longer vessel duration and waste management requirements and therefore impact more positively on employment than leave *in situ*. For individual pipelines, the effect on employment would likely result in the continuation of existing jobs, rather than lead to the creation of new employment opportunities although collective recovery of all the pipelines in the CMS area could result in creation of new jobs, although they might only be short-term. The significance of the positive impact can, however, be assessed as low.

Communities

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 hold the required permits for waste management. The communities around the port and the waste disposal sites are therefore, expected to be adapted to the types of activities required and the decommissioning activities 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.

5.5.5 Cost considerations

More details of the cost assessment by difference for the pipelines in group 1 are presented in Appendix 9. The assumption is that the pipelines >16" would be removed using the 'cut and lift' method, and that the integrity of the smaller pipelines is such that they would be removed using the reverse reel method. The leave *in situ* option assumes that the surface laid pipeline ends, and associated mattresses would be removed, irrespective of the recommendation of this comparative assessment[25]. Should the pipeline ends be left *in situ* this would clearly increase the difference in cost between the complete and partial removal options and leave *in situ*. Please refer Appendix 9.3 for a more extensive explanation of the assumptions used in the assessment. Note that the ends of PL929 & PL930 and PL935 & PL936 on the approaches are piggybacked and each pair of pipelines could therefore be removed at the same time, although the bulk of the pipelines are laid in separate trenches.

For PL929 and PL930 the complete removal option the cost by difference would be an order of magnitude more than both the partial removal and leave *in situ* options in the short-term. In both cases once removal had been completed no more costs would be incurred for legacy pipeline surveys.

For PL929 and PL930 the partial removal option would also cost an order of magnitude more than the leave *in situ* option. Note that in the absence of survey data the partial removal option for PL930 assumes that the length of exposures would be similar to PL929. In both cases legacy surveys would be required sometime in future. Also note that the full length of these pipelines has not been surveyed, meaning that the cost of partial removal could increase.

Using a similar approach for PL935 and PL936, the complete removal option for both would cost an order of magnitude more than the leave *in situ* option in the short-term. In both cases, once completed no more costs would be incurred for future pipeline surveys. In both cases legacy surveys would be required sometime in future. It should also be noted that no survey data are available for PL936, so the assumption meantime is that there are no exposures, as per PL935. This may change once survey data becomes available.

Pipelines, or parts thereof, that are left *in situ* would likely be subject to future pipeline inspections. Future pipeline surveys can be expected to cost less than the operations associated with complete removal and the need to deal with the associated waste materials onshore. For the purposes of this cost assessment, it is assumed that 1x post decommissioning pipeline status surveys would be required, followed by 3x legacy surveys for any infrastructure being left *in situ*. Refer Table A9.6.1 and Table A9.7.1.

5.6 Comparative Assessment for pipelines in group 2

The 'complete removal', and 'leave *in situ*' decommissioning options are compared for all the pipelines in group 2 with the partial removal option also being considered for the Munro MH (PL2109 & PL2110) pipelines.

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[25] When decommissioning pipelines or umbilicals *in situ*, it is quite common for the surface laid pipeline and umbilical ends to be removed, so this is the assumption used for the cost assessment.

The pipeline lengths vary from ~5km up to ~21km. The Munro MH pipelines piggyback clamps were furnished with plastic spoilers in an attempt to promote self-burial of the pipelines. This was partly successful.

The pipelines considered here are PL1436 & PL1437 (10in & 3in, 3LPP), PL1922 & PL1925 (10/12in & 3in 3LPP), PL1923 & PL1926 (10in & 3in, 3LPP), PL1924 & PL1927 (10in & 3in 3LPP), PL2109 & PL2110 (10in FBE & CWC, 2in 3LPP), PL2430 & PLU2431 (12in & 3in 3LPP) and PL2894 & PL2895 (10in & 2in 3LPP). All the pipelines in group 2 are piggybacked and all but one are coated using 3LPP; PL2109 has a concrete weight coating. Survey data for most pipelines except for PL1924 & PL1927 and PL2109 & PL2110 has shown good depth of burial with no exposures. Historically in any year PL2109 & PL2110 have been found to have multiple exposures, albeit with an overall length less than 1km (Table A1.2.1).

Several of the pipelines have pipeline crossings along their length. Although this is a consideration the effect of pipeline crossings is not discussed in detail here. Please refer section 3.15, section 3.16 and section 3.

Please refer Appendix 7 for summary comparison assessment tables and more details.

5.6.1 Technical considerations

Both the complete removal and leave *in situ* options are technically feasible as is partial removal option for the Munro MH pipelines - PL2109 & PL2110, respectively. As these pipelines are piggybacked and thereby complicating any attempt at reverse reeling or reverse S-lay it is likely that the pipelines would be recovered in sections using ‘cut and lift’. This would involve dispersal of the existing seabed or deposited rock overlying the pipelines followed by ‘cut and lift’ operations.

Although repetitive, the ‘cut and lift’ method would be feasible but would take a significant amount of time to achieve. Should the pipelines be recovered in road transportable lengths between 10m and 12m long this would mean between 80 and 100 sections being recovered per km of pipeline. Given the length of the pipelines, recovery using the ‘cut and lift’ method would be an unrealistic prospect for most, if not all of them.

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

In the case of the Munro MH pipelines (PL2109 & PL2110, intermittent exposures over an overall length ~1.5km) assuming there would be benefits in recovering the first 1.5km of pipeline, this would be feasible if not time-consuming to achieve.

From a technical perspective deposition of additional rock would be feasible, as would any post-trenching and piggybacked pipelines have been left *in situ* before, so any of these options would be technically feasible.

5.6.2 Safety considerations

The difference in potential safety risk between the options is sufficiently large that a HAZID was not considered necessary at this stage. A HAZID would ordinarily be carried out as part of the preparatory activities.

Safety Risk to Offshore Project Personnel

With exception of considerations for reversed reeling which would not apply in this instance, the key differences between the options are largely as described for the group 1 pipelines in section 5.5.2 and so for brevity the discussion will not be repeated here.

Short-term Safety Risk to Fishermen and Other Marine Users

With exception of considerations for reversed reeling which would not apply in this instance, the key differences between the options are largely as described for the group 1 pipelines in section 5.5.2 and so for brevity the discussion will not be repeated here.

Residual Safety Risk to Fishermen and Other Marine Users

Most of the discussion for the group 1 pipelines concerning residual risk to fishermen and other marine users would also apply here, but it is worth discussing the partial removal option in a bit more detail.

Historically, PL2109 & PL2110 have been found with multiple exposures for the first 1.5km length of pipeline, although the exposures themselves have only amounted to a total of a few hundred metres. The partial removal option might leave the seabed free of snag hazards in the short-term, but as the seabed in this area is mobile the situation could change. The cut ends of multiple exposures remediated today could become snag hazards in the future. Remediation such as addition of deposited rock would be acceptable from a residual safety risk, but this could lead to a change in topography, movement of the sediment and unpredictable scour patterns. Post-trenching may work in the short-term, but it would not be certain that the cut pipeline ends would not reappear. Arguably, that cut pipeline ends would exist at all would be worse than exposed pipelines. A solution to this would be to remove the first 1.5km of PL2109 & PL2110 in its entirety. This would remove the current exposures and limit the number of ends remaining thereby removing potential snagging hazards. Should these exposures have been removed the burial status would be such that no snagging hazards along the pipelines should arise in future.

Health & Safety Risk to Onshore Project Personnel

With exception of considerations for reverse reeling which would not apply in this instance, the key differences between the options are largely as described for the group 1 pipelines in section 5.5.2 and so for brevity the discussion will not be repeated here.

5.6.3 Environmental considerations

Please refer section 5.5.3 concerning environmental considerations as the discussion for the group 1 pipelines will largely apply here. Therefore, the discussion is not repeated here. However, the area and proportion of the seabed within the Dogger Bank SAC affected by the decommissioning options for the group 2 pipelines is slightly different and this is discussed in Appendix 7.3.

5.6.4 Societal considerations

Please refer section 5.5.4 as the societal impacts of operational activities for the group 2 pipelines are broadly similar from a societal perspective. Therefore, it is proposed not to repeat the discussion here.

5.6.5 Cost considerations

More details of the cost assessment by difference for the pipelines in group 2 are presented in Appendix 9. The assumption used here is that the piggybacked pipelines would be removed using the ‘cut and lift’ method. For purposes of the assessment the leave *in situ* option assumes that the surface laid pipeline ends, and associated mattresses would be removed, although this may not be the recommendation of this comparative assessment. This means that any difference in cost would be increased should the pipeline ends be decommissioned *in situ*.

Please refer Appendix 9.3 for a more extensive explanation of the assumptions used in the assessment.

Using the assumption that the piggybacked pipelines would be removed using the ‘cut and lift’ method the costs would be an order of magnitude greater than for leave *in situ*. Once removal had been completed no more costs would be incurred for legacy pipeline surveys.

Using the assumption that ~1.5km of the piggybacked pipelines PL2109 & PL2110 would be removed using the ‘cut and lift’ method, the cost by difference in the short-term would be less than half the cost for complete removal and almost 4x more than leave *in situ*. For the purposes of this cost assessment, it is assumed that 1x post decommissioning pipeline status surveys would be required, followed by 3x legacy surveys for any infrastructure being left *in situ*. Refer Table A9.6.1 and Table A9.7.1.

5.7 Comparative Assessment for pipelines in group 3

The ‘complete removal’, and ‘leave *in situ*’ decommissioning options are compared for all the umbilicals in group 3 with the partial removal option being considered for just PLU4685 where ~52m of the umbilical would be removed, otherwise all the umbilicals exhibit a good depth of burial throughout, with no exposures or spans. The umbilicals being considered here are PLU4686 & PLU4685, PLU4889 & PLU4888 and PLU4890. The lengths of the umbilicals vary from ~8.6km up to ~13km.

The umbilicals all crossover other infrastructure and so the presence of pipeline crossings would not influence the assessment other than there being a need to disperse any deposited rock and remove any concrete mattresses that impede access to the umbilical at the crossing.

Please refer Appendix 8 for summary comparison assessment tables and more details.

5.7.1 Technical considerations

Although they could be removed using the ‘cut and lift’ method, all the umbilicals would be considered candidates for reverse reeling, although their depth of burial is such that the trenches would need to be excavated using an MFE. Once the umbilicals had been removed the trenches may need to be backfilled. Local excavations for the umbilical ends may need to be mechanically back-filled if possible, but should difficulties ensue, small quantities of rock would be placed on the cut pipeline ends, but this should all be feasible. By inspection, the partial removal option for PLU4685 (removal of a total length ~60m of exposures ~27m long and ~33m long (between KP0.028 and KP0.280) would be acceptable from a technical perspective and preferred to complete removal. The exposures and freespans between KP0.222 and ~KP0.280 (total length 52m) would be removed as a continuous length.

Umbilicals have also been left *in situ* before, so this is technically achievable.

5.7.2 Safety considerations

Please refer section 5.5.2 as the safety considerations are broadly similar, although focus would be on the reverse reeling aspects of the assessment. Note that the partial removal option is only considered for PLU4685. By inspection, the partial removal option for PLU4685 (removal of a total length ~60m of exposures ~27m long and ~33m long (between KP0.028 and KP0.280) would be acceptable from a safety perspective and preferred to complete removal. The exposures and freespans between KP0.222 and ~KP0.280 would be removed as a continuous length. For brevity, the discussion will not be repeated here.

5.7.3 Environmental considerations

Please refer section 5.5.3 as the environmental impacts of operational activities for the group 3 umbilicals are broadly similar but note that the partial removal component is not being assessed here so repetition of the discussion is not proposed here. By inspection, the partial removal option for PLU4685 (removal of a total length ~60m of exposures (~27m long) and exposure (~33m long) between KP0.028 and KP0.280) would be acceptable from an environmental perspective and preferred to complete removal. The exposures and freespans between KP0.222 and KP0.280 would be removed as a continuous length. Note that the area and proportion of the seabed within the Dogger Bank SAC affected by the decommissioning options for the group 3 umbilicals is slightly different and this is discussed in Appendix 8.3.

5.7.4 Societal considerations

Please refer section 5.5.4 as we believe that the societal impacts of operational activities for the group 3 umbilicals are broadly similar from a societal perspective. By inspection, the partial removal option for PLU4685 (removal of a total length ~60m of exposures ~27m long and ~33m long (between KP0.028 and KP0.280) would be acceptable from a societal perspective. Therefore, it is proposed not to repeat the discussion here.

5.7.5 Cost considerations

More details of the cost assessment by difference for the pipelines in group 3 are presented in Appendix 9. The assumption used here is that the umbilicals would be completely removed using the reverse reel method. The leave *in situ* option assumes that the surface laid umbilical ends and associated mattresses would be removed, although this may not have been the recommendation of this comparative assessment. By inspection, the partial removal option for PLU4685 (removal of a total length ~60m of exposures ~27m long and ~33m long (between KP0.028 and KP0.280) would be acceptable from a cost perspective and preferred to complete removal.

Please refer Appendix 9.3 for an explanation of the assumptions used in the assessment.

For all the umbilicals in group 3, the complete removal option would cost less than an order of magnitude more than the leave *in situ* option but in the short-term but once completed, no more costs would be incurred for future umbilical surveys.

Umbilicals, or parts thereof, that are left *in situ* would likely be subject to future surveys. Future pipeline surveys can be expected to cost less than the operations associated with complete removal and the need to deal with the associated waste materials onshore. For the purposes of this cost assessment, it is assumed that 1x post decommissioning pipeline status surveys would be required, followed by 3x legacy surveys for any infrastructure being left *in situ*. Refer Table A9.6.1 and Table A9.7.1.

6 Conclusions

6.1 Overview

The comparative assessment was undertaken with a focus on the decommissioning options for the various mattresses and pipelines associated with the Caister-Murdoch System developments. A general comparative assessment was carried out for the mattresses, while the pipelines were split into three groups as indicated in Table 4.2.1. Pipeline groups 1 & 2 were assessed for the complete removal, partial removal and leave *in situ* decommissioning options, while pipeline group 3 was assessed for complete removal, partial removal and leave *in situ* decommissioning options for only PLU4685; there is a short exposure on the final approach and a few short exposures and spans between KP0.222 and KP0.280 (measured from Hawksley) that would need to be dealt with.

The assessment in pipeline groups 1 & 2 for partial removal was restricted just to those pipelines found to have exposures in the past, that is, PL929, and PL2109 & PL2110. However, at the time of writing no burial survey data had been seen since the original installations, so the burial status for PL930 and PL936 would need to be confirmed.

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

6.2 Conclusion for mattresses

Three types of mattresses were installed: Fronded mattresses that were anchored, fronded mattress with concrete bases and concrete mattresses, and the assessment concluded that a using a variety of equipment it would be technically feasible to remove all different types of mattresses.

With planning the recovery works could be carried out using remotely operated equipment subsea and on the back of the recovery vessel, so from a health and safety perspective the risk to project personnel should be manageable and could be considered low. However, to recover the mattresses at all would pose more of a threat to offshore and onshore project personnel than leaving the mattresses *in situ*.

Should the mattresses be buried[26], both complete removal and leave *in situ* options would leave the seabed free of snagging hazards. However, by completely removing the mattresses the risk of snagging is removed in perpetuity so the complete removal option would result in lower residual risks to mariners and other users of the sea. The inference here is that as long as the mattresses remain *in situ* there would be the possibility that they become exposed. The cut pipeline ends would likely be remediated with additional rock. Should the mattresses be left *in situ* additional rock would be deposited at a cut pipe end next to a mattress rather than on or near the point of burial in existing rock. The deposition of additional rock at cut pipeline ends could play a part in creating unpredictable local scour patterns and so the requirement should be minimised where possible. If it could be demonstrated that the mattresses are fully buried under sediment, there would likely be no increased snagging risk associated with the leave *in situ* option. Surveys would need to be done in future, however, in order to verify that the risk of snagging would remain low.

Energy requirements and emissions to air would be such that there would be a significant difference between the options. However, the gap between complete removal and leave *in situ* would reduce when indirect energy requirements such as that required for replacement of unrecovered material, are accounted for.

Conservatively if it could be assumed that the removal of each mattress would affect a 5m wide perimeter around each[27], the overall area of seabed affected would equate to 0.173km^2. Remembering that the seabed area of the Dogger Bank SAC is 12,331km^2, this would mean that 0.0014% of the Dogger Bank SAC area would be directly impacted by the disturbance created by the mattress removal activities. ,That is, the area affected would be negligible. The area of the SNS SAC is 36,950 km^2, and few if any mattresses associated with PL929 and PL930 are located here. By inspection, the area of SNS SAC affected by the decommissioning of mattresses would be negligible.

[26] Burial assumes that the edges of the mattresses and most of the fronds are buried under sediment, although the tops of the fronds may be visible;

[27] The calculation is conservative as most of the mattresses are laid side-by-side rather than individually.

Should the mattresses be left *in situ*, the area affected would be much less than this albeit affected permanently. The area impacted by leaving the mattresses *in situ* would equate to ~0.016km^2. This would equate to ~0.00013% of the Dogger bank SAC for all of the fronded and concrete mattresses considered here. The area disturbed would be an order of magnitude smaller than that disturbed by removal activities, albeit permanently. In percentage terms neither the temporary nor permanently affected areas would be significant.

Note that several concrete mattresses associated with the CMS pipelines need to be removed anyway due to commitments in third party decommissioning programmes for Ketch [11] and Schooner [12].

From a waste perspective, experience would suggest that of the ~7,060Te of material that could be recovered, very little would be destined for landfill once recovered. The concrete bases would likely be crushed and recycled while the polypropylene rope used to hold the concrete blocks together and the synthetic materials used for the fronds and fronded mattress anchor bases would likely be recycled for energy recovery.

From societal perspective, offshore recovery operations would have little impact on commercial fishing activities with much of the work being required in the 500m zones of the various installations. The majority of the recovery operations could be expected to take place in the Murdoch 500m safety zone. It is unlikely that the recovery operations would result in new jobs, but rather would result in an extension to existing jobs.

For the pipeline and umbilical ends on the approaches, the costs for completely removing the mattresses and underlying pipelines and umbilicals would be an order of magnitude greater than for leave *in situ*.

For the pipeline and umbilical ends on the approaches, the costs for completely removing the mattresses and underlying pipelines and umbilicals would be an order of magnitude greater than for leave *in situ*. The costs for removing the mattresses dedicated to all the subsea installations (Boulton HM, Hawksley EM, McAdam MM, Murdoch K.KM, and Watt QM) and three of the pipeline related protection structures (Kelvin Subsea Tee Assembly, and PSNL) would be less than an order of magnitude greater for complete removal than for leave *in situ*. The costs for removing the mattresses around the Kelvin Pigging Manifold Assembly and Katy Tee would cost more than an order of magnitude than leave *in situ* because of the quantity combined with mass of mattress material that would need to be recovered. Note that for the purposes of the assessment the mattresses around PSSL and the Kelvin-Murdoch Subsea Pigging Skid are allocated to the pipelines on the approaches rather than the PSSL protection structure itself and so are not categorised as being ‘dedicated’ to the structures.

However, the difference in cost would likely be offset by the need to recover those mattresses that would have been disturbed anyway as a result of the removal of installations, tee protection structures and pigging manifold structures, as it is likely that an MFE would be used to clear away local sediment. This means that the cost by difference would not be as great as portrayed in this assessment.

Further, leave *in situ* costs include incremental costs for carrying out 1x post decommissioning survey and 3x legacy surveys of the short sections of mattresses and any underlying pipelines and umbilicals left *in situ*. Ordinarily these costs would be borne as part of the pipeline surveys, but there could be a scenario where mattress status surveys alone would be required, with the burial status of the remaining pipelines and being such that they would no longer need to be surveyed.

In conclusion the recommendation is that the mattresses and where applicable the underlying pipelines and umbilicals on the approaches and adjacent to the subsea installations and pipeline protection structures should be fully removed.

6.3 Conclusion for pipelines in groups 1

Except for approaches all the individual pipelines are largely trenched and buried with historical survey data suggesting that for PL929 some exposures can be expected. The assessment found that for the complete removal option the technical feasibility, short-term safety risk to project personnel both offshore and onshore would be ‘tolerable’ rather than broadly acceptable or preferred. Otherwise, except for cost there was little to differentiate the options.

In practical terms leave *in situ* decommissioning would technically be easier to achieve.

Many of the health and safety hazards described herein are common to all decommissioning options and would increase with amount of material removed. In the short-term the leave *in situ* option – which might include removal of the pipeline ends, would give rise to lower risks to project personnel.

Differences are found between the safety assessment with more work required offshore and onshore for complete removal and where applicable partial removal options rather than leave *in situ* and consequently higher safety risk. Conversely there would be lower safety risks to mariners arising from complete removal than either partial removal or leave *in situ* because the pipelines would no longer be present as a potential snag hazard. However, the assessment concluded that even with the pipelines remaining *in situ* the snagging risk posed to fishermen and other users of the sea would remain low on the basis that the pipelines would remain mostly buried - albeit with exposures, and the situation would be no different to what it is now.

Should the deposition of rock be the decommissioning option of choice for dealing with exposures, the amount of seabed sediment affected would be proportional to the lengths of pipeline being remediated. Clearly the area impacted would be much less than that effected by complete removal but the deposition of hard strata such as rock would have a permanent effect on the seabed and albeit locally would likely alter the topography, movement of the sediment and cause unpredictable scour patterns. This also means that any pursuit of the partial removal option should aim to minimise the number of cut pipeline ends needing to be remediated.

Post-trenching may work in the short-term for partial removal either to rebury exposures or to rebury cut pipeline ends, but with the movement of the sediment it would not be certain that the cut pipeline ends would not reappear.

The ends of PL929 & PL930 and PL935 & PL936 are piggybacked, and each pair of pipelines could therefore be removed at the same time, although the bulk of the pipelines are laid in separate trenches necessitating separate removal operations and surveys.

Decommissioning activities associated with PL929, PL930, PL935 and PL936 would have a negligible effect on the conservation objectives of the Dogger Bank and SNS SACs.

For PL929 and PL930 the complete removal option the cost by difference would be an order of magnitude more than both the partial removal and leave *in situ* options in the short-term. In both cases once removal had been completed no more costs would be incurred for legacy pipeline surveys.

For PL929 and PL930 the partial removal option would also cost an order of magnitude more than the leave *in situ* option. Note that in the absence of survey data the partial removal option for PL930 assumes that the length of exposures would be similar to PL929. In both cases legacy surveys would be required sometime in future. Also note that the full length of these pipelines has not been surveyed, meaning that the cost of partial removal could increase.

Using a similar approach for PL935 and PL936, the complete removal option for both would cost an order of magnitude more than the leave *in situ* option in the short-term. In both cases, once completed no more costs would be incurred for future pipeline surveys. In both cases legacy surveys would be required sometime in future. It should also be noted that no survey data are available for PL936, so the assumption meantime is that there are no exposures, as per PL935. This may change once survey data become available.

Pipelines, or parts thereof, that are left *in situ* would likely be subject to future pipeline inspections. Future pipeline surveys can be expected to cost less than the operations associated with complete removal and the need to deal with the associated waste materials onshore. For the purposes of this cost assessment, it is assumed that 1x post decommissioning pipeline status surveys would be required, followed by 3x legacy surveys for any infrastructure being left *in situ*.

In conclusion, based on the comparative assessment leave *in situ* with no remediation is the recommended option for decommissioning the pipelines in group 1.

6.4 Conclusion for pipelines in groups 2

All pipelines in group 2 are piggybacked and trenched and buried with exposures expected for PL2109 & PL2110 (up to ~1.5km long). The assessment found that for the complete removal option the technical feasibility, short-term safety risk to project personnel both offshore and onshore would be ‘tolerable’ rather than broadly acceptable or preferred. Otherwise, except for cost there was little to differentiate the options. The partial removal option was considered to be broadly acceptable but least preferred.

In practical terms leave *in situ* decommissioning would technically be easier to achieve.

With exception of considerations for reversed reeling which would not apply in this instance, the key differences between the options are largely as described for the group 1 pipelines in section 6.3 and so for brevity the discussion will not be repeated here.

PL2109 & PL2110 have been found with exposures for the first ~1.5km length of pipeline. The partial removal option may leave the seabed free of snag hazards in the short-term, but as the seabed in this area is mobile the situation could change. The cut ends of multiple exposures remediated today could become snag hazards in the future. Remediation such as addition of deposited rock could lead to a change in topography, movement of the sediment and unpredictable scour patterns. This means that any pursuit of the partial removal option should aim to minimise the number of cut pipeline ends needing to be remediated. Post-trenching may work in the short-term, but it would not be certain that the cut pipeline ends would not reappear. Arguably, that cut pipeline ends would exist at all would be worse than exposed pipelines.

A solution to this would be to remove the first 1.5km of PL2109 & PL2110 in their entirety. This would remove the current exposures and limit the number of ends remaining thereby removing potential snagging hazards. Should these exposures have been removed the burial status would be such that no snagging hazards along the pipelines should arise in future.

The by difference cost of removing the piggybacked pipelines would be an order of magnitude greater than for partial removal and leave *in situ*.

Using the assumption that the piggybacked pipelines would be removed using the ‘cut and lift’ method the costs would be an order of magnitude greater than for leave *in situ*. Using the assumption that ~1.5km of the piggybacked pipelines PL2109 & PL2110 would be removed using the ‘cut and lift’ method, the cost by difference would be less than half the cost for complete removal and almost 4x more than leave *in situ*.

Pipelines, or parts thereof, that are left *in situ* would likely be subject to future pipeline inspections. Future pipeline surveys can be expected to cost less than the operations associated with complete removal and the need to deal with the associated waste materials onshore. For the purposes of this cost assessment, it is assumed that 1x post decommissioning pipeline status surveys would be required, followed by 3x legacy surveys for any infrastructure being left *in situ*.

In conclusion, based on the comparative assessment the leave in situ option is recommended for all but two sets of pipelines, and as they would seem to be sufficiently buried no remedial work should be required. The exceptions are the Munro MH (PL2109 & PL2110) pipelines for which the recommended decommissioning option is partial removal as this would likely remove the potential risk of snagging hazards in perpetuity.

6.5 Conclusion for pipelines in group 3

With the exception of a few short exposures for PLU4685 all the umbilicals are trenched and buried, and no exposures would be expected based on historical survey data. The assessment found that for the complete removal option the technical feasibility, short-term safety risk to project personnel both offshore and onshore would be ‘tolerable’ rather than broadly acceptable or preferred. Otherwise, except for cost there was little to differentiate the options.

From a purely technical perspective, reverse reel would likely be the most viable method for complete removal, although excavation would be needed to achieve this. Arguably there are some technical uncertainties with achieving this, but it is unlikely that these would render the option unfeasible.

In practical terms *in situ* decommissioning would be easier to achieve technically.

Many of the health and safety hazards described herein are common to all decommissioning options and would increase with amount of material removed. In the short-term the leave *in situ* option – which may include removal of the umbilical ends, would give rise to lower risks to project personnel.

The key differences between the complete removal and leave *in situ* decommissioning options are largely as described for the group 1 pipelines in section 6.3 and so for brevity the discussion will not be repeated here.

Differences are found between the safety assessment with more work required offshore and onshore for complete removal option rather than leave *in situ* and consequently higher safety risk. Conversely, there would be lower safety risks to mariners arising from complete removal than leave *in situ* because the umbilicals would no longer be present as a potential snag hazard. However, the assessment concluded that with the umbilicals remaining *in situ* the snagging risk posed to fishermen and other users of the sea would remain low on the basis that they would remain buried.

Finally, for all the umbilicals in group 3, the complete removal option would cost less than an order of magnitude more than the leave *in situ* option but in the short-term but once completed, no more costs would be incurred for future umbilical surveys.

By inspection, the partial removal option for PLU4685 (removal of a total length ~52m of exposed umbilical between KP0.222 and KP0.280) or ~60m including ~8m on the final approach (at KP0.028) would be acceptable from a safety perspective and preferred to complete removal and leave *in situ*.

Pipelines, or parts thereof, that are left *in situ* would likely be subject to future pipeline inspections. Future pipeline surveys can be expected to cost less than the operations associated with complete removal and the need to deal with the associated waste materials onshore. For the purposes of this cost assessment, it is assumed that 1x post decommissioning pipeline status surveys would be required, followed by 3x legacy surveys for any infrastructure being left *in situ*.

In conclusion, based on the comparative assessment leave *in situ* is the recommended option for decommissioning most of the umbilicals in group 3 and partial removal of PLU4685.

7 Supporting Documents

[1] BEIS (2019) Re-use of Oil and Gas Assets for Carbon Capture Usage and Storage Projects. Weblink last accessed: 10 June 2020: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/819901/reuse-oil-gas-assets-ccus-projects.pdf

[2] BEIS (2019) Re-use of Oil and Gas Assets for Carbon Capture Usage and Storage Projects, Annex A. Weblink last accessed 10 June 2020: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/819549/annex-a-list-pipelines-stores-potential-reuse-ccus-projects.xlsx

[3] BEIS (2020) Record of the Habitats Regulations Assessment Undertaken Under Regulation 5 of the Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (As Amended). Dogger Bank SAC Oil and Gas Decommissioning Strategic HRA, weblink last accessed 16 Sept 2020: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/799510/Dogger_Bank_Decommissioning_Strategic_HRA_rev3.0.pdf

[4] Belderson, R.H., Johnson, M.A., Kenyon, N.H. (1982) Bedforms. In Stride, A.H. (ed) Offshore tidal sands. Processes and deposits. Chapman and Hall, London, 27-57;

[5] Brown & May Marine Limited (2017) Commercial Fisheries Socioeconomic Assessment: CMS Area, BMM-SNS-C-XX-X-HS-02-00001

[6] Chrysaor (2020) CDP1a Caister Installation Decommissioning Programme; Weblink last accessed 05 Nov 2020: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/877103/Caister_-_CDP1.pdf;

[7] Chrysaor (2020) CDP1b Caister Pipeline Decommissioning Programme, CYR-SNS-C-XX-P-PM-12-00001;

[8] Chrysaor (2020) CDP2 CMS Decommissioning Programmes excl. Murdoch & Caister, CYR-SNS-C-XX-P-PM-12-00002;

[9] Chrysaor (2020) CDP3 Murdoch Installation & Trunklines Decommissioning Programmes, CYR-SNS-C-XX-P-PM-12-00003;

[10] Chrysaor (2020) CMS Area Environmental Appraisal Report, CYR-SNS-C-XX-X-HS-02-00003;

[11] DNO (2019) Ketch Decommissioning Programmes, Final July 2019. Weblink last accessed 18 Oct 2020: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/826988/Ketch_Decommissioning_Programme_BEIS_Final_July_2019.pdf

[12] DNO (2019) Schooner Decommissioning Programmes, Final July 2019. Weblink last accessed 18 Oct 2020: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/826989/Schooner_Decommissioning_Programme_BEIS_Final_July_2019.pdf

[13] HSE (Health and Safety Executive) (1997) The abandonment of offshore pipelines: Methods and procedures for abandonment. Offshore Technology report. HSE Books, Norwich. ISBN-7176-1421-2.

[14] IMCA (2011) Diver and ROV Based Concrete Mattress Handling, Deployment, Installation, Repositioning and Decommissioning;

[15] INEOS UK SNS Limited (2020) Cavendish Decommissioning Programmes. Weblink last accessed 18 Oct 2020: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/889054/RD-CAV-ZPL004_Rev07_CAV_Decommissioning_Programme_May2020_FINAL.pdf;

[16] Jee Limited (2915) Mattress Solutions. Weblink last accessed 29 Sept 2020: https://decomnorthsea.com/uploads/pdfs/projects/DNS-Mattress-Solutions_JEE-Report_June-2015.pdf

[17] Kenyon, N.H. & Cooper, B. (2005) Sand banks, sand transport and offshore wind farms, published by Kenyon MarineGeo & ABP Marine Environmental Research Limited. Weblink: www.vliz.be/imisdocs/publications/253773.pdf last accessed 20 Dec 2016;

[18] OPRED (2018) Offshore Oil and Gas Decommissioning Guidance Notes. Weblink last accessed 27 Jan 2020: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760560/Decom_Guidance_Notes_November_2018.pdf

[19] Jee (2015) Mattress Solutions, DNS-01-r01c. A report produced by Jee Limited for Decommissioning North Sea Ltd and Zero Waste Scotland, publication date 27 May 2015;

[20] JNCC (2011) Dogger Bank SAC Final Impact Assessment. URN 10/1268 Ver. 2.0 12/10. Weblink last accessed 16 Sept 2020: http://data.jncc.gov.uk/data/98f5e14d-7242-4b32-84fe-f110c5e37300/DoggerBank-IA.pdf

[21] JNCC (2017) Natura 200 - Standard Data Form, Site UK0030352, Site name: Dogger Bank. Weblink last accessed 16 Sept 2020: https://jncc.gov.uk/jncc-assets/SAC-N2K/UK0030352.pdf

[22] JNCC (2018) Supplementary Advice on Conservation Objectives for Dogger Bank Special Area of Conservation. Weblink last accessed 16 Sept 2020: http://data.jncc.gov.uk/data/26659f8d-271e-403d-8a6b-300defcabcb1/DoggerBank-3-SACO-v1.0.pdf

[23] JNCC (2019) Natura 200 - Standard Data Form, Site UK0030352, Site name: Dogger Bank. Weblink last accessed 09 Feb 2022. https://jncc.gov.uk/jncc-assets/SAC-N2K/UK0030395.pdf

[24] JNCC (2018) Supplementary Advice on Conservation Objectives for Dogger Bank Special Area of Conservation. Weblink last accessed 09 Feb 2022: https://data.jncc.gov.uk/data/206f2222-5c2b-4312-99ba-d59dfd1dec1d/SouthernNorthSea-conservation-advice.pdf

[25] van der Veen,H.H & Hulscher, S.M.J.H (2009) Predicting the occurrence of sand banks in the North Sea, Ocean Dynamics 59: 689. doi:10.1007/s10236-009-0204-7.

Appendix 1 Pipeline burial profiles & exposure data

Appendix 1.1 Murdoch PL929 & PL930

Year	KP Start	KP End	Length (m)	Description
Survey year: 2006 between KP15.049 and KP180.959 (Exposures – 115x, ∑5.838km long)				
2006	27.022	27.036	14m	Exposure
2006	27.302	27.310	8m	Exposure
2006	28.056	28.061	5m	Exposure
2006	28.068	28.072	4m	Exposure
2006	28.314	28.318	4m	Exposure
2006	28.487	28.507	20m	Exposure
2006	28.535	28.661	126m	Exposure
2006	28.694	28.700	6m	Exposure
2006	28.707	28.709	2m	Exposure
2006	28.714	28.765	51m	Exposure
2006	28.800	28.811	11m	Exposure
2006	28.821	28.830	9m	Exposure
2006	28.832	28.835	3m	Exposure
2006	28.840	28.844	4m	Exposure
2006	28.848	28.868	20m	Exposure
2006	28.930	28.952	22m	Exposure
2006	28.968	28.991	23m	Exposure
2006	29.096	29.134	38m	Exposure
2006	32.623	32.630	7m	Exposure
2006	32.826	32.867	41m	Exposure
2006	34.519	34.632	113m	Exposure
2006	37.552	37.557	5m	Exposure
2006	37.557	37.558	1m	Exposure
2006	37.559	37.560	1m	Exposure
2006	37.563	37.566	3m	Exposure
2006	57.430	57.497	67m	Exposure
2006	64.815	64.820	5m	Exposure
2006	64.836	64.839	3m	Exposure
2006	64.844	64.847	3m	Exposure
2006	64.851	64.860	9m	Exposure
2006	64.865	64.874	9m	Exposure
2006	64.874	64.878	4m	Exposure
2006	64.881	64.884	3m	Exposure
2006	65.514	65.518	4m	Exposure
2006	65.558	65.562	4m	Exposure
2006	67.193	67.197	4m	Exposure
2006	67.200	67.203	3m	Exposure
2006	67.204	67.211	7m	Exposure
2006	67.213	67.214	1m	Exposure
2006	70.754	70.756	2m	Exposure
2006	70.816	70.817	2m	Exposure
2006	70.875	70.876	1m	Exposure
2006	71.001	71.001	0.5m	Exposure
2006	71.012	71.014	3m	Exposure
2006	71.027	71.032	5m	Exposure
2006	71.029	71.032	4m	Exposure

Year	KP Start	KP End	Length (m)	Description
2006	71.068	71.071	2m	Exposure
2006	71.084	71.085	1m	Exposure
2006	71.198	71.201	3m	Exposure
2006	71.283	71.284	1m	Exposure
2006	87.160	97.162	2m	Exposure
2006	91.557	91.586	29m	Exposure
2006	91.565	91.585	20m	Exposure
2006	119.881	119.904	23m	Exposure
2006	133.127	133.208	81m	Exposure
2006	133.225	133.233	8m	Exposure
2006	133.313	133.317	4m	Exposure
2006	133.659	133.709	50m	Exposure
2006	133.765	133.774	9m	Exposure
2006	133.789	133.815	26m	Exposure
2006	133.902	133.937	35m	Exposure
2006	133.947	133.961	14m	Exposure
2006	134.269	134.338	69m	Exposure
2006	134.527	134.562	35m	Exposure
2006	134.720	134.753	33m	Exposure
2006	134.776	134.827	51m	Exposure
2006	134.990	135.216	226m	Exposure
2006	135.331	135.524	193m	Exposure
2006	135.611	135.649	38m	Exposure
2006	135.767	136.047	280m	Exposure
2006	137.274	137.439	165m	Exposure
2006	137.539	137.571	32m	Exposure
2006	139.746	139.763	17m	Exposure
2006	140.115	140.146	31m	Exposure
2006	141.008	141.023	15m	Exposure
2006	141.723	141.794	71m	Exposure
2006	144.463	144.479	16m	Exposure
2006	154.302	154.465	163m	Exposure
2006	154.620	154.749	129m	Exposure
2006	154.789	154.843	54m	Exposure
2006	154.924	155.006	82m	Exposure
2006	155.073	155.128	55m	Exposure
2006	155.194	155.340	146m	Exposure
2006	155.677	155.736	59m	Exposure
2006	155.753	155.777	24m	Exposure
2006	155.831	155.880	49m	Exposure
2006	155.898	156.703	805m	Exposure
2006	156.711	156.828	117m	Exposure
2006	156.963	157.226	263m	Exposure
2006	157.238	157.584	346m	Exposure
2006	157.856	157.945	89m	Exposure
2006	157.954	158.082	128m	Exposure
2006	158.541	158.637	96m	Exposure
2006	158.647	158.725	78m	Exposure
2006	159.162	159.250	88m	Exposure
2006	159.654	159.790	136m	Exposure

Year	KP Start	KP End	Length (m)	Description
2006	159.813	159.955	142m	Exposure
2006	160.392	160.453	61m	Exposure
2006	167.421	167.430	9m	Exposure
2006	167.467	167.500	33m	Exposure
2006	167.686	167.737	51m	Exposure
2006	167.760	167.774	14m	Exposure
2006	168.093	168.102	9m	Exposure
2006	168.170	168.189	19m	Exposure
2006	169.604	169.615	11m	Exposure
2006	172.542	172.570	28m	Exposure
2006	173.071	173.084	13m	Exposure
2006	174.321	174.363	42m	Exposure
2006	174.367	174.440	73m	Exposure
2006	175.294	175.338	44m	Exposure
2006	175.824	175.861	37m	Exposure
2006	175.892	175.935	43m	Exposure
2006	179.989	179.993	4m	Exposure
2006	180.327	180.362	35m	Exposure
Survey year: 2006 between KP15.049 and KP180.959 (Freespans – 9x, ∑155m long)				
2006	28.237	28.248	11m	Freespan
2006	57.432	57.493	61m	Freespan (reportable)
2006	144.472	144.479	7m	Freespan
2006	157.932	157.943	11m	Freespan
2006	159.771	159.789	18m	Freespan
2006	159.938	159.948	10m	Freespan
2006	160.407	160.411	4m	Freespan
2006	160.427	160.450	23m	Freespan
2006	180.948	180.958	10m	Freespan (non-reportable)
Survey year: 2007 between KP180.379 and KLP180.961 (Exposures – 1x, ∑28m long)				
2007	180.884	208.884	28m	Exposure
Survey year: 2007 between KP180.379 and KLP180.961 (Freespans – 1x, ∑16m long)				
2007	180.945	196.945	16m	Freespan
Survey year: 2014 between KP179.985 and KP180.969 (Exposures – 4x, ∑104m long)				
2014	179.985	28.541	8m	Exposure
2014	180.336	179.993	36m	Exposure
2014	180.857	180.372	37m	Exposure
2014	180.931	180.894	24m	Exposure
Survey year: 2014 between KP179.985 and KP180.969 (Freespans – 1x, ∑12.9m long)				
2014	180.956	180.968	12.9m	Freespan (non-reportable), closing span
Survey year: 2016 between KP97.654 and KP180.951 (Exposures – 43x, ∑3.610km)				
2016	119.854	119.883	29m	Exposure
2016	131.326	131.328	2m	Exposure
2016	131.487	131.488	1m	Exposure
2016	131.492	131.498	6m	Exposure
2016	131.503	131.504	1m	Exposure
2016	133.921	133.928	7m	Exposure
2016	134.079	134.080	1m	Exposure
2016	134.730	134.734	4m	Exposure
2016	134.789	134.811	22m	Exposure
2016	134.991	135.168	177m	Exposure

Year	KP Start	KP End	Length (m)	Description
2016	135.491	135.494	3m	Exposure
2016	135.613	135.622	9m	Exposure
2016	135.779	136.437	658m	Exposure
2016	137.272	137.420	148m	Exposure
2016	137.420	137.543	123m	Exposure
2016	140.113	140.144	31m	Exposure
2016	144.455	144.475	20m	Exposure
2016	154.244	154.286	42m	Exposure
2016	154.590	154.662	72m	Exposure
2016	154.892	154.953	61m	Exposure
2016	157.862	158.123	261m	Exposure
2016	158.508	158.786	278m	Exposure
2016	159.141	159.216	75m	Exposure
2016	159.237	159.300	63m	Exposure
2016	159.622	160.414	792m	Exposure
2016	160.430	160.459	29m	Exposure
2016	167.452	167.703	251m	Exposure
2016	167.745	167.747	2m	Exposure
2016	168.083	168.094	11m	Exposure
2016	168.158	168.182	24m	Exposure
2016	172.535	172.562	27m	Exposure
2016	173.062	173.077	15m	Exposure
2016	174.310	174.353	43m	Exposure
2016	174.366	174.428	62m	Exposure
2016	175.281	175.334	53m	Exposure
2016	175.381	175.387	6m	Exposure
2016	175.814	175.932	118m	Exposure
2016	179.974	179.983	9m	Exposure
2016	180.317	180.354	37m	Exposure
2016	180.830	180.837	7m	Exposure
2016	180.875	180.903	28m	Exposure
2016	180.910	180.912	2m	Exposure
Survey year: 2016 between KP180.946 and KP180.958 (Freespans – 1x, ∑12m long)				
2016	180.946	180.958	12m	Freespan (recordable), closing span
Survey year: 2017 between KP15.997 and KP66.272 (Exposures 55x, ∑708m long)				
2017	27.933	31.93	4m	Exposure
2017	28.232	33.23	5m	Exposure
2017	28.265	40.27	12m	Exposure
2017	28.295	33.29	5m	Exposure
2017	28.322	32.32	4m	Exposure
2017	28.331	41.33	13m	Exposure
2017	28.504	38.50	10m	Exposure
2017	28.565	127.57	99m	Exposure
2017	28.700	35.70	7m	Exposure
2017	28.731	59.73	31m	Exposure
2017	28.804	37.80	9m	Exposure
2017	28.830	86.83	58m	Exposure
2017	28.892	81.89	53m	Exposure
2017	28.977	41.98	13m	Exposure
2017	29.320	34.32	5m	Exposure

Year	KP Start	KP End	Length (m)	Description
2017	30.920	51.92	21m	Exposure
2017	32.539	39.54	7m	Exposure
2017	32.630	39.63	7m	Exposure
2017	32.651	35.65	3m	Exposure
2017	32.832	72.83	40m	Exposure
2017	34.513	121.51	87m	Exposure
2017	38.398	41.40	3m	Exposure
2017	38.411	52.41	14m	Exposure
2017	38.429	42.43	4m	Exposure
2017	38.437	40.44	2m	Exposure
2017	38.443	42.44	4m	Exposure
2017	38.790	43.79	5m	Exposure
2017	38.801	39.80	1m	Exposure
2017	38.900	39.90	1m	Exposure
2017	38.908	40.91	2m	Exposure
2017	38.939	47.94	9m	Exposure
2017	39.039	42.04	3m	Exposure
2017	39.048	42.05	3m	Exposure
2017	57.315	62.32	5m	Exposure
2017	63.454	68.45	5m	Exposure
2017	63.463	68.46	5m	Exposure
2017	63.470	68.47	5m	Exposure
2017	63.493	71.49	8m	Exposure
2017	63.508	68.51	5m	Exposure
2017	63.528	68.53	5m	Exposure
2017	63.567	68.57	5m	Exposure
2017	63.572	68.57	5m	Exposure
2017	64.799	69.80	5m	Exposure
2017	64.805	69.81	5m	Exposure
2017	64.877	69.88	5m	Exposure
2017	64.888	69.89	5m	Exposure
2017	64.894	69.89	5m	Exposure
2017	65.465	70.47	5m	Exposure
2017	65.474	70.47	5m	Exposure
2017	65.478	70.48	5m	Exposure
2017	65.518	70.52	5m	Exposure
2017	65.527	122.53	57m	Exposure
2017	65.612	69.61	4m	Exposure
2017	65.629	70.63	5m	Exposure
2017	65.638	70.64	5m	Exposure

Table A1.1.1: PL929 - pipeline exposure & span survey data[28]

[28] Some exposures and spans may overlap.

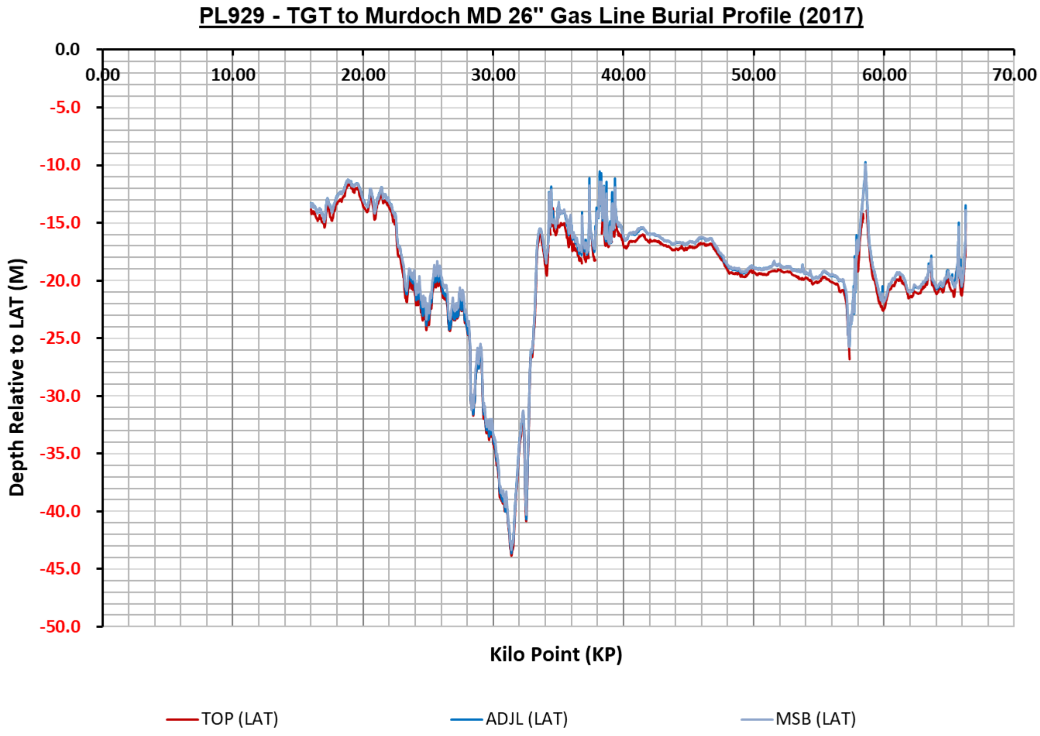


Figure A1.1.1: PL929 seabed & burial profile ~KP16 to ~KP66 (2017)

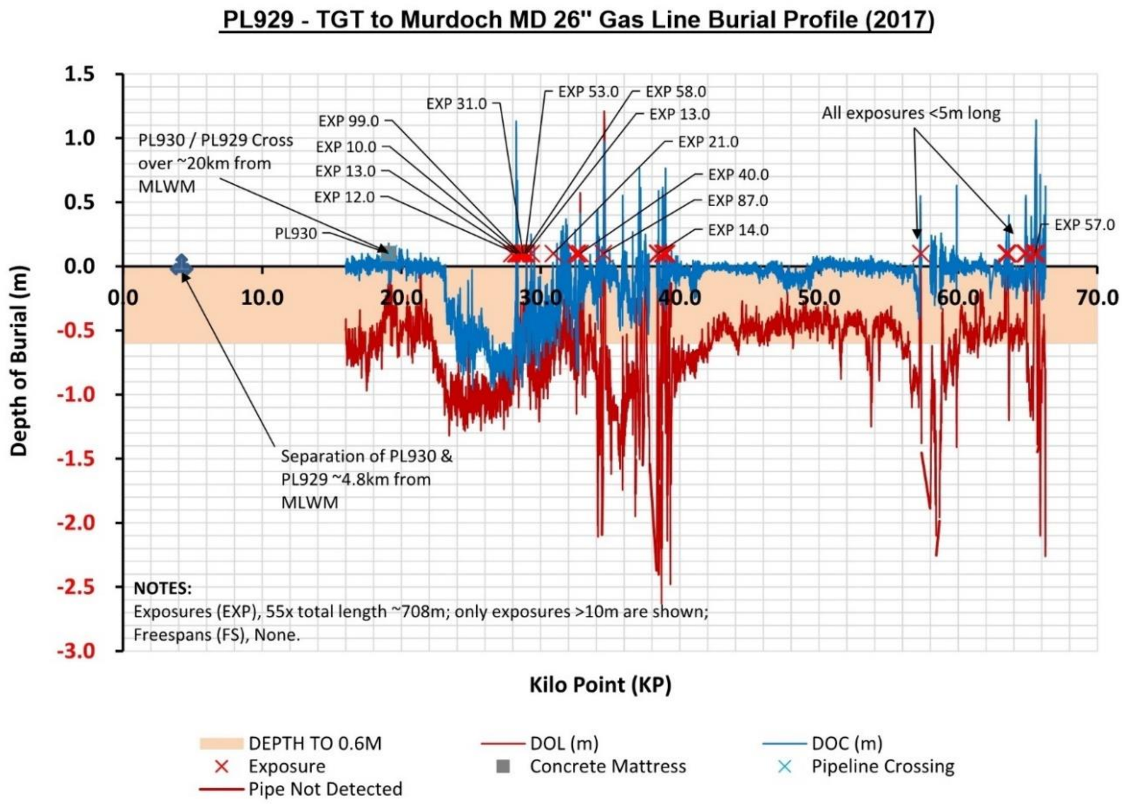


Figure A1.1.2: PL929 depth of cover profile ~KP16 to ~KP66 (2017)[29]

[29] Pipe not detected – pipeline buried to deeply to obtain meaningful signal from transponder used in survey.

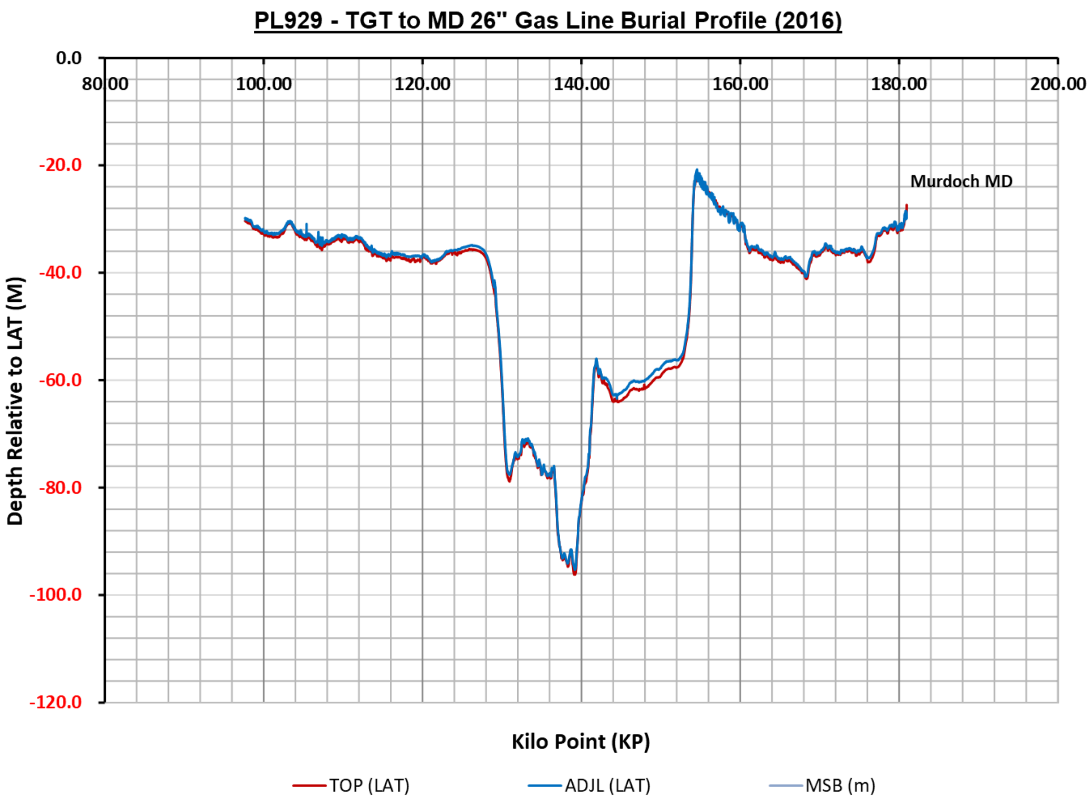


Figure A1.1.3: PL929 seabed & burial profile ~KP97 to ~KP181 (2016)

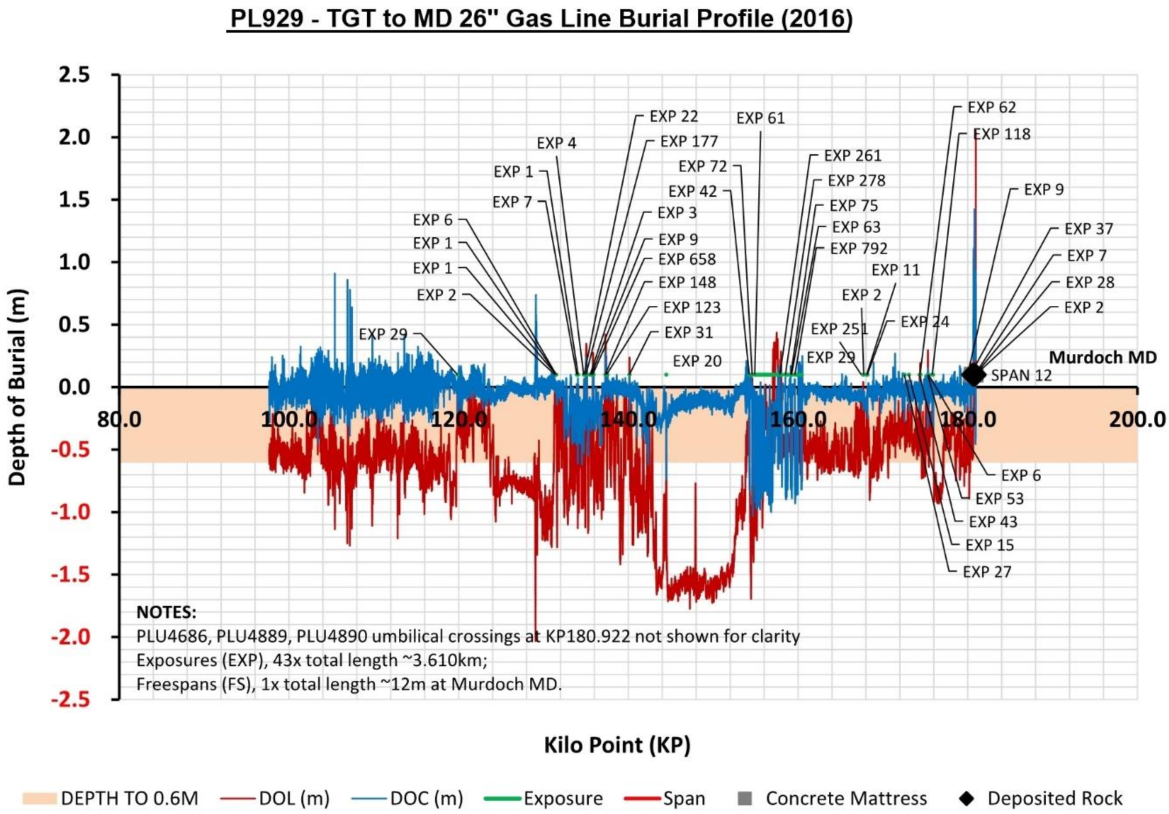


Figure A1.1.4: PL929 depth of cover profile ~KP97 to ~KP181 (2016)

Appendix 1.2 Munro MH PL2109 & PL2110

Year	KP Start	KP End	Description	Length (m)	Comment
2009	0.029	0.075	Exposure	46m	Sub-total length of exposures 379m.
2009	0.077	0.099	Exposure	22m	
2009	0.106	0.155	Exposure	49m	
2009	0.163	0.377	Exposure	214m	
2009	0.396	0.420	Exposure	23m	
2009	0.621	0.641	Exposure	20m	
2009	4.983	4.987	Exposure	4m	
2009	4.994	4.995	Exposure	1m	
2012	0.052	0.080	Exposure	28m	Sub-total length of exposures 1157.5m. Refer Figure 3.8.3.
2012	0.101	0.119	Exposure	18.5m	
2012	0.161	0.260	Exposure	99m	
2012	0.272	0.284	Exposure	11.4m	
2012	0.342	0.415	Exposure	73m	
2012	0.426	1.060	Exposure	634m	
2012	1.115	1.294	Exposure	179m	
2012	1.295	1.410	Exposure	115m	
2015	-0.037	-0.035	Exposure	2m	Sub-total length of exposures 231m.
2015	0.030	0.059	Exposure	29m	
2015	0.078	0.100	Exposure	22m	
2915	0.124	0.181	Exposure	57m	
2015	0.291	0.336	Exposure	45m	
2017	4.917	4.917	Point Exposure	<5.0m	Sub-total length of exposures and spans 26m. Refer Figure 3.8.3.
2017	4.943	4.943	Point Exposure	<5.0m	
2017	4.983	4.985	Freespan	2.2m	
2017	4.988	4.993	Freespan	5.2m	
2017	4.993	5.002	Exposure	8.4m	

NOTE

1. Origin of KP taken at PL2109 pipeline end, Munro MH.

Table A1.2.1: PL2109 & PL2110 - pipeline exposures

Appendix 2 Schematics

Appendix 2.1 Murdoch MA & MD

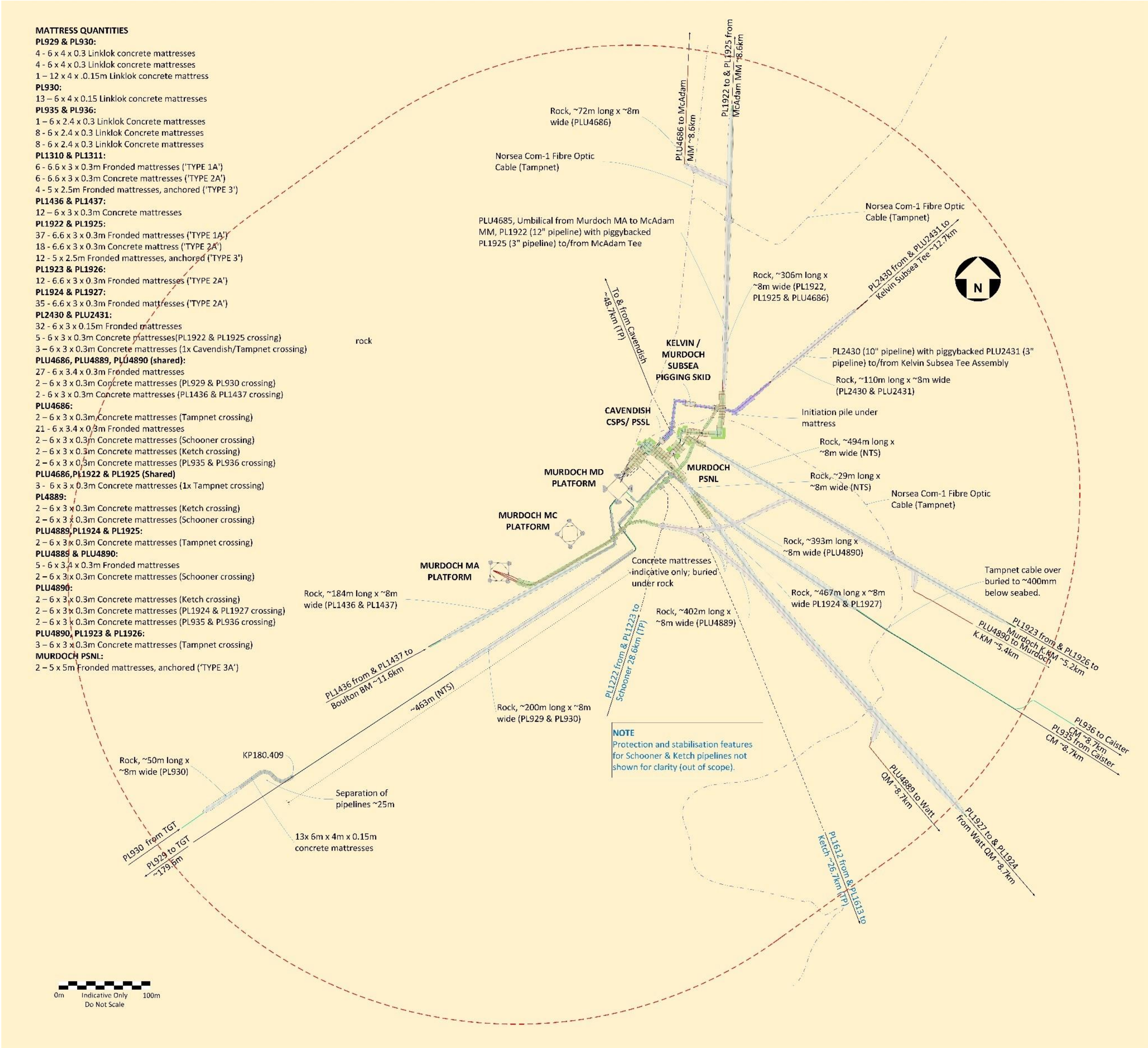


Figure A2.1.1: Schematic of pipelines near Murdoch Installations

Appendix 2.2 Caister CM

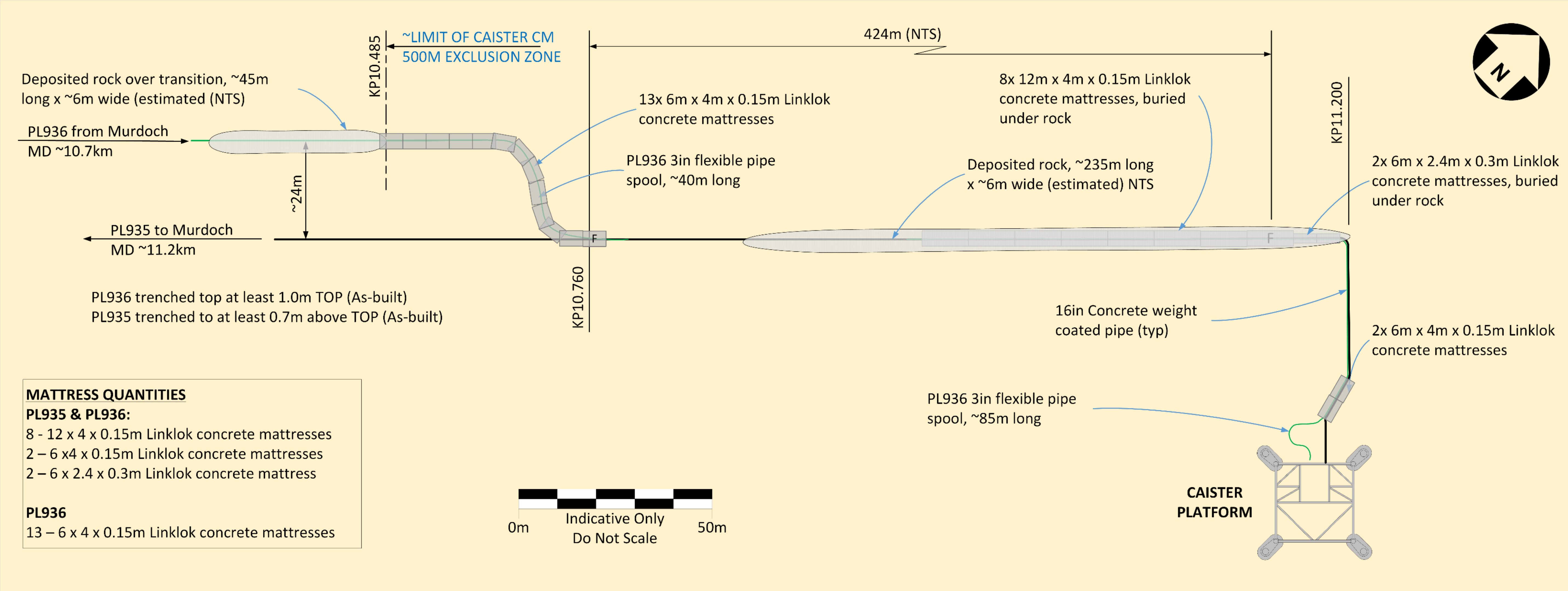


Figure A2.2.1: Schematic of pipelines near Caister CM

Appendix 2.3 Murdoch PL935 & PL936

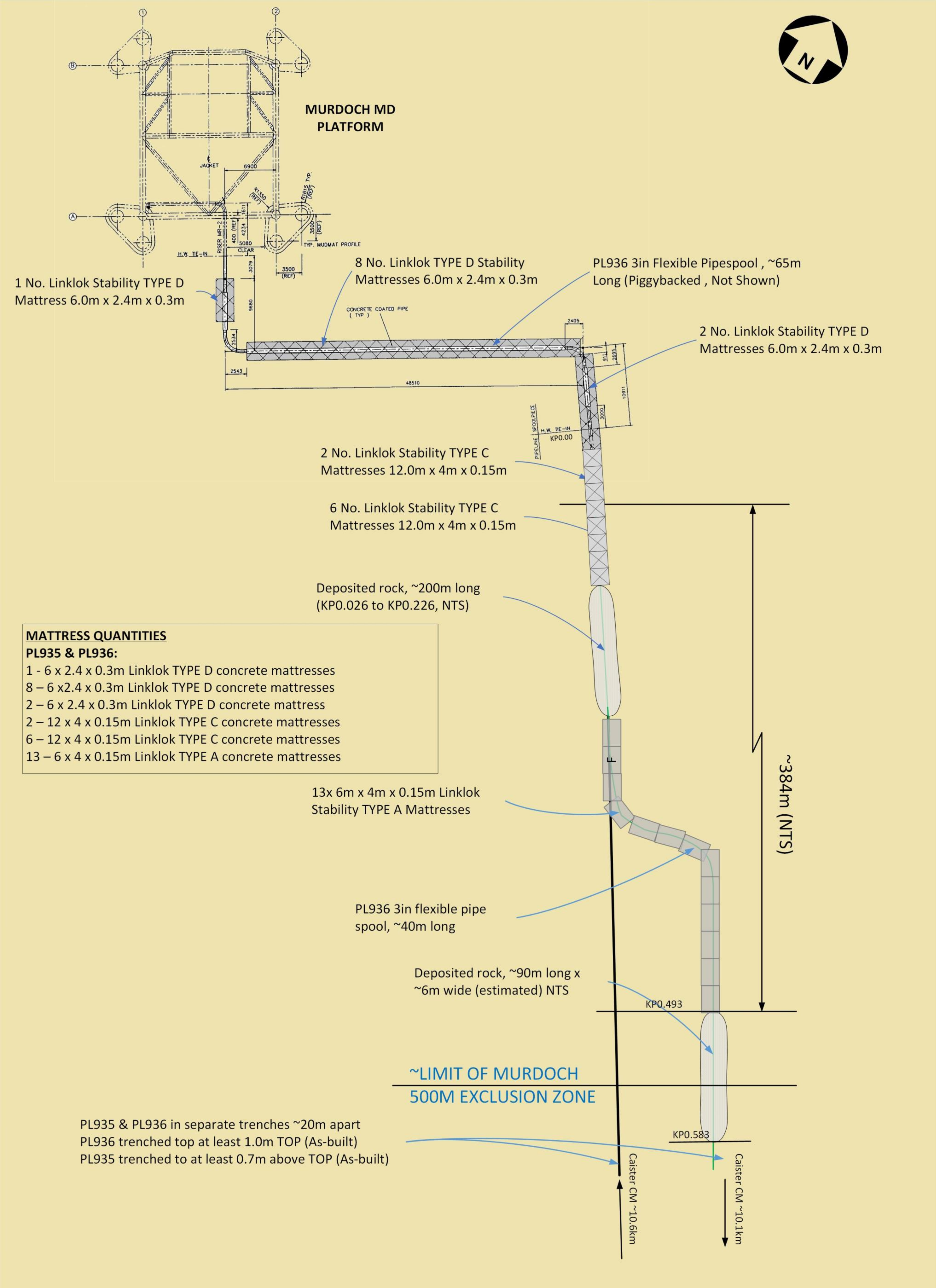


Figure A2.3.1: Schematic of PL935 & PL936 near Murdoch MD

Appendix 2.4 Boulton BM

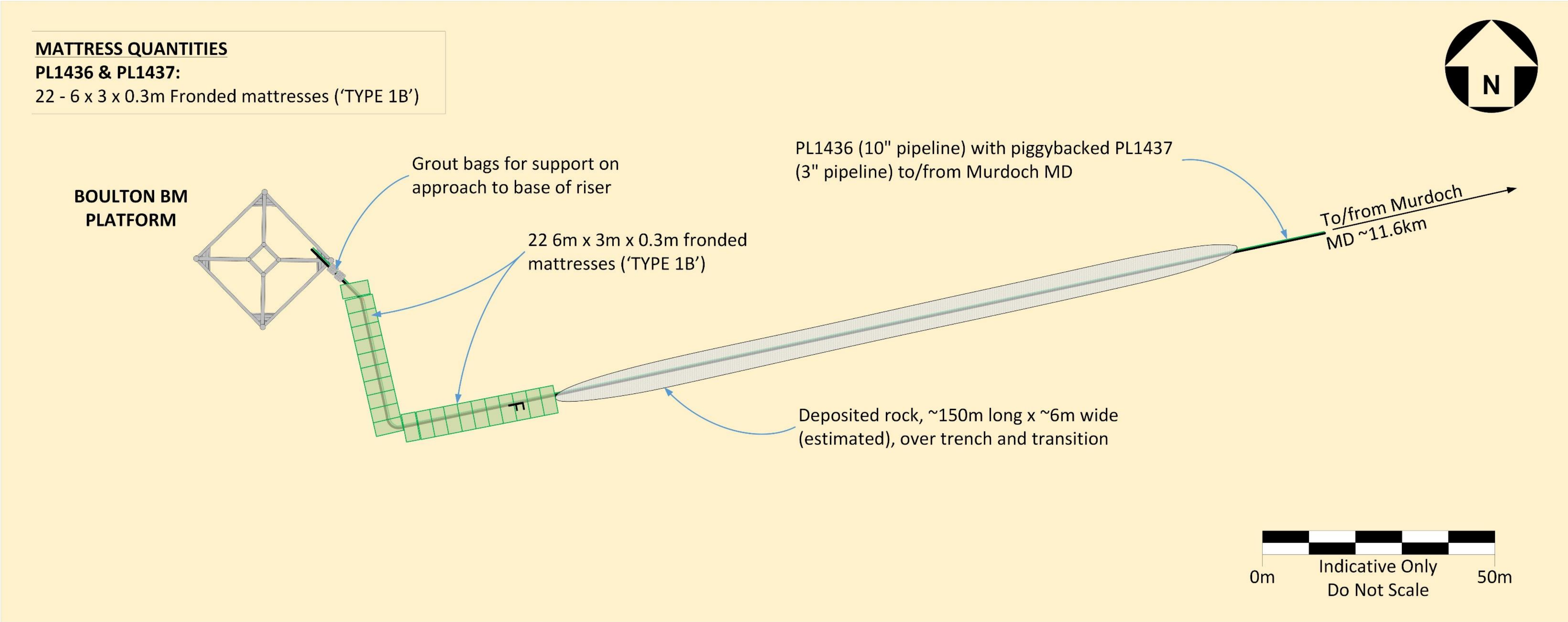


Figure A2.4.1: Schematic of pipelines near Boulton BM

Appendix 2.5 Boulton HM

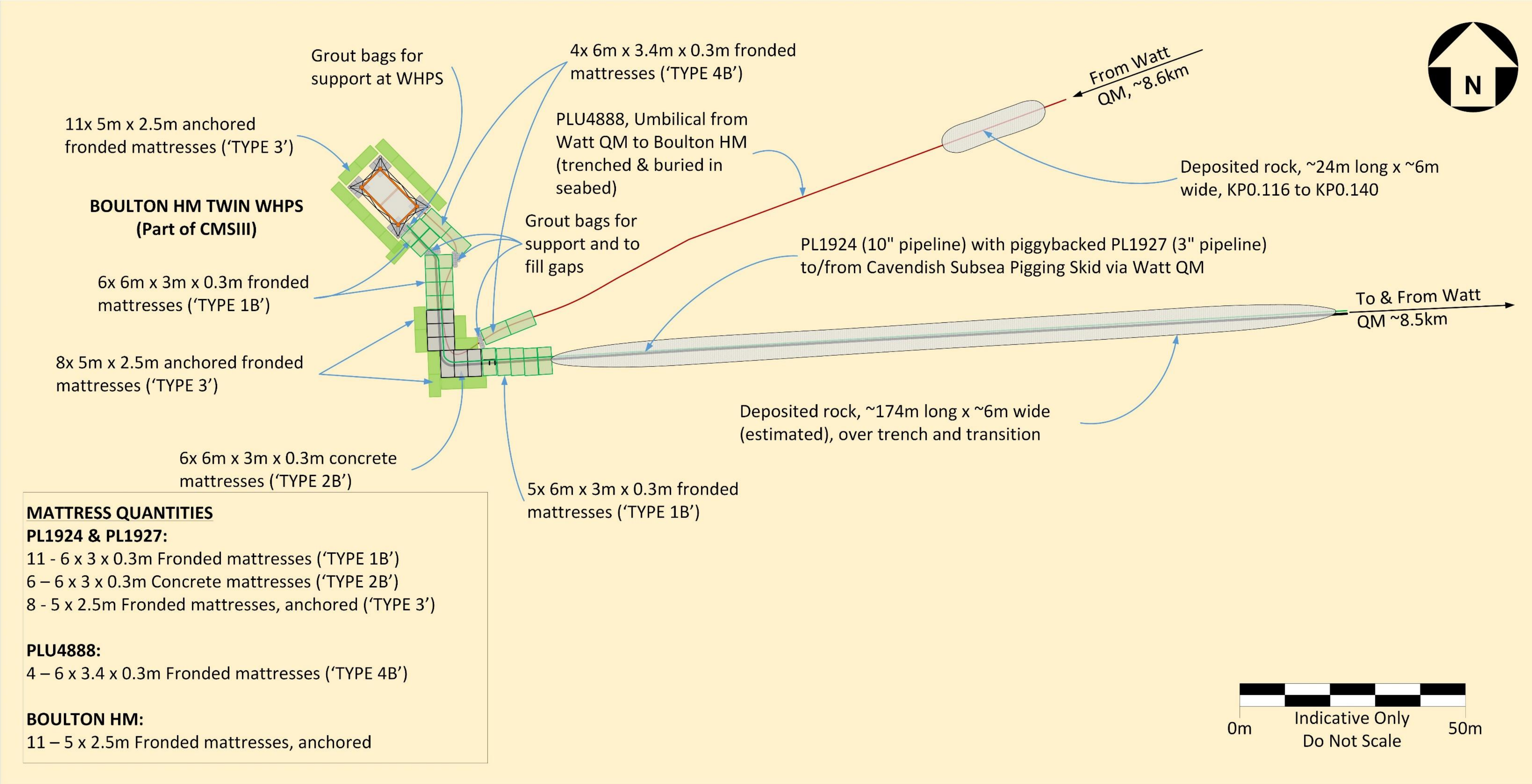


Figure A2.5.1: Schematic of pipelines near Boulton HM

Appendix 2.6 Hawksley EM

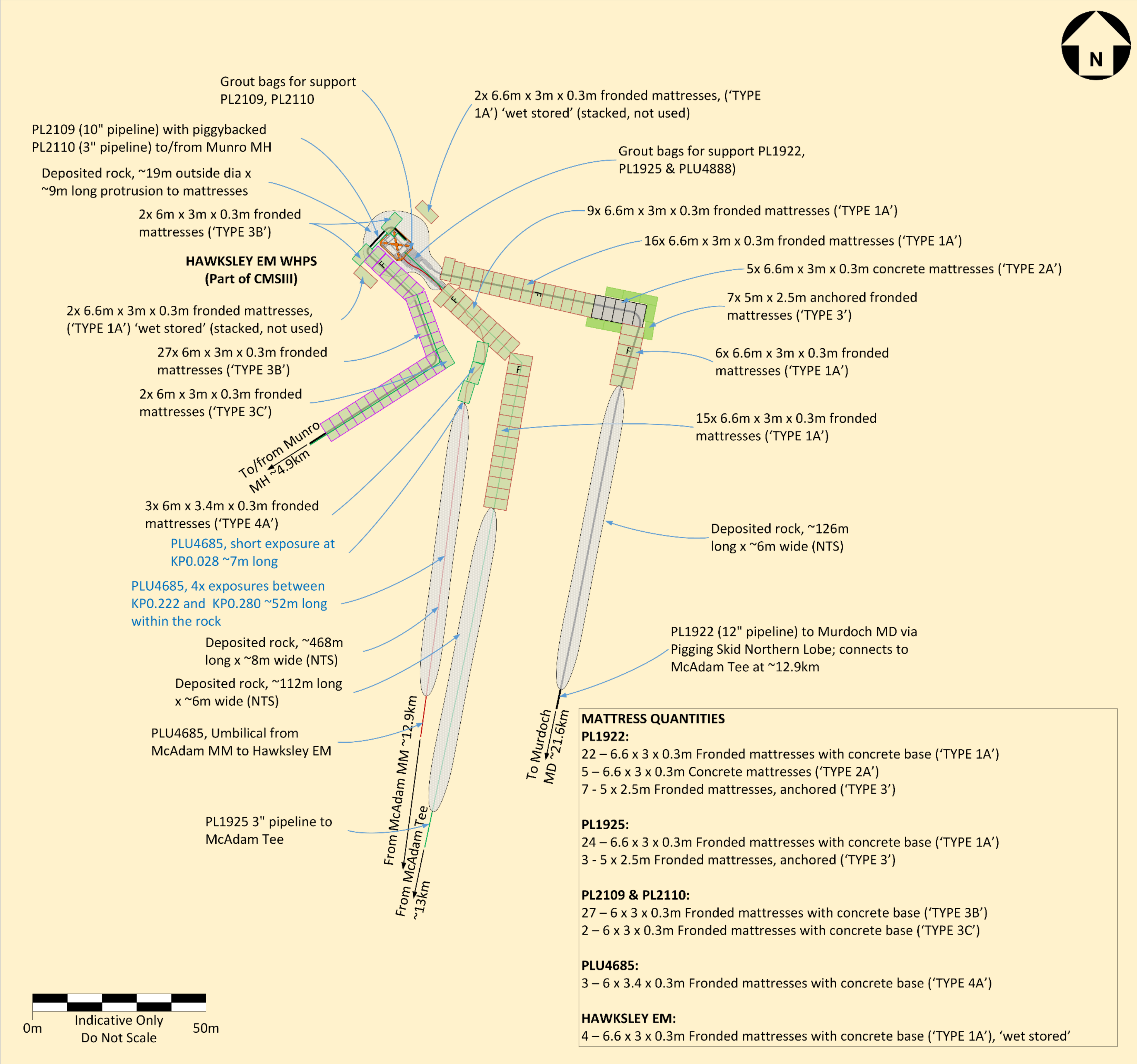
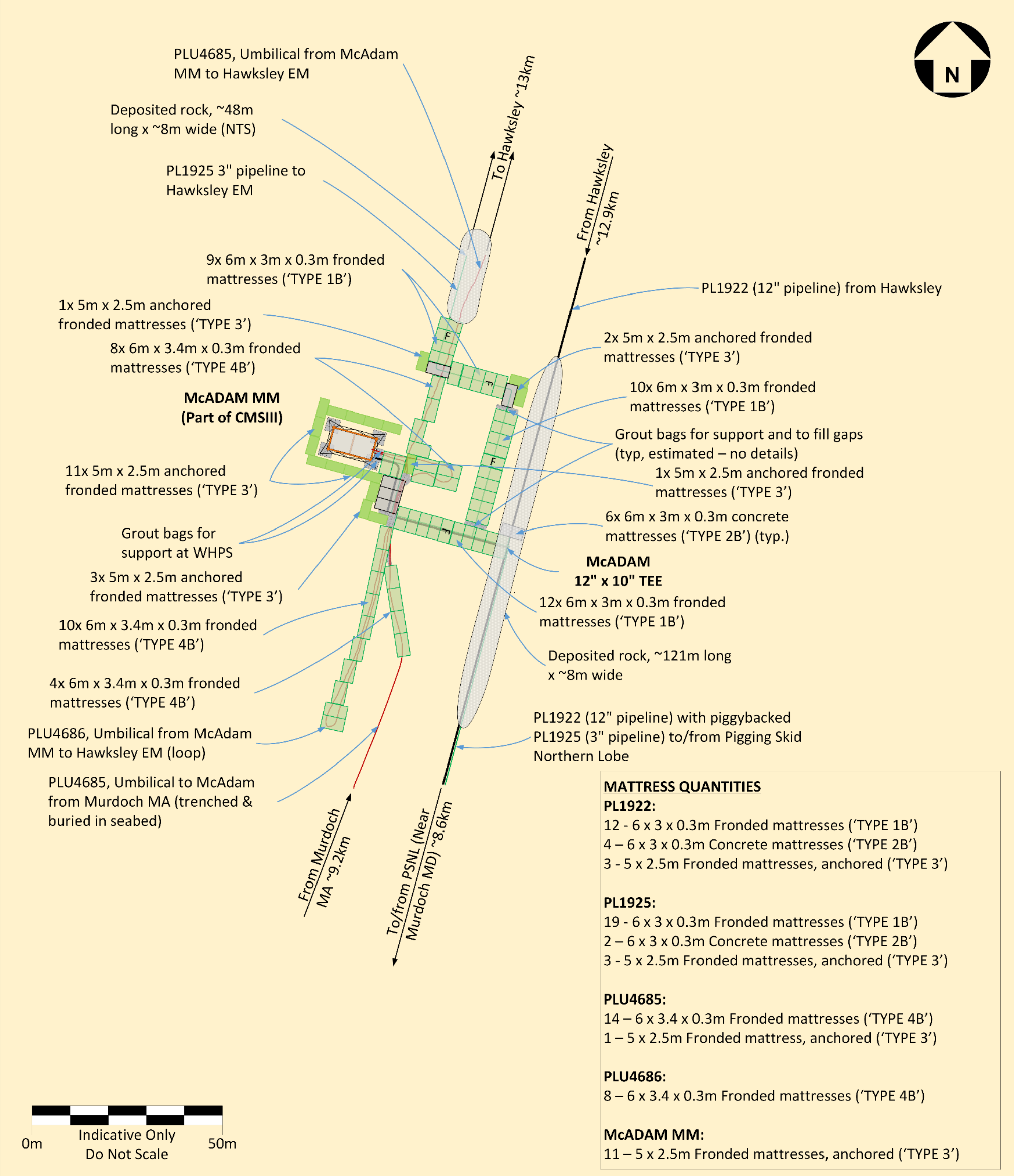


Figure A2.6.1: Schematic of pipelines near Hawksley EM

Appendix 2.7 McAdam MM



MATTRESS QUANTITIES

PL1922:
12 - 6 x 3 x 0.3m Fronded mattresses ('TYPE 1B')
4 – 6 x 3 x 0.3m Concrete mattresses ('TYPE 2B')
3 - 5 x 2.5m Fronded mattresses, anchored ('TYPE 3')

PL1925:
19 - 6 x 3 x 0.3m Fronded mattresses ('TYPE 1B')
2 – 6 x 3 x 0.3m Concrete mattresses ('TYPE 2B')
3 - 5 x 2.5m Fronded mattresses, anchored ('TYPE 3')

PLU4685:
14 – 6 x 3.4 x 0.3m Fronded mattresses ('TYPE 4B')
1 – 5 x 2.5m Fronded mattress, anchored ('TYPE 3')

PLU4686:
8 – 6 x 3.4 x 0.3m Fronded mattresses ('TYPE 4B')

McADAM MM:
11 – 5 x 2.5m Fronded mattresses, anchored ('TYPE 3')

Figure A2.7.1: Schematic of pipelines near McAdam MM

Appendix 2.8 Munro MH

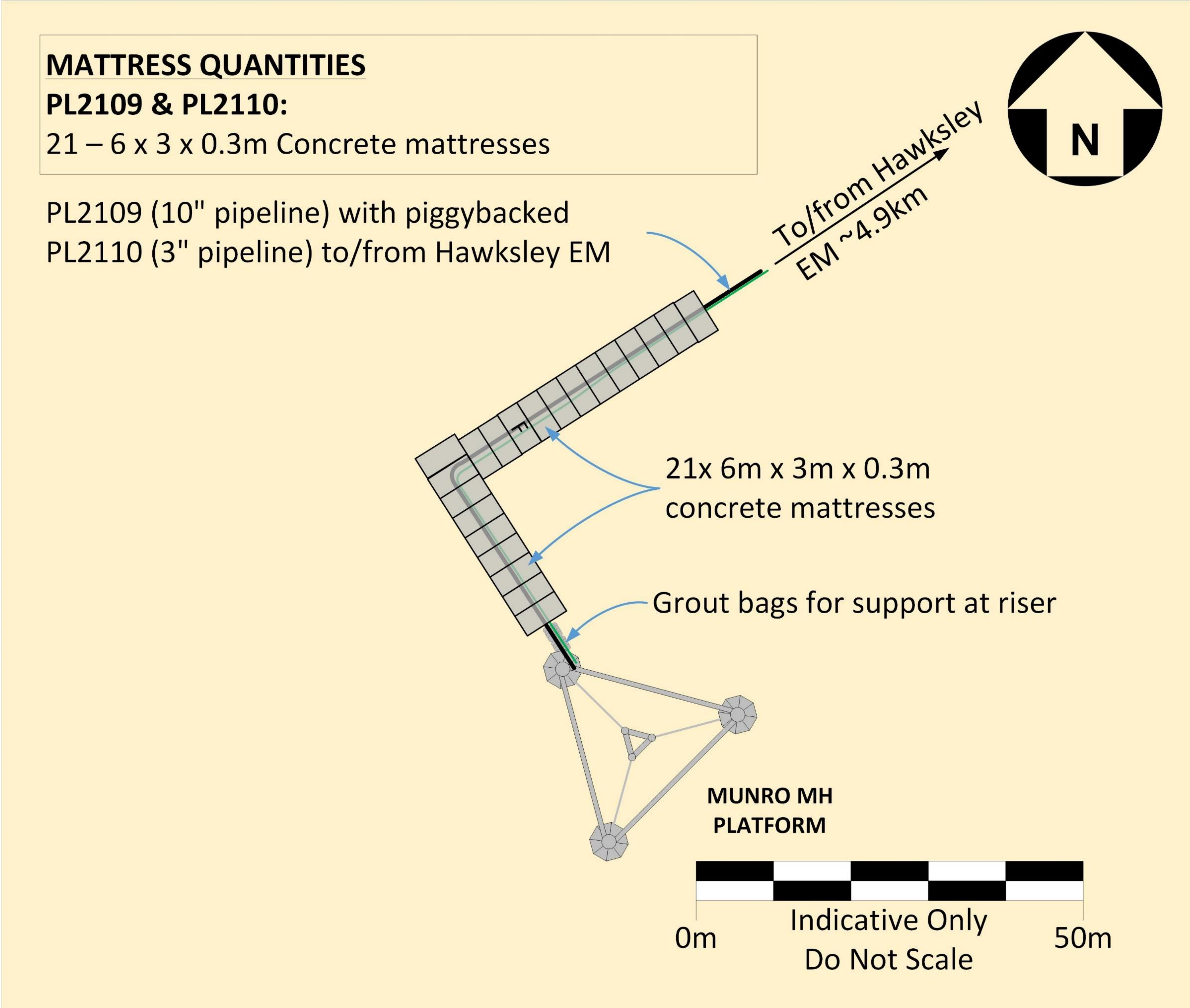


Figure A2.8.1: Schematic of pipelines near Munro MH

Appendix 2.9 Murdoch K.KM

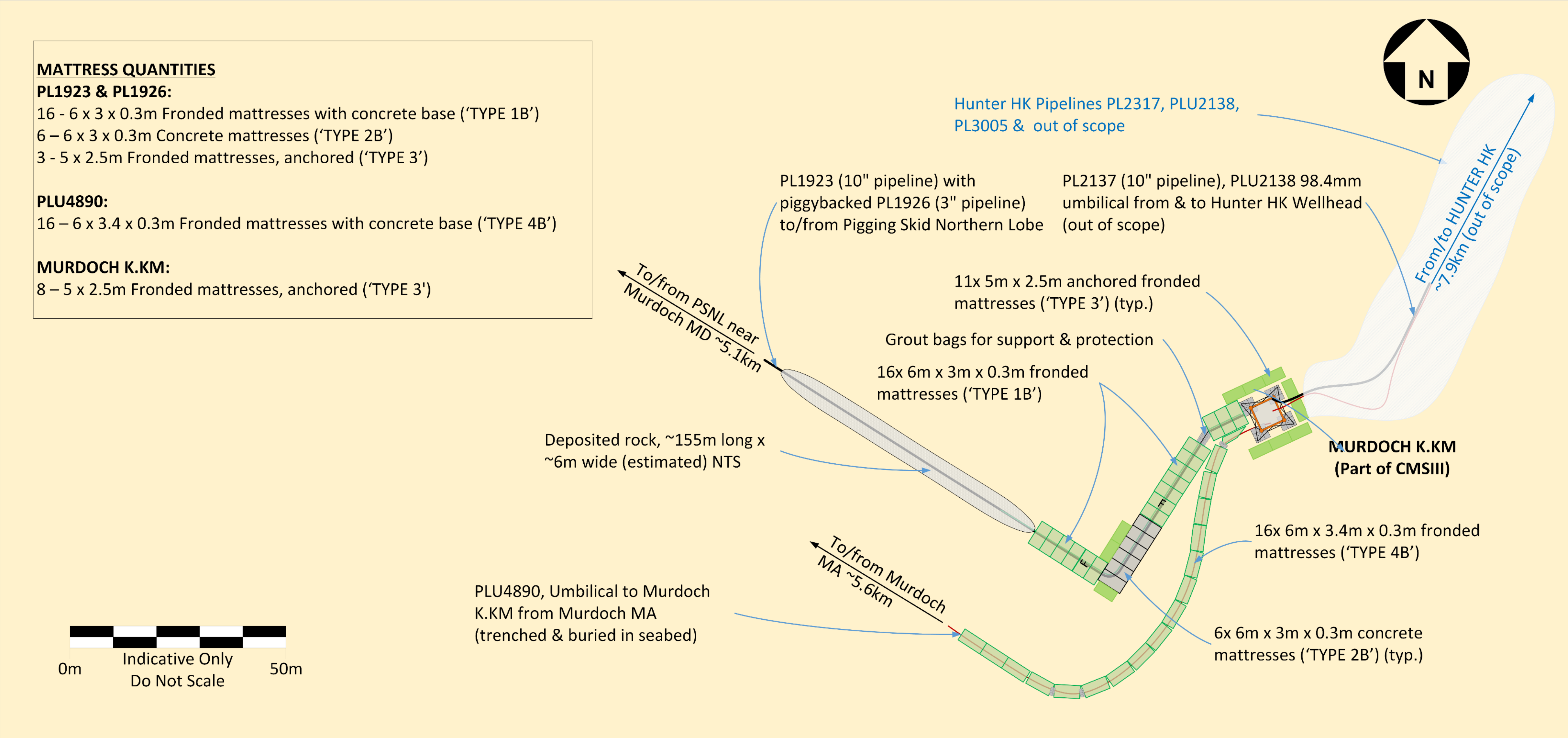


Figure A2.9.1: Schematic of pipelines near Murdoch K.KM

Appendix 2.10 Kelvin TM

MATTRESS QUANTITIES
PL2430 & PLU2431:
4 – 6 x 3 x 0.15m Concrete mattresses
5 – 6 x 3 x 0.15m Concrete mattresses 'wet stored'
6 – 6 x 3 x 0.15m Concrete mattresses

KELVIN SUBSEA TEE ASSEMBLY
2 – 6 x 3 x 0.3m Concrete mattresses

PL2894 & PL2895
13 – 6 x 3 x 0.3m Concrete mattresses

KELVIN PMA SKID
8 – 6 x 3 x 0.3m Concrete mattresses

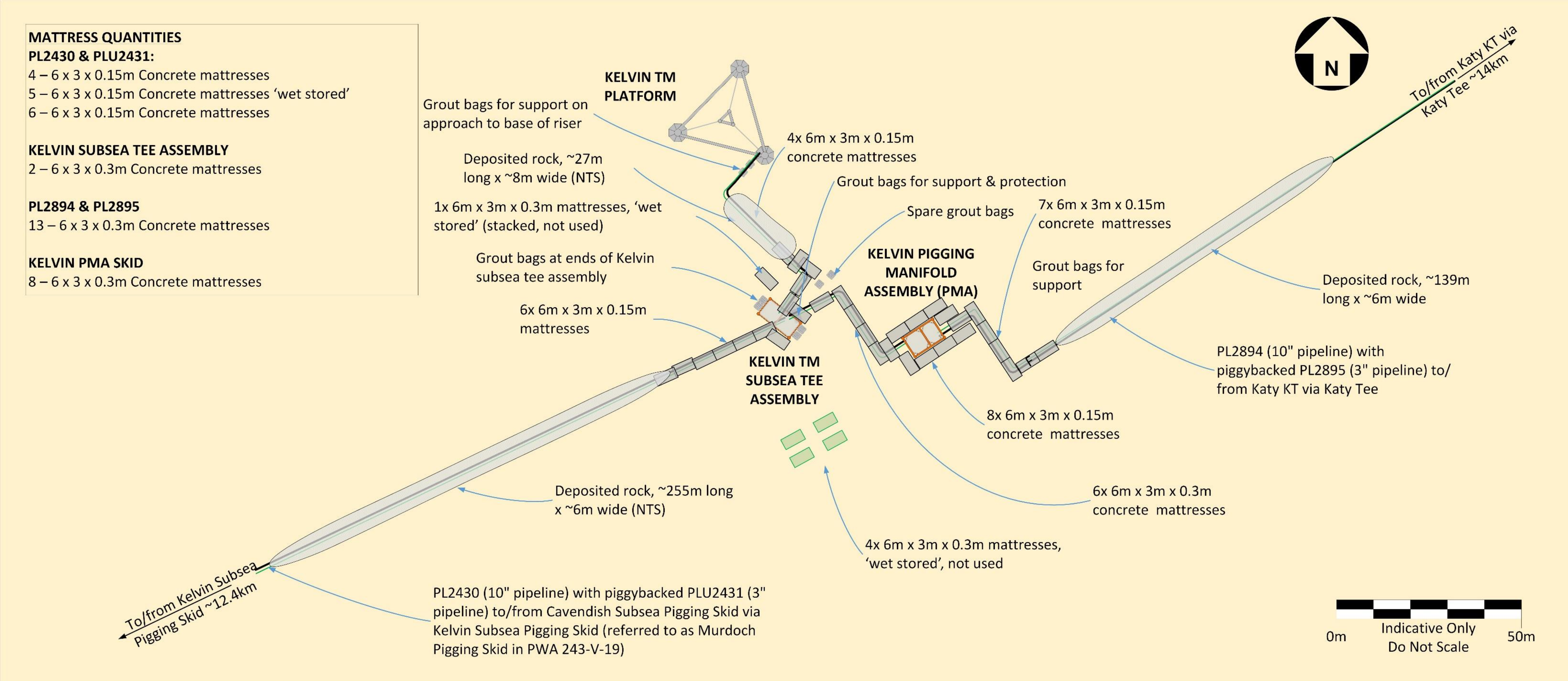


Figure A2.10.1: Schematic of pipelines near Kelvin TM

Appendix 2.11 Katy KT

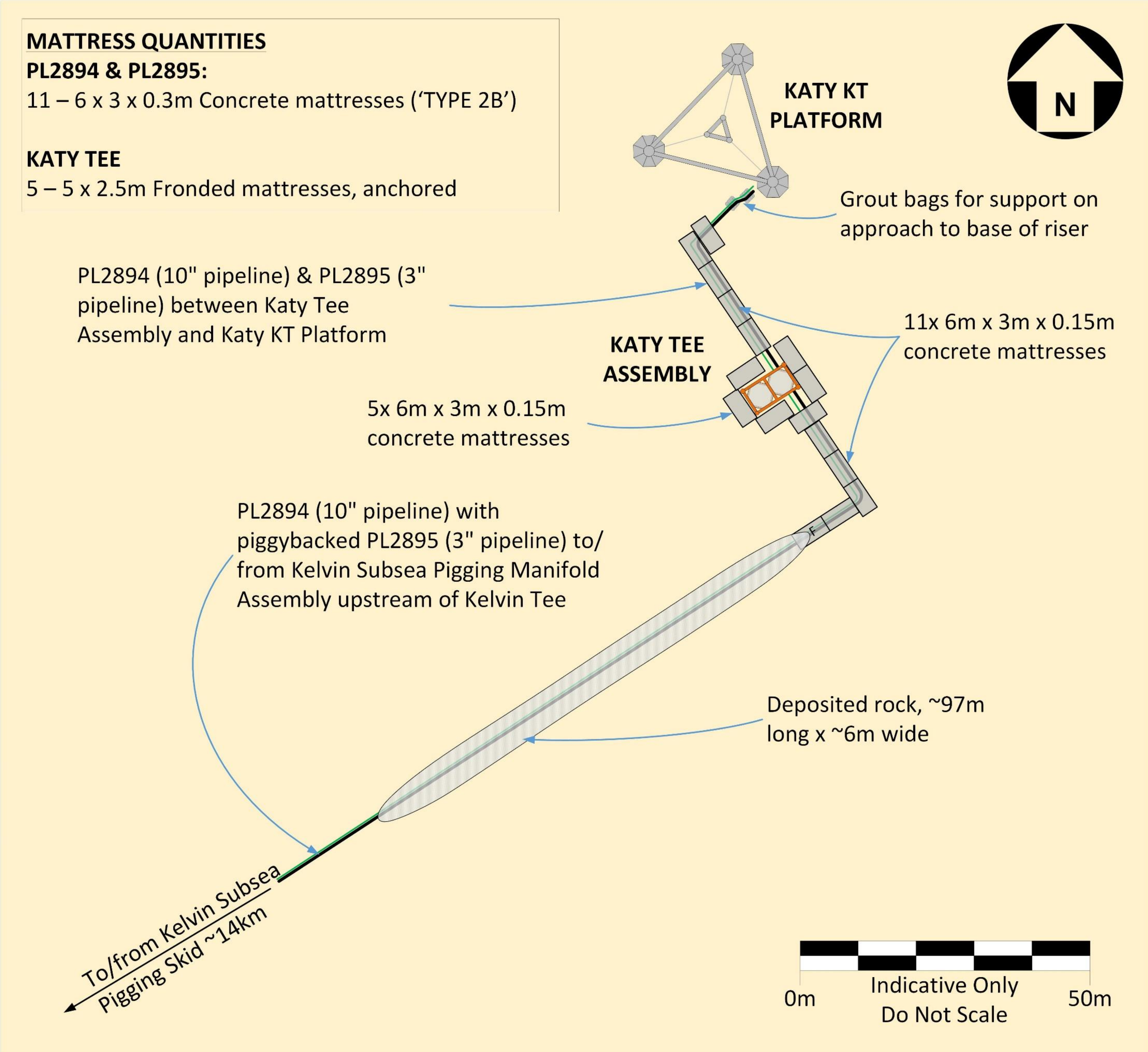


Figure A2.11.1: Schematic of pipelines near Katy KT

Appendix 2.12 Watt QM

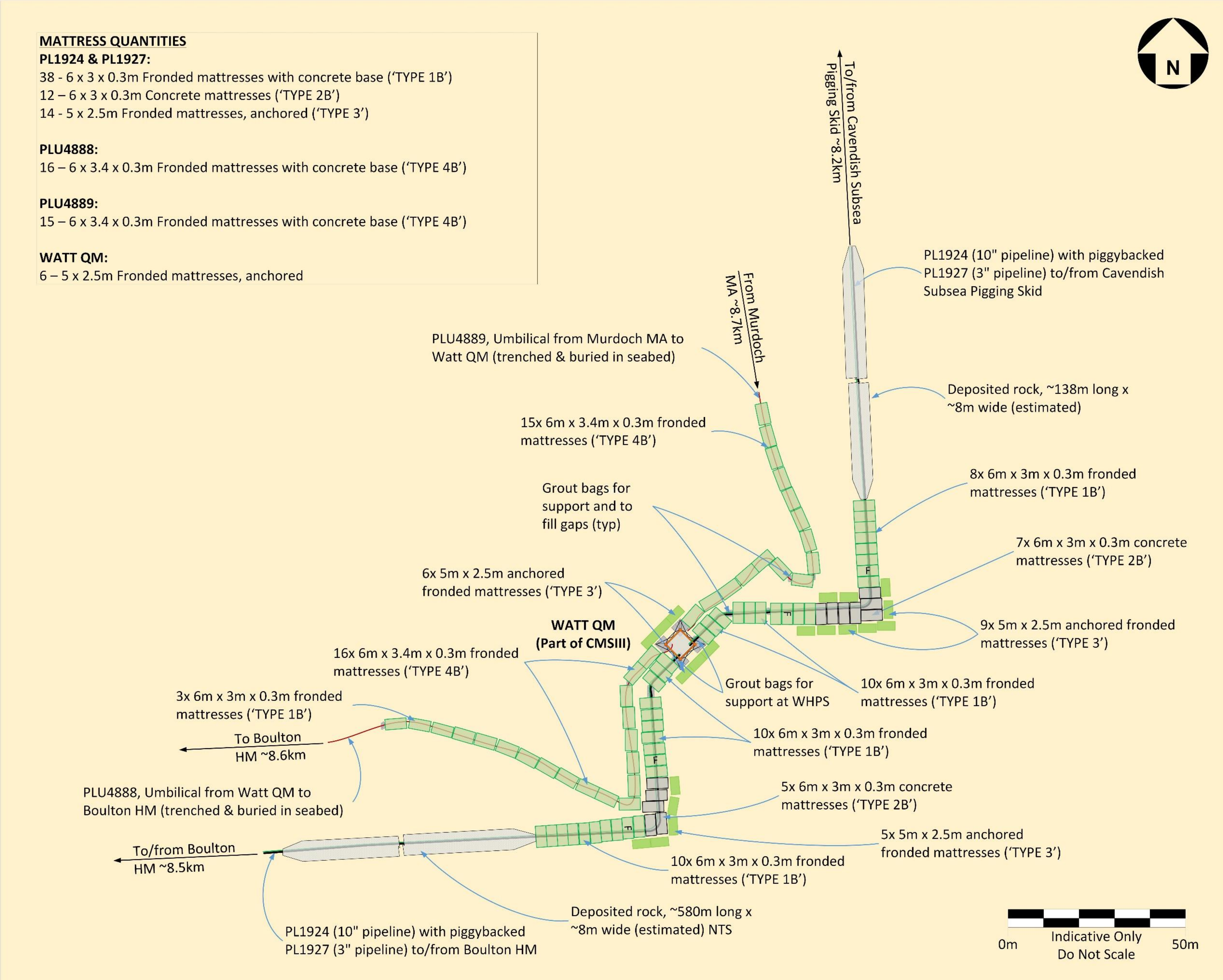


Figure A2.12.1: Schematic of pipelines near Watt QM

Appendix 3 Pipeline crossing schematics

Appendix 3.1 Pipeline crossings outside Murdoch 500m zone

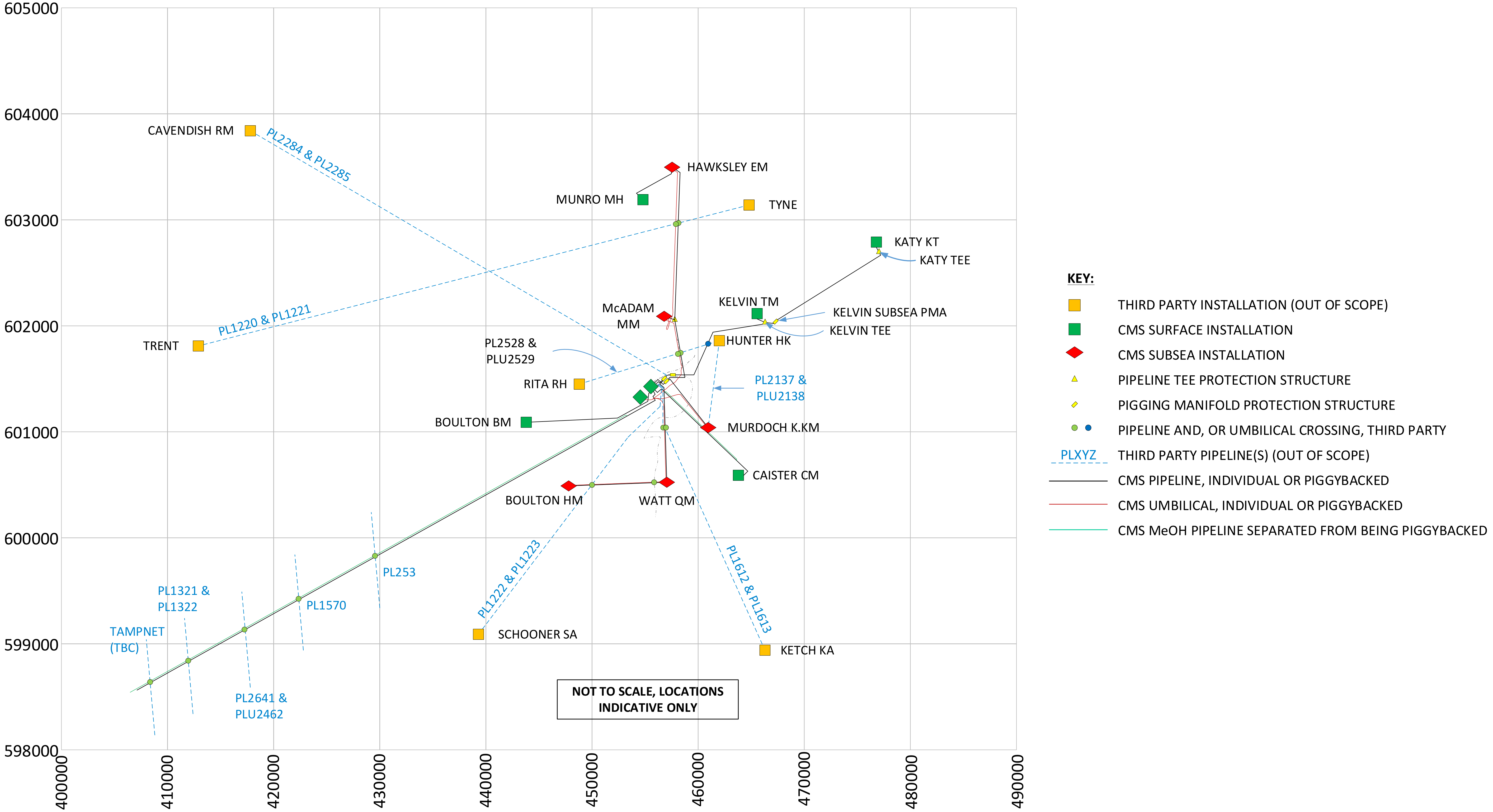


Figure A3.1.1: Schematic of Pipeline Crossings outside Murdoch 500m Zone[30]

[30] Murdoch MC not shown, area near Murdoch complex indicative only. Refer Figure A3.2.1.

Appendix 3.2 Pipeline crossings inside Murdoch 500m zone

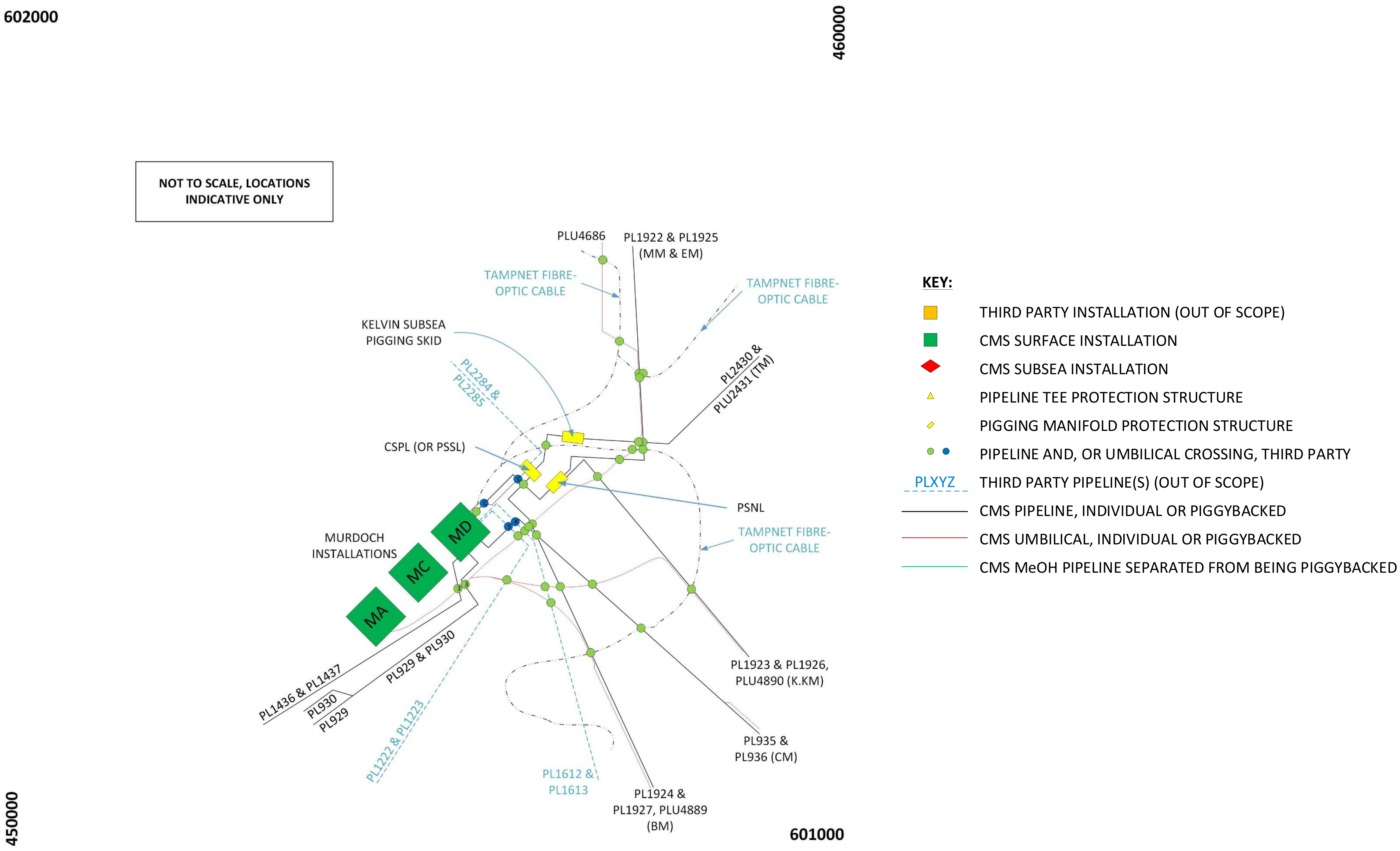


Figure A3.2.1: Schematic of Pipeline Crossings inside Murdoch 500m Zone

Appendix 4 Deposited rock schematics

Appendix 4.1 Deposited rock outside Murdoch 500m zone

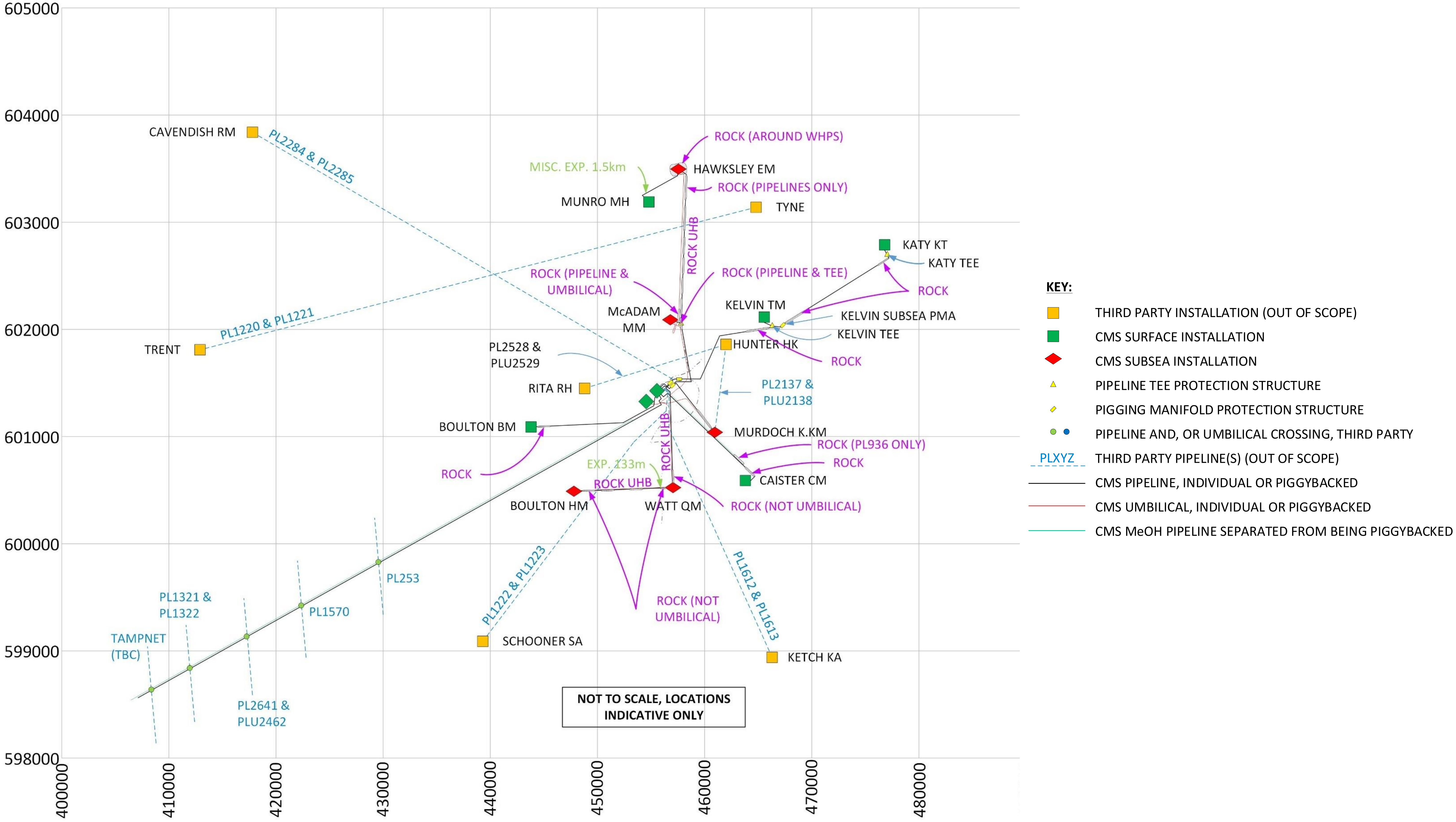


Figure A4.1.1: Schematic of deposited rock outside Murdoch 500m Zone[31]

[31] Murdoch MC not shown, area near Murdoch complex indicative only. Refer Figure A3.2.1.

Appendix 4.2 Deposited rock in or near Murdoch 500m zone

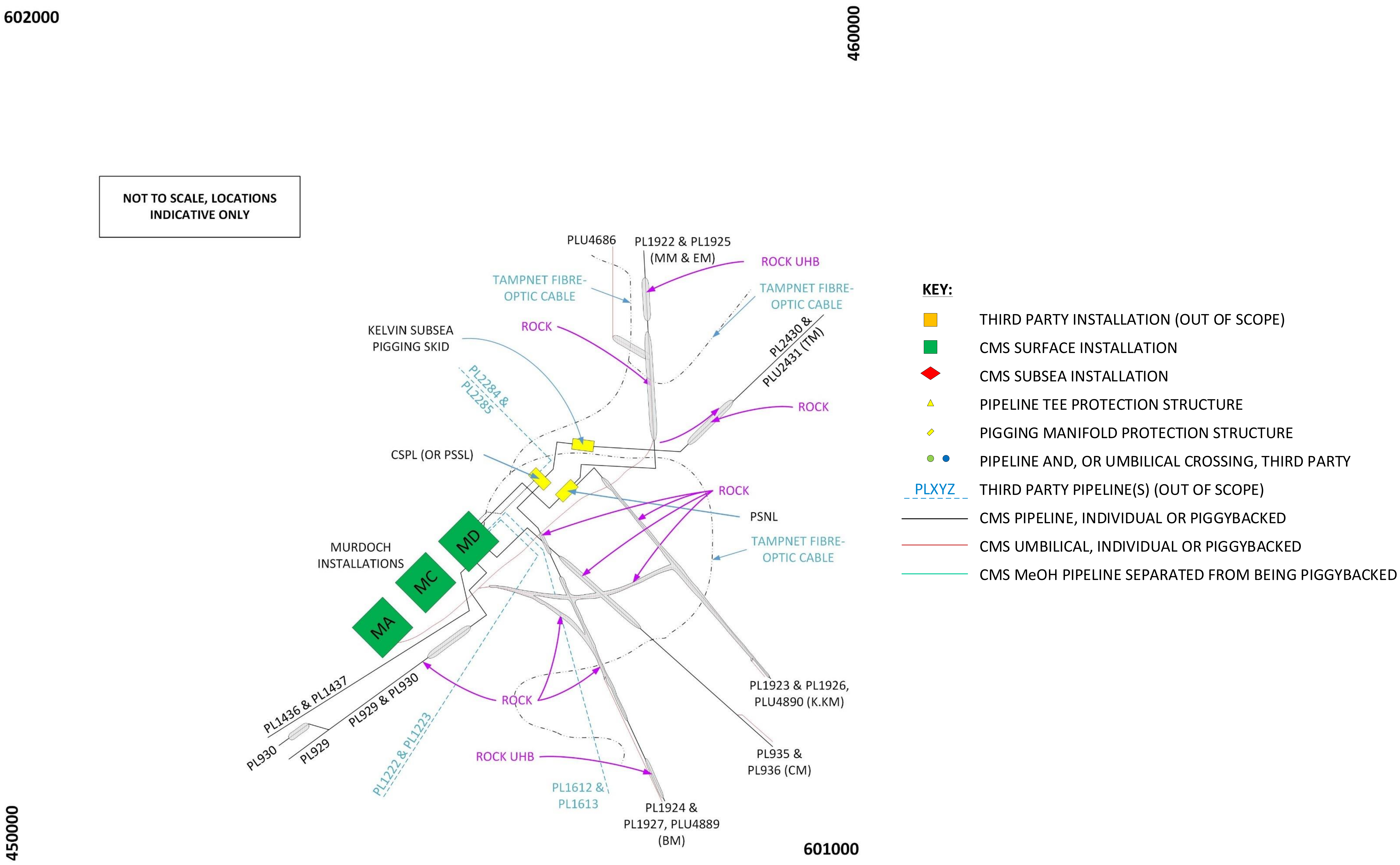


Figure A4.2.1: Schematic of Deposited Rock in or near Murdoch 500m Zone

Appendix 5 Mattresses – comparative assessment tables

Appendix 5.1 Mattresses – technical assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 3 LEAVE *IN SITU*
Technical	**Offshore Execution**	Risk of project failure.	Technically, complete removal of the mattresses would be achievable, but some complications could arise where the mattresses are buried and not visible. It can be expected that there would be integrity failures as they are being recovered, but contingency measures could be put in place. The fronded mattresses that are anchored will likely be more problematic to remove due to how they are constructed.	Technically, the mattresses could be left *in situ*.
		Technological challenge.	Technology is currently available to excavate, cut and recover the mattresses to shore.	n/a
		Technical challenge.	Excavation of mattresses buried under sediment could prove problematic but using an MFE there should be no issues in displacing sediment. There is purpose designed and built equipment that would be suitable for removing all but the largest mattresses, but at the most basic level grabs or grapples could be used to recover the mattresses to deck.	Buried fronded and concrete mattresses have been left *in situ* before.
Technical	**Legacy**	Risk of project failure.	No mattress surveys would be required in future.	It can be expected that mattress status surveys would be required in future. Such surveys have been carried out previously as part of pipeline surveys so they can be achieved.
		Technological challenge.	As above.	There are no technological issues associated with carrying out status surveys
		Technical challenge.	As above.	As above.

Table A5.1.1: Mattresses - technical assessment

Appendix 5.2 Mattresses – safety assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 3 LEAVE *IN SITU*
Safety	**Offshore Execution**	Health & safety risk offshore project personnel.	More offshore work than leave *in situ*. Excavation of the mattresses and recovery. There is experience of recovering fronded and concrete mattresses. Procedures could be put in place to minimise safety threats associated with instances where mattresses fall apart on recovery. The work would be manageable from an HSE perspective. Most, if not all of the work could be done using remotely operated equipment with no divers. Material handling on vessel decks could be remotely operated.	Less offshore work than the complete removal option.
		Health & safety risk to mariners.	The risk to mariners in the short-term would be aligned with the duration the activities would be undertaken in the field. Duration of vessels in the field would be longer than for leave *in situ*. Once a mattress has been lifted the ability of a vessel to move out of the way would be restricted, but only for a relatively short time.	The duration of vessels in the field would be significantly shorter than for complete removal.
		Safety risk onshore project personnel.	Significantly more material handling associated with dealing with the mattresses (97 anchored fronded mattresses, 448 fronded mattresses with concrete bases, and 372 concrete mattresses) and underlying sections of pipeline and umbilical would present an increased safety risk to personnel, but this would manageable.	The quantity of material recovered would be significantly less than for complete removal.
Safety	**Legacy**	Health & safety risk offshore project personnel.	No umbilical surveys or remediation related activities would be required.	Mattress status surveys would be required, but this activity is considered routine with well managed risks.
		Health & safety risk to mariners.	No infrastructure left *in situ* therefore no residual snag hazards. Lower risk as potential snag hazards completely removed. Although bottom dredging, demersal fishing nets should not adversely interact with the temporary excavations.	The mattresses whose bases remain but become exposed would present a snagging risk.
		Safety risk onshore project personnel.	Nothing to differentiate the options	

Table A5.2.1: Mattresses - safety assessment

Appendix 5.3 Mattresses – environmental assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 3 LEAVE *IN SITU*
Environmental	**Offshore Execution**	Energy & emissions.	Energy use and resulting emissions for this option would be higher than for leave *in situ*, but no energy and emissions would be needed to create new material.	Least amount of energy used, and least emissions generated in the short term, although any gains would be offset by the energy and emissions required to create new material to replace that which would be left *in situ*.
		Seabed disturbance, area affected.	The amount of seabed disturbed would be directly related to the number of mattresses removed. The area affected would be largest for this option, but the seabed could be expected to make a full recovery.	The least area of seabed would be disturbed for the leave *in situ* decommissioning option.
		Disturbance to protected area (Dogger Bank SAC, 12,331km^2).	Complete removal of the 97 anchored fronded mattresses would result in 0.018km^2 (0.00015%) of seabed within the Dogger Bank SAC being disturbed. Complete removal of the 448 fronded mattresses with concrete bases would result in 0.095km^2 (0.00077%) being disturbed and compete removal of the 372 concrete mattresses would result in 0.083km^2 (0.00067%) of seabed being disturbed. Total: 0.197km^2 or 0.0016%). The figures in brackets are the % of Dogger Bank SAC that would be affected. As the mattresses were laid on the surface rather than excavated into position the Dogger Bank and associated communities would be classed as vulnerable to the disruption required to completely remove the mattresses. Albeit temporary, the complete removal option would result in the most disruption to the Dogger Bank SAC although no materials that would be alien to the local fauna would be left behind. This option would be preferred on the basis that any disruption would be temporary. Further, the contours of the seabed would be allowed to reform naturally rather than be influenced by the presence of the mattresses; the area affected positively in this way could be expected to much larger than the area directly affected by the removal activities.	This option would result in the least disruption to the Dogger Bank SAC although the materials would be left behind – including a very small proportion of plastics, would be alien to the local fauna. Should 97 anchored fronded mattresses be left *in situ*, this would equate to 0.001km^2 (0.00001%) of the Dogger Bank SAC where materials being permanently left behind would alien to the local fauna. Equivalent figures for the 448 fronded mattresses with concrete bases and 372 concrete mattresses are 0.009km^2 (0.00007%) and 0.009km^2 (0.00007%). Total: 0.019km^2 or 0.00015%. As a proportion of the Dogger Bank SAC these figures are extremely small, although they do not take account of the in-combination or combined effect of other decommissioning proposals in the area. This option would be non-preferred on the basis that the 'disturbance' would be permanent.
		Effect on water column: • Liquid discharges to sea; • Liquid discharges to surface water; • Noise.	Discharges and releases to the water column would be related to the duration of activities being undertaken and would therefore be greatest for the complete removal option. A complication is that recovery of the anchored fronded mattresses could result in the synthetic materials being ripped as they are recovered, releasing small quantities of synthetic materials into the water column.	Discharges and releases would be least for the leave *in situ* option.
		Waste creation and use of resources such as landfill. Recycling and replacement of materials.	This option would result in the largest mass of material (total ~7,060Te for mattresses) being returned to shore as well as the underlying pipelines and umbilicals. Experience would suggest that all of the material could be recycled or in the case of plastics converted for use as energy. No material would be lost as no material would be left *in situ*.	No material such as mattresses and underlying pipelines and umbilicals would be returned to shore for recycling and so the material would be lost, and new material would be needed to replace the loss.
Environmental	**Legacy**	Energy & emissions.	No burial surveys required.	It can be expected that future surveys would be required.
		Seabed disturbance, area affected.	As above.	Burial surveys would not usually involve disturbance to the seabed, and it is assumed that no remedial activities would be required otherwise, so no impact.
		Disturbance to protected area (Dogger Bank SAC).	As above.	As above.
		Effect on water column: • Liquid discharges to sea; • Liquid discharges to surface water; • Noise.	As above.	It can be expected that future surveys would be required, over and above those required for pipeline surveys. This is because the mattresses would not generally be as well buried as trenched and buried pipelines. Over time it can be expected that small quantities of synthetic materials would be released into the water column as the fronds, anchored fronded mattress bases and polypropylene rope eventually degrade.
		Waste creation and use of resources such as landfill. Recycling and replacement of materials.	No activity required.	No activity expected.

NOTE:
1. As per note 2 below the mass of material recovered may be less than the figure quoted here as some mattresses are situated on pipeline crossings and buried in areas not near the pipeline ends;
2. The calculation for the indirect area disturbed by the removal of the mattress is considered conservative. The reason for this is that there are several concrete mattresses under several third-party pipeline crossings that are likely to be buried and therefore they would be candidates for remaining *in situ*. Furthermore, there are several concrete mattresses on either PL929, PL930 or both at ~KP4.8 (Figure 3.2.4), KP20 (Figure 3.2.3) and KP180.409 (Figure 3.2.1) that are not on pipeline ends and likely to be buried, in which case they would be left *in situ*. The same applies for several mattresses on PL936 at ~KP0.493 and ~KP10.485 (Figure A2.2.1, Figure A3.2.1 respectively).

Table A5.3.1: Mattresses – environmental assessment

Appendix 5.4 Mattresses - societal assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 3 LEAVE *IN SITU*
Societal	**Offshore Execution**	Effect on commercial activities.	The impact of decommissioning vessel traffic on local commercial activities such as fishing would be greatest for complete removal.	Impact of decommissioning vessel traffic on local commercial activities such as fishing would least for leave *in situ*.
		Employment.	Decommissioning activities associated with complete removal would contribute greatest to continuity of employment.	Decommissioning activities associated with leave *in situ* would contribute the least to continuity of employment for leave *in situ*.
		Communities or impact on amenities.	Decommissioning activities associated with complete removal would contribute the most to continuity of work in ports and disposal sites.	Decommissioning activities associated with leave *in situ* would contribute the least to continuity of work in ports and disposal sites.
Societal	**Legacy**	Effect on commercial activities.	No impact as no legacy related activities would be required.	Impact of survey vessel traffic on local commercial activities such as fishing would be more than for complete removal but where applicable about the same as for the partial removal option.
		Employment.	Should the mattresses be completely removed, there would be no opportunities for employment.	Should the mattresses be left *in situ* the opportunity for continuation of employment would be limited to survey work.
		Communities or impact on amenities.	Once the mattresses had been removed there would be no related work in ports and disposal sites.	The mattresses may not be sufficiently buried so there is a possibility of remedial work being required in future, resulting in a continuity of employment rather than any new jobs.

Table A5.4.1: Mattresses – societal assessment

Appendix 5.5 Mattresses – cost assessment for pipeline and umbilical ends only

CRITERIA	ASPECT	ASSET	OPTION 1 COMPLETE REMOVAL	OPTION 3 LEAVE *IN SITU*
Economics	**Offshore Execution**	PL929 & PL930, PL935 & PL936, all piggybacked pipelines and all umbilicals.	For PL929, PL930, PL935, PL936 and all piggybacked pipelines and umbilicals the cost by difference for removing the mattresses and underlying pipelines would be an order of magnitude greater for complete removal than for leave *in situ*.	The cost of leave *in situ* would be the least expensive of the two decommissioning options.
	Legacy	All pipelines and umbilicals.	Should the pipeline(s) and umbilicals have been completely removed no burial surveys would be required in future.	Future burial surveys will be required. The premise is that if two successive surveys demonstrate that the mattresses and underlying pipelines or umbilicals remain buried and stable no more surveys would be required.

NOTES:
1. Leave *in situ* costs include incremental costs for carrying out 1x post decommissioning survey and 3x legacy surveys of the short sections of mattresses left *in situ*. Ordinarily these costs would be borne as part of the pipeline surveys. However, there could be a scenario where mattress status surveys are required, but their burial status is such that no more surveys would be required for the pipelines;
2. Refer Table A9.4.1.

Table A5.5.1: Mattresses – cost assessment for mattresses incl. pipeline and umbilical ends

Appendix 5.6 Mattresses – cost assessment for installations and structures

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 3 LEAVE *IN SITU*
Economics	**Offshore Execution**	n/a	The costs for removing the mattresses associated with Kelvin Pigging Manifold Assembly would be an order of magnitude greater for complete removal than for leave *in situ*.	The cost of leave *in situ* would be the least expensive of the two decommissioning options.
		n/a	The costs for removing the mattresses associated with Murdoch PSNL, Hawksley EM, Murdoch K.KM, Kelvin Subsea Tee Assembly, Boulton HM, Katy Tee, McAdam MM and Watt QM would be less than an order of magnitude greater for complete removal than for leave *in situ*.	As above.
	Legacy	n/a	Should the pipeline(s) have been completely removed no pipeline or umbilical burial surveys would be required in future.	Future burial surveys will be required. The premise is that if two successive surveys demonstrate that the mattresses and associated underlying pipelines and umbilicals remain buried and stable no more surveys would be required.

NOTE
1. Leave *in situ* costs include incremental costs for carrying out 1x post decommissioning survey and 3x legacy surveys of the short sections of mattresses left *in situ*. Ordinarily these costs would be borne as part of the pipeline surveys. However, there could be a scenario where mattress status surveys are required, but their burial status is such that no more surveys would be required for the pipelines;
2. Refer Table A9.5.1.

Table A5.6.1: Mattresses – cost assessment for installations and structures

Appendix 6 Pipelines group 1 – Comparative Assessment tables

Appendix 6.1 Pipeline group 1 - technical assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 2 PARTIAL REMOVAL[1]	OPTION 3 LEAVE *IN SITU*
Technical	**Offshore Execution**	Risk of project failure.	Technically, complete removal of the pipelines would most likely be achievable, but complications could arise because the pipelines are buried. The larger diameter pipelines that are concrete coated could be removed using 'cut and lift'. Assuming that their integrity could be assured, the smaller pipelines could be reverse reeled. 'Cut and lift' could be a fall-back approach for the smaller pipelines.	Buried pipe has been uncovered and the 'cut and lift' method can and has been used for removing relatively short sections of pipe so this would be achievable. Assuming that the lengths involved would justify the approach, the smaller pipelines could be reverse reeled. 'Cut and lift' could be a fall-back approach for the smaller pipelines. Rock has also been deposited with no technical issues. Post-trenching has been done before, sometimes with issues depending on the terrain.	Technically, the pipeline(s) could be left *in situ*
		Technological challenge.	Technology is currently available to excavate, cut and recover the pipelines to shore.	Technology is currently available to excavate, cut and recover the pipelines to shore as well as to deposit rock or to post-trench the pipelines.	n/a
		Technical challenge.	Excavation of pipeline(s) buried in the seabed or under deposited rock could prove problematic but would still be achievable. 'Cut and lift' method could be used but the reverse reel method could also be used for recovery of individual small diameter pipeline(s) whose integrity remains intact.	Excavation of pipeline(s) buried in the seabed or under deposited rock could prove problematic but would still be achievable. 'Cut and lift' method could be used but the reverse reel method could also be used for recovery of sufficiently long individual lengths of small diameter pipeline(s) whose integrity remains intact. Deposition of additional rock has been done before and would not present a technical challenge. Post-trenching has been done before, sometimes with issues depending on the terrain.	Stable and buried pipeline(s) have been left *in situ* before so this option would be achievable.
Technical	**Legacy**	Risk of project failure.	No pipeline surveys would be required in future.	Pipeline surveys have been undertaken in the past, so this is achievable with no complications.	Pipeline surveys have been undertaken in the past, so this is achievable with no complications.
		Technological challenge.	As above.	The technology is currently available for carrying out pipeline surveys.	The technology is currently available for carrying out pipeline surveys.
		Technical challenge.	As above.	There would be no technical issues associated with carrying out pipeline surveys in future although the stop-start nature of the remaining pipeline could lead to spurious results.	There would be no technical issues associated with carrying out pipeline surveys in future.

NOTE
1. For group 1 pipelines partial removal option only applies to PL929 & PL930 as indicated in Table 4.2.1

Table A6.1.1: Pipeline group 1 - technical assessment

Appendix 6.2 Pipeline group 1 – safety assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 2 PARTIAL REMOVAL[1]	OPTION 3 LEAVE *IN SITU*
Safety	**Offshore Execution**	Health & safety risk offshore project personnel (PL929 & PL930).	More offshore work than leave *in situ*. Excavation of the pipeline and recovery. There is experience of recovering small individual pipelines by reverse reel. The 'cut and lift' method for removal would be repetitive, with the number of repetitions - 80-100 sections of pipe per km. Potential for spalling concrete would increase with the number of lifting operations involved. For PL929 (26in & CWC) this would equate to between 15,000 and 18,000 lengths of pipe needing to be recovered. The work is repetitive but arguably it would be manageable from an HSE perspective. Most of the work could be done using equipment operated remotely and most could be done without using divers. Material handling on vessel decks could be automated given the right resources and focus. Assuming that its integrity remains intact, once excavated, PL930 could be removed using reverse reel or reverse S-lay.	The amount of offshore work would be less than that required for complete removal. Piece-meal nature of the work associated with locating exposed pipelines and excavating cut points could be a source of frustration leading to accidents.	At most only the pipeline ends would be dealt with; less offshore work than for complete removal or partial removal. Significantly less work and therefore a shorter duration of activities than for complete removal.
			As above.	Deposition of rock and post-trenching has been carried out on plenty of occasions and would be safer to achieve than pipe recovery operations.	As above.
		Health & safety risk offshore project personnel (PL935 & PL936).	As above, except for PL935 (16in & CWC) between 930 and 1,120 lengths of pipe needing to be recovered. given the right resources and focus. Assuming that its integrity remains intact, once excavated, PL936 could be removed using reverse reel.	Historical survey data suggests that PL935 would have no exposures. No survey data are available for PL936, but the design depth of burial was to be ~500mm deeper than for PL935.	As above.
		Health & safety risk to mariners.	The risk to mariners in the short-term would be aligned with the duration the activities would be undertaken in the field. Duration of vessels in the field would be longer than for leave *in situ* or partial removal. Using the reverse reel or reverse S-lay method for the smaller pipelines would mean that the vessel would be attached to a pipeline and could not move out of the way quickly. Using the 'cut and lift' method would also restrict the ability of a vessel to move out of the way, but for a relatively short time. As above.	The risks would be similar to those associated with complete removal but for a shorter duration. The risk to mariners in the short term would be aligned with the duration the activities would be undertaken in the field. Deposition of rock would take less time than removal and could be 'aborted' relatively quickly. Post-trenching can be a slow process, but the time could be comparable to removal activities.	Only the pipeline ends would likely be dealt with; duration of vessels in the field would be significantly shorter than for complete removal.
		Safety risk onshore project personnel.	Significantly more onshore cutting, lifting, and handling associated with dealing with the pipelines; presents an increased safety risk to personnel.	Safety risk is directly associated with the duration and repetitive nature of the work. Less onshore cutting, lifting, and handling so less safety risk to onshore personnel. Quarrying of rock, its transportation, and transfer to a rock discharge vessel at quayside.	No onshore work except for that possibly associated with the pipeline ends, which may be common for all options.
Safety	**Legacy**	Health & safety risk offshore project personnel.	No pipeline surveys or remediation related activities.	Pipeline surveys would be required, but this activity is considered routine with well managed risks.	Pipeline surveys would be required, but this activity would be considered routine with well managed risks.
		Health & safety risk to mariners.	No infrastructure left *in situ* therefore no residual snag hazards. Lower risk as potential snag hazards completely removed.	Theoretically snagging hazards could remain even though these would have been dealt with at the time. Future survey data would provide evidence that exposures and potential snagging risks remain limited.	For PL929 and PL930 there would be a slightly lower level of snagging risk than for partial removal due to the continued presence of exposures. For those sections pipelines that are buried there would be little to no snagging risk.
		Safety risk onshore project personnel.	Nothing to differentiate the options		

NOTE
1. For group 1 pipelines partial removal option only applies to PL929 & PL930 as indicated in Table 4.2.1.

Table A6.2.1: Pipeline group 1 - safety assessment

Appendix 6.3 Pipeline group 1 – environmental assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 2 PARTIAL REMOVAL[1]	OPTION 3 LEAVE *IN SITU*
Environmental	**Offshore Execution**	Energy & emissions.	Energy use and resulting emissions for this option would be higher than for either – where applicable, partial removal or for leave *in situ*, but no energy and emissions would be needed to create new material.	Energy use and resulting emissions for operational activities would likely be lower for this option than for the complete removal but higher than for the leave *in situ* option. Not helped by the additional energy and emissions needed to create new material to replace that which would be left *in situ*.	Least amount of energy used, and least emissions generated in the short term, although any gains would be offset by the energy and emissions required to create new material to replace that which would be left *in situ*.
			Use of energy would likely be more than required for the deposition of rock or post-trenching.	The energy required to query rock, to transport the rock to location and to deposit the rock or for post-trenching would likely be less than required for full removal but more than for leave *in situ*.	As above.
		Seabed disturbance, area affected.	The amount of seabed disturbed would be directly related to the length of pipeline being removed. The area affected would be largest for this option.	This area of seabed disturbed would fall in-between the complete removal and leave *in situ* option. The amount of seabed disturbed by the deposition of rock would be comparable to that disturbed for operations to partially remove the pipelines and umbilicals, albeit permanently.	The least area of seabed would be disturbed for the leave *in situ* decommissioning option.
		Disturbance to protected area (Dogger Bank SAC, 12,331km^2).	Complete removal of PL929, PL930, PL935 and PL936 would result in 1.8km^2, 1.8km^2, 0.112km^2 and 0.107km^2 of seabed within the Dogger Bank SAC being disturbed. As a proportion this would equate to 0.015%, 0.015%, 0.001% and 0.001% of the overall area. The Dogger Bank and associated communities would be classed as highly vulnerable to the disruption and excavation required to completely remove the pipelines. The complete removal option would result in the most disruption to the Dogger Bank SAC albeit temporary.	Significantly less of the Dogger Bank SAC area would be disrupted for removing up to ~8km of either PL929 or PL930 in group 1 compared to recovering the full length of the pipelines. This option would be preferred to the complete removal option but would not be preferred over the leave *in situ* option. Any materials left behind would be alien to the local fauna. Deposition of rock. Assuming a 10m wide corridor, potentially up to 2x 0.08km^2 of the Dogger Bank SAC would be disturbed. As a proportion of the SAC by inspection this would be negligible. Same area affected by post-trenching.	This option would result in the least disruption to the Dogger Bank SAC although the materials being left behind would be alien to the local fauna.
		Effect on water column: • Liquid discharges to sea; • Liquid discharges to surface water; • Noise.	Discharges and releases to the water column would be related to the duration of activities being undertaken and would therefore be greatest for the complete removal option.	Discharges and releases to the water column are related to the duration of activities being undertaken and would therefore be greater than leave *in situ* but much less than for complete removal.	Discharges and releases would be least for the leave *in situ* option, at least in the short-term.
		Waste creation and use of resources such as landfill. Recycling and replacement of materials.	This option would result in the largest mass of material being returned to shore. No material would be lost as no material would be left *in situ*.	This option sits in-between complete removal and leave *in situ* decommissioning options. Deposition of rock would require more materials to be excavated and would be lost as the material would not be available for use elsewhere.	No material would be returned to shore for recycling and so the material would be lost, and new material would be needed to replace the loss.
Environmental	**Legacy**	Energy & emissions.	No pipeline status or burial surveys required.	It can be expected that future surveys would be required.	
		Seabed disturbance, area affected.	As above.	Pipeline burial surveys do not usually involve disturbance to the seabed, and it is assumed that no remedial activities would be required otherwise, so no impact.	
		Disturbance to protected area (Dogger Bank SAC)	As above.	As above.	
		Effect on Water Column: • Liquid discharges to sea; • Liquid discharges to surface water; • Noise.	As above.	It can be expected that future surveys would be required.	
		Waste creation and use of resources such as landfill. Recycling and replacement of materials.	No activity required.	Assuming no remediation required, t nothing to differentiate the partial removal and leave *in situ* options from a waste perspective.	

NOTE
1. For group 1 pipelines partial removal option only applies to PL929 & PL930 as indicated in Table 4.2.1.

Table A6.3.1: Pipeline group 1 – environmental assessment

Appendix 6.4 Pipeline group 1 - societal assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 2 PARTIAL REMOVAL[1]	OPTION 3 LEAVE *IN SITU*
Societal	**Offshore Execution**	Effect on commercial activities.	The impact of decommissioning vessel traffic on local commercial activities such as fishing would be greatest for complete removal.	The impact of decommissioning vessel traffic on local commercial activities such as fishing would probably be less than for complete removal but more than for the leave *in situ* option.	Impact of decommissioning vessel traffic on local commercial activities such as fishing would least for leave *in situ*.
		Employment.	Decommissioning activities associated with complete removal would contribute greatest to continuity of employment.	Little to differentiate the partial removal and leave *in situ* options.	Decommissioning activities associated with leave *in situ* would contribute the least to continuity of employment for leave *in situ*.
		Communities or impact on amenities.	Decommissioning activities associated with complete removal would contribute the most to continuity of work in ports and disposal sites.	Decommissioning activities would contribute to continuity of work in ports and disposal sites less than for complete removal but more than for leave *in situ* option.	Decommissioning activities associated with leave *in situ* would contribute the least to continuity of work in ports and disposal sites.
Societal	**Legacy**	Effect on commercial activities.	No impact as no legacy related activities would be required.	Impact of survey vessel traffic on local commercial activities such as fishing would be less than for the complete removal option but about the same as for the leave *in situ* option.	Impact of survey vessel traffic on local commercial activities such as fishing would be more than for complete removal but where applicable about the same as for the partial removal option.
		Employment.	Should the pipeline(s) be completely removed, there would be no opportunities for continuation of employment.	Should the pipeline(s) be partially removed the opportunity for continuation of employment would be associated with survey work would probably be the same as for the leave *in situ* option. The possibility of remedial work could be slightly higher for the partial removal option due to the larger number of pipeline ends that could become exposed in future. However, this would not be a reason to pursue this option.	Should the pipeline(s) be left *in situ* the opportunity for continuation of employment would be associated with survey work and where applicable would be the same as for the partial removal option.
		Communities or impact on amenities.	Once the pipeline(s) had been removed there would be no opportunities for continuity of work in ports and disposal sites.	As above.	Should the pipeline(s) be left *in situ* there would be few opportunities for continuity of work in ports and disposal sites other than associated with survey related and possible remedial work.

NOTE
1. For group 1 pipelines partial removal option only applies to PL929 & PL930 as indicated in Table 4.2.1.

Table A6.4.1: Pipeline group 1 – societal assessment

Appendix 6.5 Pipeline group 1 – cost assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 2 PARTIAL REMOVAL[1]	OPTION 3 LEAVE *IN SITU*
Cost	**Offshore Execution**	n/a	Using the assumption that PL929 would be removed using the 'cut and lift' method the costs would be an order of magnitude greater than for partial removal and leave *in situ*.	Using the assumption that parts of PL929 would be removed using the 'cut and lift' method, the cost would be less than an order of magnitude greater than leave *in situ*. By inspection it would be cheaper to deposit rock rather than execute partial removal operations but more expensive that the cost of leave *in situ*.	The cost of leave *in situ* would be the least expensive of the three decommissioning options.
		n/a	Using the assumption that PL930 would be removed using the reverse reel method the costs would be less than an order of magnitude greater than for partial removal and leave *in situ*.	Using the assumption that parts of PL930 would be removed using the reverse reel method, the cost be less than two times greater than leave *in situ*. By inspection it would be cheaper to deposit rock or carry out post-trenching rather than execute partial removal operations but more expensive that the cost of leave *in situ*.	The cost of leave *in situ* would be the least expensive of the three decommissioning options.
		n/a	Using the assumption that PL935 would be removed using the 'cut and lift' method the cost would be an order of magnitude greater than for leave *in situ*.	n/a	The cost of leave *in situ* would be the least expensive of the decommissioning options.
		n/a	Using the assumption that the individual pipeline PL936 would be removed using the reverse reel method the costs would cost an order of magnitude more than for leave *in situ* in the short-term.	n/a	The cost of leave *in situ* would be the least expensive of the two decommissioning options.
	Legacy	n/a	Should the pipeline(s) have been completely removed no pipeline burial surveys would be required in future.	Future burial surveys will be required. The premise is that if two successive surveys demonstrate that the pipeline remains stable no more surveys would be required. This will be the same for both the partial removal and leave *in situ* decommissioning options.	

NOTE

1. For group 1 pipelines partial removal option only applies to PL929 & PL930 as indicated in Table 4.2.1. Note that the full length of these pipelines has not been surveyed, meaning that the cost of partial removal could increase;
2. The partial removal and leave *in situ* options assume that the surface laid pipeline ends have been removed although this may not have been the recommendation of this comparative assessment. This means that any difference in cost would be increased should the ends be decommissioned *in situ*;
3. The assessment assumes 1x post decommissioning survey would be required irrespective of the decommissioning options, and 3x legacy surveys would be required for any pipelines being left *in situ*;
4. Refer Table A9.6.1.

Table A6.5.1: Pipeline group 1 – cost assessment

Appendix 7 Pipeline group 2 – Comparative Assessment tables

Appendix 7.1 Pipeline group 2 - technical assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 2 PARTIAL REMOVAL[1]	OPTION 3 LEAVE *IN SITU*
Technical	**Offshore Execution**	Risk of project failure.	Technically, complete removal of the pipelines would most likely be achievable, but complications could arise because the pipelines are piggybacked and buried. The larger diameter pipelines that are concrete coated could be removed using 'cut and lift'. The smaller pipelines although piggybacked could be removed in the same operation assuming for example, hydraulic shears have been of sufficient size and capacity.	Buried pipe has been uncovered and the 'cut and lift' method can and has been used for removing relatively short sections of piggybacked pipe so this would be achievable. The length of PL2109 & PL2110 to be removed would be ~1.5km.	Technically, the pipeline(s) could be left *in situ.*
		Technological challenge.	Technology is currently available to excavate, cut and recover the pipelines to shore.	Technology is currently available to excavate, cut and recover the pipelines to shore.	n/a
		Technical challenge.	Excavation of pipeline(s) buried in the seabed or under deposited rock could prove problematic but would still be achievable. 'Cut and lift' method could be used for recovery of piggybacked pipelines.	Excavation of pipeline(s) buried in the seabed or under deposited rock could prove problematic but would still be achievable. 'Cut and lift' method could be used to recover short lengths of piggybacked pipelines.	Stable and buried pipeline(s) have been left *in situ* before so this approach would be achievable.
Technical	**Legacy**	Risk of project failure.	No pipeline surveys would be required in future.	Pipeline surveys have been undertaken in the past, so this is achievable with no complications.	Pipeline surveys have been undertaken in the past, so this is achievable with no complications.
		Technological challenge.	As above.	The technology is currently available for carrying out pipeline surveys.	The technology is currently available for carrying out pipeline surveys.
		Technical challenge.	As above.	There would be no technical issues associated with carrying out pipeline surveys in future although the stop-start nature of the remaining pipeline could lead to spurious results.	There would be no technical issues associated with carrying out pipeline surveys in future.

NOTE
1. For group 2 pipelines partial removal option only applies to Boulton HM pipelines PL1924 & PL1927 and Munro MH pipelines PL2109 & PL2110 as indicated in Table 4.2.1.

Table A7.1.1: Pipeline group 2 - technical assessment

Appendix 7.2 Pipeline group 2 – safety assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 2 PARTIAL REMOVAL[1]	OPTION 3 LEAVE *IN SITU*
Safety	**Offshore Execution**	Health & safety risk offshore project personnel.	More offshore work than either where applicable partial removal or leave *in situ* involving excavation, cutting and recover to deck. Use of the 'cut and lift' method for removal would be repetitive, with the number of repetitions increasing with the length of pipeline. For the shortest pipeline(s) ~5.1km long this would equate to between 425 and 510 lengths of pipe needing to be recovered, increasing to between 1,800 to 2,160 lengths for the longest pipeline(s) that are ~21.6km long. The work would be repetitive but manageable from an HSE perspective. Most of the work could be done using equipment operated remotely and done without divers. Material handling on vessel decks could be automated given the right resources and focus.	The amount of offshore work would be less than that associated with complete removal. The potential piece-meal nature of the work associated with locating exposed pipelines and excavating cut points could be a source of frustration leading to accidents. Deposition of rock and post-trenching has been carried out on plenty of occasions and would be safer to achieve than pipe recovery operations.	At most only the pipeline ends would be dealt with; less offshore work than for complete removal or partial removal. Significantly less work and therefore a shorter duration of activities than for complete removal.
		Health & safety risk to mariners.	The risk to mariners in the short-term would be aligned with the duration the activities undertaken in the field. Duration of vessels in the field would be longer than for either partial removal (where applicable) or leave *in situ*. Using the 'cut and lift' method would also restrict the ability of a vessel to move out of the way, but only for a relatively short time.	The risks would be similar to those associated with complete removal but for a shorter duration. The risk to mariners in the short term would be aligned with the duration of the activities undertaken in the field.	Duration of vessels in the field would be shorter than for complete removal.
		Safety risk onshore project personnel.	Significantly more onshore cutting, lifting, and handling associated with dealing with the pipelines; presents an increased safety risk to personnel.	Safety risk is directly associated with the duration and repetitive nature of the work. Less onshore cutting, lifting, and handling than the complete removal option, so less safety risk to onshore personnel.	No onshore work.
Safety	**Legacy**	Health & safety risk offshore project personnel.	No pipeline surveys or remediation related activities.	Pipeline surveys would be required, but this activity is considered routine with well managed risks. Potentially could take slightly longer than for leave *in situ* due to fragmented nature of remaining pipeline but otherwise – where applicable, there would be little to differentiate partial removal from the leave *in situ* option.	Pipeline surveys would be required, but this activity is considered routine with well managed risks and would be of short duration.
		Health & safety risk to mariners.	No infrastructure left *in situ* therefore no residual snag hazards. Lower risk as potential snag hazards completely removed.	Exposures would have been removed with only the cut ends remaining potential snagging hazards in future although these would have been dealt with at the time. The potential for snag hazards would be minimised by removal of the continuous sections of pipelines that contain a number of exposures. For PL2109 & PL2110 it would mean removal of 1.5km of pipeline(s) as this would minimise the number of cut ends remaining. Future survey data would provide evidence that exposures and potential snagging risks remain limited.	Where applicable, there would be a slightly higher level of snagging risk than for partial removal due to the continued presence of exposures. For those sections pipelines that are buried there would be little to no snagging risk.
		Safety risk onshore project personnel.	Nothing to differentiate the options		

NOTE
1. For group 2 pipelines partial removal option only applies to Munro MH pipelines PL2109 & PL2110 as indicated in Table 4.2.1.

Table 7.2.1: Pipeline group 2 - safety assessment

Appendix 7.3 Pipeline group 2 – environmental assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 2 PARTIAL REMOVAL[1]	OPTION 3 LEAVE *IN SITU*
Environmental	**Offshore Execution**	Energy & emissions.	Energy use and resulting emissions for this option would be higher than for either – where applicable, partial removal or for leave *in situ*, but no energy and emissions would be needed to create new material.	Energy use and resulting emissions for operational activities would be lower for this option than for the complete removal but higher than for the leave *in situ* option. Not helped by the additional energy and emissions needed to create new material to replace that which would be left *in situ*.	Least amount of energy used, and least emissions generated in the short term, although any gains would be offset by the energy and emissions required to create new material to replace that which would be left *in situ*.
		Seabed disturbance, area affected.	The amount of seabed disturbed would be directly related to the length of pipeline being removed. The area affected would be largest for this option.	This area of seabed disturbed would fall in-between the complete removal and leave *in situ* option.	The least area of seabed would be disturbed for the leave *in situ* decommissioning option.
		Disturbance to protected area (Dogger Bank SAC, 12,331km^2).	Complete removal of the shortest pipeline(s) ~5.1km long would result in 0.051km^2, and the longest pipeline(s) ~12.7km long would result in ~0.127km^2 of seabed within the Dogger Bank SAC being disturbed. As a proportion for this would equate to between 0.0004% and 0.001% of the overall area for the shortest and longest pipeline(s) respectively. The Dogger Bank and associated communities would be classed as highly vulnerable to the disruption and excavation required to completely remove the pipelines. The complete removal option would result in the most disruption to the Dogger Bank SAC albeit temporary.	Significantly less of the Dogger Bank SAC area would be disrupted for removing up to ~1.5km of PL2109 & PL2110 compared to recovering the full length of the pipelines ~5.1km for each piggybacked pair of pipelines. This option would be preferred to the complete removal option but would not be preferred over the leave *in situ* option. Any materials left behind would be alien to the local fauna.	This option would result in the least disruption to the Dogger Bank SAC although the materials being left behind would be alien to the local fauna.
		Effect on water column: • Liquid discharges to sea; • Liquid discharges to surface water; • Noise.	Discharges and releases to the water column would be related to the duration of activities being undertaken and would therefore be greatest for the complete removal option.	Discharges and releases to the water column are related to the duration of activities being undertaken and would therefore be greater than leave *in situ* but much less than for complete removal.	Discharges and releases would be least for the leave *in situ* option, at least in the short-term.
		Waste creation and use of resources such as landfill. Recycling and replacement of materials.	This option would result in the largest mass of material being returned to shore. No material would be lost as no material would be left *in situ*.	This option sits in-between complete removal and leave *in situ* decommissioning options	No material would be returned to shore for recycling and so the material would be lost, and new material would be needed to replace the loss.
Environmental	**Legacy**	Energy & emissions	No pipeline status or burial surveys required.	Future survey requirements would be largely the same as for leave *in situ*.	It can be expected that future surveys would be required.
		Seabed disturbance, area affected.	No pipeline status or burial surveys required.	Pipeline burial surveys do not usually involve disturbance to the seabed, and it is assumed that no remedial activities would be required otherwise, so no impact.	
		Disturbance to protected area (Dogger Bank SAC).	As above.	As above.	
		Effect on water column: • Liquid discharges to sea; • Liquid discharges to surface water; • Noise.	As above.	It can be expected that future surveys would be required.	
		Waste creation and use of resources such as landfill. Recycling and replacement of materials.	No activity required.	Assuming no pipeline remedial activities would be required as part of legacy related activities, there would be nothing to differentiate the partial removal and leave *in situ* options from a waste perspective.	

NOTE

1. For group 2 pipelines partial removal option only applies to Munro MH pipelines PL2109 & PL2110 as indicated in Table 4.2.1.

Table A7.3.1: Pipeline group 2 – environmental assessment

Appendix 7.4 Pipeline group 2 - societal assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 2 PARTIAL REMOVAL[1]	OPTION 3 LEAVE *IN SITU*
Societal	**Offshore Execution**	Effect on commercial activities.	The impact of decommissioning vessel traffic on local commercial activities such as fishing would be greatest for complete removal.	The impact of decommissioning vessel traffic on local commercial activities such as fishing would probably be less than for complete removal but more than for the leave *in situ* option.	Impact of decommissioning vessel traffic on local commercial activities such as fishing would least for leave *in situ*.
		Employment.	Decommissioning activities associated with complete removal would contribute greatest to continuity of employment.	Decommissioning activities associated with complete removal would contribute greatest to continuity of employment but there would probably be little to differentiate the partial removal and leave *in situ* options.	Decommissioning activities associated with leave *in situ* would contribute the least to continuity of employment for leave *in situ*.
		Communities or impact on amenities.	Decommissioning activities associated with complete removal would contribute the most to continuity of work in ports and disposal sites.	Decommissioning activities would contribute to continuity of work in ports and disposal sites less than for complete removal and more than for leave *in situ* option.	Decommissioning activities associated with leave *in situ* would contribute the least to continuity of work in ports and disposal sites.
Societal	**Legacy**	Effect on commercial activities.	No impact as no legacy related activities would be required.	Impact of survey vessel traffic on local commercial activities such as fishing would be more than for complete removal but where applicable about the same as for the partial removal option.	
		Employment.	Should the pipeline(s) be completely removed, the opportunity for continuation of employment would be minimal.	Should the remainder of the pipeline(s) be left *in situ* the opportunity for continuation of employment would be associated with survey work and where applicable would be the same as for the leave *in situ* option. Where applicable, there would be little to choose between partial removal and leave in situ.	Should the pipeline(s) be left *in situ* the opportunity for continuation of employment would be associated with survey work and where applicable there would be very little to choose between partial removal and leave *in situ*.
		Communities or impact on amenities.	Once the pipeline(s) had been removed there would be no related opportunities for continuity of work in ports and disposal sites.	Should the remainder of the pipeline(s) be left *in situ* there would be few opportunities for continuity of work in ports and disposal sites other than associated with survey related and unlikely remedial work. Where applicable, there would be little to choose between partial removal and leave *in situ*.	Should the pipeline(s) be left *in situ* there would be few opportunities for continuity of work in ports and disposal sites other than associated with survey related and unlikely remedial work. Where applicable, there would be very little to choose between partial removal and leave *in situ*.

NOTE
1. For group 2 pipelines partial removal option only applies to Munro MH pipelines PL2109 & PL2110 as indicated in Table 4.2.1.

Table A7.4.1: Pipeline group 2 – societal assessment

Appendix 7.5 Pipelines group 2 – cost assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 2 PARTIAL REMOVAL[1]	OPTION 3 LEAVE *IN SITU*
Cost	**Offshore Execution**	n/a	The cost by difference would be an order of magnitude greater than for leave *in situ*.	~1.5km of the piggybacked pipelines PL2109 & PL2110 removed. The cost by difference would be less than half the cost for complete removal and almost 4x more than leave *in situ*.	The cost of leave *in situ* would be the least expensive of the three decommissioning options.
	Legacy	n/a	Should the pipeline(s) have been completely removed no pipeline burial surveys would be required in future.	Future burial surveys will be required. The premise is that if two successive surveys demonstrate that the pipeline remains stable no more surveys would be required. This will be the same for both the partial removal and leave *in situ* decommissioning options.	

NOTE
1. For group 2 pipelines partial removal option only applies to Munro MH pipelines PL2109 & PL2110 as indicated in Table 4.2.1;
2. The partial removal and leave *in situ* options assume that the surface laid pipeline ends have been removed although this may not have been the recommendation of this comparative assessment. This means that any difference in cost would be increased should the ends be decommissioned *in situ*;
3. The assessment assumes 1x post decommissioning survey would be required irrespective of the decommissioning options, and 3x legacy surveys would be required for any pipelines being left *in situ*;
4. Refer Table A9.6.1.

Table A7.5.1: Pipeline group 2 – cost assessment

Appendix 8 Pipeline group 3 (umbilicals) – comparative assessment tables

Appendix 8.1 Pipeline group 3 (umbilicals) – technical assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 3 LEAVE *IN SITU*
Technical	**Offshore Execution**	Risk of project failure.	Technically, complete removal of the pipelines would most likely be achievable, but complications could arise because the umbilicals are buried, either within the seabed or under deposited rock.	Technically, the umbilicals could be left *in situ*
		Technological challenge.	Technology is currently available to excavate, cut and recover, or reverse reel the umbilicals eventually to shore.	n/a
		Technical challenge.	Excavation of pipelines buried in the seabed and under deposited rock could prove problematic but achievable. 'Cut and lift' method could be used but the reverse reel method could also be used for recovery of the umbilicals.	Stable and buried umbilical(s) have been left *in situ* before so this approach would be achievable.
Technical	**Legacy**	Risk of project failure.	No umbilical surveys would be required in future.	Umbilical surveys have been undertaken in the past although sometimes there can be issues with detectability, as it depends on the amount of steel armour. However, in this instance the umbilicals have been surveyed before with no complications.
		Technological challenge.	As above.	The technology is currently available for carrying out umbilical surveys.
		Technical challenge.	As above.	In this instance there should be no technical issues associated with carrying out umbilical surveys in future.

Table 8.1.1: Pipeline Group 3 - Technical Assessment

Appendix 8.2 Pipeline group 3 (umbilicals) – safety assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 3 LEAVE *IN SITU*
Safety	**Offshore Execution**	Health & safety risk offshore project personnel.	More offshore work than leave *in situ*. Excavation of the umbilical(s) and recovery. There is experience of recovering small individual umbilicals by reverse reel. As a fall-back, the 'cut and lift' method could be used for removal although the work would be repetitive, with the number of repetitions - 80-100 sections of umbilical per km. The work would be manageable from an HSE perspective. Most of the work could be done using equipment operated remotely and most could be done without using divers. Material handling on vessel decks could be automated given the right resources and focus.	At most only the umbilical ends would be dealt with; less offshore work than for complete removal. Significantly less work and therefore a shorter duration of activities than for complete removal.
		Health & safety risk to mariners.	The risk to mariners in the short term would be aligned with the duration the activities would be undertaken in the field. Duration of vessels in the field would be longer than for leave *in situ.* Using the reverse reel method would mean that the vessel would be attached to an umbilical and could not move out of the way quickly. Using the 'cut and lift' method would also restrict the ability of a vessel to move out of the way, but for a relatively short time.	At most only the umbilical ends would be dealt with; duration of vessels in the field would be significantly shorter than for complete removal.
		Safety risk onshore project personnel.	Significantly more off-reeling, onshore cutting, lifting, and material handling associated with disposal of the umbilicals; presents an increased safety risk to personnel.	No onshore work except for that possibly associated with the pipeline ends, which may be common for both options.
Safety	**Legacy**	Health & safety risk offshore project personnel.	No umbilical surveys or remediation related activities would be required.	Umbilical surveys would be required, but this activity is considered routine with well managed risks.
		Health & safety risk to mariners.	No infrastructure left *in situ* therefore no residual snag hazards. Lower risk as potential snag hazards completely removed.	The umbilicals have a good depth of burial. No increase in snagging risk as a result of their being left *in situ*.
		Safety risk onshore project personnel.	Nothing to differentiate the options	

Table A8.2.1: Pipeline group 3 - safety assessment

Appendix 8.3 Pipeline group 3 (umbilicals) – environmental assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 3 LEAVE *IN SITU*
Environmental	**Offshore Execution**	Energy & emissions.	Energy use and resulting emissions for this option would be higher than for leave *in situ*, but no energy and emissions would be needed to create new material.	Least amount of energy used, and least emissions generated in the short term, although any gains would be offset by the energy and emissions required to create new material to replace that which would be left *in situ*.
		Seabed disturbance, area affected.	The amount of seabed disturbed would be directly related to the length of umbilical being removed. The area affected would be largest for this option.	The least area of seabed would be disturbed for the leave *in situ* decommissioning option.
		Disturbance to Protected Area (Dogger Bank SAC, 12,331km^2).	Complete removal of the shortest umbilical ~5.9km long would result in 0.059km^2, and the longest umbilical ~13.0km long would result in ~0.13km^2 of seabed within the Dogger Bank SAC being disturbed. As a proportion for this would equate to between 0.0005% and 0.00`1% of the overall area for the shortest and longest umbilical, respectively. The Dogger Bank and associated communities would be classed as highly vulnerable to the disruption and excavation required to completely remove the umbilical. The complete removal option would result in the most disruption to the Dogger Bank SAC albeit temporary.	This option would result in the least disruption to the Dogger Bank SAC although the materials being left behind would be alien to the local fauna.
		Effect on Water Column: • Liquid discharges to sea; • Liquid discharges to surface water; • Noise.	Discharges and releases to the water column are related to the duration of activities being undertaken and would therefore be greatest for the complete removal option.	Discharges and releases would be least for the leave *in situ* option, at least in the short-term.
		Waste creation and use of resources such as landfill. Recycling and replacement of materials.	This option would result in the largest mass of material being returned to shore. No material would be lost as no material would be left *in situ*.	No material would be returned to shore for recycling and so the material would be lost, and new material would be needed to replace the loss.
Environmental	**Legacy**	Energy & emissions.	No umbilical status or burial surveys required.	It can be expected that future surveys would be required.
		Seabed disturbance, area affected.	As above.	Umbilical burial surveys do not usually involve disturbance to the seabed, and it is assumed that no remedial activities would be required otherwise, so no impact.
		Disturbance to protected area (Dogger Bank SAC).	As above.	As above.
		Effect on water column: • Liquid discharges to sea; • Liquid discharges to surface water; • Noise.	As above.	It can be expected that future surveys would be required.
		Waste creation and use of resources such as landfill. Recycling and replacement of materials.	No activity required.	Assuming no umbilical remedial activities would be required as part of legacy related activities, there would be nothing to differentiate the complete removal and leave *in situ* options from a waste perspective.

Table A8.3.1: Pipeline group 3 – environmental assessment

Appendix 8.4 Pipeline group 3 (umbilicals) - societal assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 3 LEAVE *IN SITU*
Societal	**Offshore Execution**	Effect on commercial activities.	The impact of decommissioning vessel traffic on local commercial activities such as fishing would be greatest for complete removal.	Impact of decommissioning vessel traffic on local commercial activities such as fishing would least for leave *in situ*.
		Employment.	Decommissioning activities associated with complete removal would contribute greatest to continuity of employment.	Decommissioning activities associated with leave *in situ* would contribute the least to continuity of employment for leave *in situ*.
		Communities or impact on amenities.	Decommissioning activities associated with complete removal would contribute the most to continuity of work in ports and disposal sites.	Decommissioning activities associated with leave *in situ* would contribute the least to continuity of work in ports and disposal sites.
Societal	**Legacy**	Effect on commercial activities.	No impact as no legacy related activities would be required.	Impact of survey vessel traffic on local commercial activities such as fishing would be more than for complete removal but where applicable about the same as for the partial removal option.
		Employment.	Should the umbilical(s) be completely removed, the opportunity for continuation of employment would be minimal.	Should the umbilical(s) be left *in situ* the opportunity for continuation of employment would be limited to survey work.
		Communities or impact on amenities.	Once the umbilical(s) had been removed there would be no related opportunities for continuity of work in ports and disposal sites.	The umbilical(s) are sufficiently buried so it would be unlikely that any remedial work would be required.

Table A8.4.1: Pipeline group 3 – societal assessment

Appendix 8.5 Pipeline group 3 – cost assessment

CRITERIA	ASPECT	SUB-CRITERIA	OPTION 1 COMPLETE REMOVAL	OPTION 3 LEAVE *IN SITU*
Economics	**Offshore Execution**	n/a	Using the assumption that individual umbilicals could be removed using the reverse reel method, the costs would be greater than for leave *in situ*, but less than an order of magnitude greater.	The cost of leave *in situ* would be the least expensive of the two decommissioning options.
	Legacy	n/a	Should the mattresses have been completely removed no burial surveys would be required in future.	Future burial surveys will be required. The premise is that if two successive surveys demonstrate that the mattresses remain buried and stable no more surveys would be required.

NOTE

1. The leave *in situ* options assume that the surface laid umbilical ends have been removed although this may not have been the recommendation of this comparative assessment. This means that any difference in cost would be increased should the ends be decommissioned *in situ*;
2. The assessment assumes 1x post decommissioning survey would be required irrespective of the decommissioning options, and 3x legacy surveys would be required for any umbilicals being left *in situ*;
3. Refer Table A9.6.1.

Table A8.5.1: Pipeline group 3 – cost assessment

Appendix 9 Cost as a differentiator

Appendix 9.1 Overview

The following section details the qualitative comparative assessment made to distinguish the decommissioning options. Note that the figures quoted do not account for the overall costs of decommissioning the pipelines – they only account for the difference in cost once activities common to both options have been discounted.

The costs have been normalised and categorised as indicated in Table A9.1.1.

High / Intolerable & not acceptable	Medium / Tolerable non-preferred	Low/Broadly acceptable & most preferred	Low/Broadly acceptable but least preferred
More than 10x (order of magnitude) the cheapest cost	More than 2x the cheapest cost	Cheapest cost	Less than 2x more than cheapest cost

Table A9.1.1: Categories of impact – cost assessment

Appendix 9.2 Cost assessment tables – a brief explanation

Table A9.4.1. This compares costs for removing the mattresses as well as the underlying pipelines and umbilicals and includes the incremental costs of carrying out 1x post decommissioning and 3x legacy surveys sometime in future.

Table A9.5.1. The compares costs for removing mattresses vs. leaving mattresses *in situ* and includes the incremental costs of carrying out 1x post decommissioning and 3x legacy surveys sometime in future.

Table A9.6.1. The compares costs for the pipeline decommissioning options with the leave *in situ* and partial removal options assuming that the pipeline ends would be removed. The costs include 1x post-decommissioning along the full length of the pipelines but exclude 3x legacy surveys.

Table A9.7.1. The compares costs for the pipeline decommissioning options with the leave *in situ* and partial removal options assuming that the pipeline ends would be removed. The costs include 1x post-decommissioning along the full length of the pipelines and includes 3x legacy surveys.

Appendix 9.3 Assumptions

The following key assumptions have been used in the cost by difference assessment:

- Operator and contractor management and engineering costs are excluded on the basis that this cost would be incurred whichever decommissioning option would be pursued;
- Any pipelines being removed would need to be excavated but would be left to naturally backfill;
- Large diameter pipelines >10” and piggybacked pipelines would be removed using the ‘cut and lift’ method; vessel deck capacity assumed to be 750Te before a port call is required;
- Small diameter pipelines (3” & 4”) and umbilicals or parts thereof would be removed using the reverse reel method assuming that they integrity could be assured. Reel capacity of the recovery vessel is assumed to be 2.5km, maximum 2x reels;
- For removal of mattresses based on average space requirements and stacking height, a port call is taken to be required for every cargo load that exceeds 430Te;
- All activities could be achieved using remotely operated equipment guided by ROVs, no diving related activities would be required;
- All pipeline and recovery operations could be achieved using a subsea support vessel or similar, supported by the necessary equipment spreads such as ROVs, excavation tools, hydraulic shears, mattress recovery equipment, etc;
- Mobilisation and demobilisation cost of construction vessels are excluded for two reasons: The first is because mobilisation and demobilisation costs would be incurred for the overall decommissioning activity, not just for one pipeline, and the other is that for the purposes of this assessment it has been assumed that the same type of vessel – an anchor handling vessel, furnished with reels, ROV equipment, excavation equipment and hydraulic cutting spread would be used;

- Port calls have been accounted for on the basis that a vessel needs to transit to port to offload materials recovered from the seabed;
- NPT on marine operations is taken as 15%;
- No allowance has been made for the deposition of small quantities of rock on cut pipeline ends; these costs are unlikely to be significant;
- No account has been made for efficiency. For example, to an extent it might be possible to reduce the number of port calls by using a cargo barge in the field. However, any advantages of this approach would need be offset by the need for appropriate weather conditions and transit tugs;
- For surveys it has been assumed that 1x post decommissioning pipeline survey would be required for each pipeline, and 3x legacy pipeline surveys for those instances where a pipeline or part thereof would be left *in situ* following completion of decommissioning activities. The legacy survey requirement would be based on risk assessments following post-decommissioning surveys and would typically be documented in the close out report. Excluding the trunklines and mobilisation and demobilisation cost, the cost of carrying out a pipeline survey ranges between ~£25k and £102k depending on the length of pipeline;
- The costs associated with mobilisation and demobilisation of survey vessels is excluded since it is not a differentiator, and because mobilisation and demobilisation costs would be incurred for the overall survey activity, not just for one pipeline;
- It is assumed that the 'cut and lift' method would be used to remove pipelines >10" and piggybacked pipelines whereas small individual pipelines including umbilicals and parts thereof would be reeled onto a drum on the back of the anchor handling vessel;
- The costs associated with piggybacked pipeline have been combined on the basis that none or both of the piggybacked pipelines would be dealt with at the same time;
- It should be noted that no survey data are available for PL936, so the assumption meantime is that there are no exposures, as per PL935. This may change once survey data become available;
- The leave *in situ* option assumes that the surface laid umbilical ends have been removed although this may not have been the recommendation of this comparative assessment;
- Leave *in situ* costs relate to the cost of recovering the surface laid pipeline ends and mattresses on approach to the installations, pipeline tees and pigging manifold assemblies and includes the cost of 1x post decommissioning survey and 3x legacy pipeline surveys;
- Partial removal concerns removal of the surface laid pipeline ends and mattresses as well as an exposed length of pipeline and includes the cost of 1x post decommissioning survey and 3x legacy surveys;
- Complete removal costs relate to complete recovery of the pipelines to shore as well as the mattresses and includes the cost of 1x survey following completion of decommissioning.

Appendix 9.4 Pipeline ends and mattress decommissioning cost by difference

PIPELINE ID	PIGGYBACKED	GROUP ID	END REMOVAL LENGTH	NO. OF MATTRESSES	LEAVE PIPELINE ENDS *IN SITU* (£M)	REMOVAL OF PIPELINE ENDS (£M)	LEAVE PIPELINE ENDS *IN SITU* NORMALISED	REMOVAL OF PIPELINE ENDS NORMALISED
PL929 & PL930	N	1	147	15 / 62 (13)	£0.003	£0.514	0.03	5.0
PL935 & PL936	N	1	0	28 / 29 (26)	£0.004	£0.455	0.04	5.0
PL1436 & PL1437	Y	2	185	16	£0.004	£0.467	0.04	5.0
PL1922 & PL1925	Y	2	0	34	£0.008	£1,292	0.03	5.0
PL1923 & PL1926	Y	2	190	176	£0.002	£0.367	0.02	5.0
PL1924 & PL1927	Y	2	459	37	£0.008	£1.357	0.03	5.0
PL2109 & PL2110	Y	2	109	153	£0.004	£0.568	0.04	5.0
PL2430 & PLU2431	Y	2	415	50	£0.004	£0.564	0.03	5.0
PL2894 & PL2895	Y	2	282	55	£0.003	£0.341	0.04	5.0
PLU4685	N	3	184	24	£0.006	£0.074	0.41	5.0
PLU4686	N	3	150	19	£0.008	£0.223	0.19	5.0
PLU4888	N	3	317	71	£0.004	£0.548	0.03	5.0
PLU4889	N	3	432	26	£0.006	£0.257	0.12	5.0
PLU4890	N	3	196	29	£0.006	£0.284	0.11	5.0

NOTES:
1. Should mattresses be removed, the underlying pipeline and umbilicals would also need to be removed;
2. The ends of PL929 & PL930 and PL935 & PL936 are piggybacked but otherwise the pipelines lie in separate trenches; Mattresses at separation in brackets;
3. Leave *in situ* costs are for 1x post decommissioning survey and 3x legacy surveys. Note that survey costs would be incremental to the pipeline survey cost;
4. Removal of pipeline ends allows for 1x post decommissioning survey, but only the pipeline ends;
5. Reminder - the increased cost for the same length of ends being removed is due to the additional survey time required for the longer pipelines being left *in situ*;
6. Note that several concrete mattresses (~51x) associated with the CMS pipelines need to be removed anyway due to commitments in third party decommissioning programmes for Ketch [10] and Schooner [11].

Table A9.4.1: Pipeline end and mattress cost assessment (incl. legacy surveys)

Appendix 9.5 Mattress decommissioning cost by difference for installations and structures

PIPELINE ID OR STRUCTURE	No. of FA	No. of FC	No. of C	LEAVE *IN SITU* (£M)	COMPLETE REMOVAL (£M)	LEAVE *IN SITU* NORMALISED	COMPLETE REMOVAL NORMALISED
Murdoch PSNL	2	0	0	£0.003	£0.004	3.35	5.0
Hawksley EM	0	4	0	£0.003	£0.025	0.57	5.0
Murdoch K.KM	8	0	0	£0.003	£0.015	0.96	5.0
Boulton HM	11	0	0	£0.003	£0.020	0.71	5.0
Kelvin Subsea Tee Assembly	0	4	0	£0.003	£0.011	1.12	5.0
Kelvin Pigging Manifold Assembly	0	0	8	£0.003	£0.041	0.29	5.0
Katy Tee	5	0	0	£0.003	£0.026	0.46	5.0
McAdam MM	12	0	0	£0.003	£0.022	0.65	5.0
Watt QM	6	0	0	£0.003	£0.011	1.26	5.0

NOTES:

1. FA – Anchored fronded mattresses, FC – Fronded mattresses with concrete bases, C – Concrete mattresses;
2. Leave *in situ* costs include *incremental* costs for carrying out 1x post decommissioning survey and 3x legacy surveys of the mattresses left *in situ*. Ordinarily these costs would be borne as part of the pipeline surveys. However, there could be a scenario where mattress status surveys are required, but the burial status of the pipelines could be such that full pipeline surveys would no longer be required;
3. For the purposes of this assessment the leave *in situ* costs assume a nominal survey length ~200m.

Table A9.5.1: Mattress cost assessment, installations, and protection structures

Appendix 9.6 Pipeline decommissioning cost by difference (excl. legacy surveys)

PIPELINE ID	PIGGYBACKED	GROUP ID	END REMOVAL LENGTH	PARTIAL REMOVAL LENGTH	COMPLETE REMOVAL LENGTH	LEAVE *IN SITU* (£M)	PARTIAL REMOVAL (£M)	COMPLETE REMOVAL (£M)	PIPELINE END REMOVAL NORMALISED	PARTIAL REMOVAL NORMALISED	COMPLETE REMOVAL NORMALISED
PL929	N	1	147m	6,147m	179,577m	£1.17	£7.53	£165.71	0.04	0.2	5.0
PL930	N	1	-	6,147m	179,577m		£2.39	£22.06		0.5	5.0
PL935	N	1	185m	-	10,518m	£0.32		£10.77	0.1		5.0
PL936	N	1	-	-	10,022m			£1.20			5.0
PL1436 & PL1437	Y	2	190m	-	11,365m	£0.31		£9.11	0.2		5.0
PL1922 & PL1925	Y	2	459m	-	21,197m	£0.11		£18.13	0.03		5.0
PL1923 & PL1926	Y	2	109m	-	5,159m	£0.17		£4.27	0.2		5.0
PL1924 & PL1927	Y	2	415m	-	16,438m	£0.60		£13.82	0.2		5.0
PL2109 & PL2110	Y	2	282m	1,582m	4,855m	£0.29	£1.49	£4.98	0.3	1.5	5.0
PL2430 & PLU2431	Y	2	184m	-	12,494m	£0.29		£10.79	0.1		5.0
PL2894 & PL2895	Y	2	150m	-	14,042m	£0.26		£11.19	0.1		5.0
PLU4685	N	3	317m	369m	12,683m	£0.17	£0.28	£1.47	0.6	0.9	5.0
PLU4686	N	3	432m	-	8,768m	£0.16		£1.38	0.6		5.0
PLU4888	N	3	196m	-	8,400m	£0.13		£1.06	0.6		5.0
PLU4889	N	3	315m	-	8,391m	£0.14		£1.08	0.7		5.0
PLU4890	N	3	315m	-	5,543m	£0.13		£0.75	0.9		5.0

NOTES:
1. The ends of PL929 & PL930 and PL935 & PL936 are piggybacked but otherwise the pipelines lie in separate trenches;
2. Partial removal length for PL929 (6,000m) is based on 2006 survey data and will be subject to change. For the purposes of this assessment PL930 uses the same length as PL929;
3. For PL929, PL930, PL2109 and PL2110 the length quoted for ‘partial removal’ includes ~82m at the Munro MH pipeline end and the cost quoted for ‘partial removal’ includes the cost for dealing with the pipeline or umbilical ends.

Table A9.6.1: Pipeline & mattress cost assessment (excl. legacy surveys)

Appendix 9.7 Pipeline decommissioning cost by difference (incl. legacy surveys)

PIPELINE ID	PIGGYBACKED	GROUP ID	END REMOVAL LENGTH	PARTIAL REMOVAL LENGTH	COMPLETE REMOVAL LENGTH	LEAVE *IN SITU* (£M)	PARTIAL REMOVAL (£M)	COMPLETE REMOVAL (£M)	PIPELINE END REMOVAL NORMALISED	PARTIAL REMOVAL NORMALISED	COMPLETE REMOVAL NORMALISED
PL929	N	1	147m	6,147m	179,577m	£3.74	£10.10	£165.70	0.1	0.3	5.0
PL930	N	1	-	6,147m	179,577m	£3.43	£4.96	£22.35	0.8	1.1	5.0
PL935	N	1	185m	-	11,003m	£0.48		£10.77	0.2		5.0
PL936	N	1	-	-	10,692m	£0.20		£1.20	0.9		5.0
PL1436 & PL1437	Y	2	190m	-	11,365m	£0.48		£9.11	0.3		5.0
PL1922 & PL1925	Y	2	459m	-	21,197m	£0.96		£18.13	0.3		5.0
PL1923 & PL1926	Y	2	111m	-	5,159m	£0.25		£4.27	0.3		5.0
PL1924 & PL1927	Y	2	415m	-	16,438m	£0.83		£13.82	0.3		5.0
PL2109 & PL2110	Y	2	282m	1,582m	4,855m	£0.36	£1.56	£4.98	0.4	1.6	5.0
PL2430 & PLU2431	Y	2	184m	-	12,494m	£0.47		£10.79	0.2		5.0
PL2894 & PL2895	Y	2	150m	-	14,042m	£0.46		£11.19	0.2		5.0
PLU4685	N	3	317m	369m	12,683m	£0.35	£0.46	£1.47	1.2	1.6	5.0
PLU4686	N	3	432m	-	8,768m	£0.29		£1.38	1.0		5.0
PLU4888	N	3	196m	-	8,400m	£0.26		£1.06	1.2		5.0
PLU4889	N	3	315m	-	8,391m	£0.27		£1.08	1.2		5.0
PLU4890	N	3	315m	-	5,543m	£0.21		£0.75	1.4		5.0

NOTES:

1. The ends of PL929 & PL930 and PL935 & PL936 are piggybacked but otherwise the pipelines lie in separate trenches;
2. Partial removal length for PL929 (6,000m) is based on 2006 survey data and will be subject to change. For the purposes of this assessment PL930 uses the same length as PL929;
3. For PL929, PL930, PL2109 and PL2110 the length quoted for 'partial removal' includes ~82m at the Munro MH pipeline end and the cost quoted for 'partial removal' includes the cost for dealing with the pipeline or umbilical ends.

Table A9.7.1: Pipeline & mattress cost assessment (incl. legacy surveys)