ULVERSTON CANAL

Optioneering Report

Cadent Gas Limited

Report No.: 119H8FGN-8, Rev. A
Document No.: 006
Date: 2018-12-20

Project name:	Ulverston Canal	DNV GL Oil & Gas
Report title:	Optioneering Report	Integrity Solutions
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Date of issue:	2018-12-20	
Project No.:	10095348	
Organisation unit:	CSG	
Report No.:	119H8FGN-8, Rev. A	
Document No.:	006	

Applicable contract(s) governing the provision of this Report:
Cadent Gas Limited Technical Consulting Services Frame Work Agreement. Project specific contract No: 6200016598. WRF Reference No: NC1001

Objective: Provide a high-level engineering options review in relation to the gas pipeline and provide commentary on options available to ensure gas supply in the long term.

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Keywords:
Ulverston, Ulverston Canal, Barrow to Whasset, Canal Embankment, Desk Study, SPIA, Options Report, Diversion.

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
A	2018-12-20	First Draft issued to Client for comments	A Farrance	J Lucas	T F Illson

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EXECUTIVE SUMMARY

Cadent Gas Limited (Cadent) own and operate the 300mm diameter Barrow to Whasset High Pressure (HP) Gas Pipeline located within the embankment/towpath of the Ulverston Canal in Cumbria. The gas pipeline has a history of leakage due to stress corrosion cracking (SCC) and the embankment / towpath also has a history of ground settlement and instability.

This Engineering Options Report was prepared following Ground Investigations along the section of canal embankment which supports the gas pipeline and a Soil / Pipeline Interaction Analysis (SPIA), undertaken by DNV GL. The purpose of this report is to provide a high-level review on the options available to Cadent for the continued safe operation of the pipeline.

The findings of the Ground Investigation Report (GIR) are reported in DNV GL Report No. 1 19H8FGN-6 /6/ and the (SPIA) is reported in DNV GL Report No. 1-19H8FGN-7 /7/. The findings have been summarised within this Report.

The GIR found that the pipeline is in an environmentally sensitive area with low geohazard risk. The embankment shows features consistent with / indicative of slope instability. The GPR surveys suggest the pipeline has been subjected to differential ground movement in the past. The report recommended Cadent engage the canal owner to discuss the stability of the canal embankment and any monitoring necessary.

The results of the SPIA suggest that the pipeline is currently operating above the previously established axial stress limits. Considerations should be made to the stress condition of the bends where the pipeline runs underneath the canal. It is recommended that inspection and residual stress measurements are made in this area to ensure that excessive bending stresses are not apparent.

Based upon the information and assumptions stated within this report, a number of engineering solutions have been considered:

- Do Nothing – pipeline and embankment in its current state and continue to monitor.
- Pipeline remediation – inspect all welds and fit epoxy repair sleeves where required.
- Pipeline (and embankment) remediation – review stability of the embankment and undertake selective inspection and epoxy repair.
- Pipeline diversion outside of the embankment.

Each of the potential options will require differing enabling works to allow for the works to be undertaken, including surveying, investigations, permits to work and stakeholder engagement.

Limitations / constrictions for each have been considered and any residual risks to the pipeline have been outlined within Section 5.

Following development of a qualitative optioneering matrix, the preferred engineering option for remediation would be to divert the pipeline. The preferred route would be Diversion Route 3, based upon the capital costs and residual risk following construction.

1 INTRODUCTION

Cadent Gas Limited (Cadent) own and operate the 300mm diameter Barrow to Whasset High Pressure (HP) Gas Pipeline which is located within the northern shoulder of the Ulverston Canal embankment / towpath in Cumbria. The embankment's crest is bituminous-surfaced and carries a single carriageway road used by private users and pedestrians. The embankment has a long history of settlement and a series of investigations, monitoring and remedial works have been carried out by the canal owner in the past to retain the integrity of the canal structure. The pipeline also has a history of leakages linked to Stress Corrosion Cracking (SCC) and therefore any effects of future settlement pose a threat to the pipeline's integrity.

As part of a developed management and protection strategy, Cadent Gas Limited (formerly National Grid Gas Distribution) commissioned Residual Stress Measurements (RSM) at two locations on the pipeline in February 2008 [/1/] to determine the actual stresses within the pipeline. Vibrating wire strain gauges were subsequently installed to monitor the stress changes of the pipeline at the two RSM locations. As part of the review of the data, the 2008 report summarised a number of engineering options for Cadent, which included a number of routes to be considered for diversion.

Installation of the strain gauges allowed for measurements to be undertaken until 2011 and DNV GL recommended that the pipeline be diverted by 2014 [/2/]. Monitoring of the strain gauges by DNV GL was continued in 2016 [/3/], 2017 [/4/] and 2018 [/5/] at the request of Cadent.

As Cadent have planned to divert the pipeline in the long term, they require evidence to determine whether the integrity of the pipeline may be compromised before the diversion is completed, and support on the associated engineering options. Therefore in 2018, Cadent commissioned DNV GL to undertake ground investigations to determine the condition of the embankment and carry out a Soil / Pipeline Interaction Analysis (SPIA) to predict the stresses induced within pipeline from the settlement.

All information, comments and opinions given in this report are based on the information gathered from the GIR and SPIA review. However, there may be further unknown conditions at the site that have not been considered.

1.1 Scope and Objectives

The scope of this report is to advise Cadent of the options available for the continued safe operation of the pipeline. The following objectives are therefore identified:

1. Summarise the findings of the Ground Investigation Report [/6/] and SPIA report [/7/];
2. Highlight key hazards, areas of concern and restrictions regarding the embankment and pipeline following the GIR and SPIA;
3. Outline the available engineering options for mitigation including previously discussed diversion routes;
4. Provide a high-level optioneering assessment that can be utilised as part of ongoing internal pipeline management discussions and with stakeholders.

2 SITE DESCRIPTION

2.1 Site Location

Ulverston Canal in Ulverston, Cumbria runs in an easterly direction from the A590 Canal Street to Morecombe Bay. The canal has been dammed at its entrance to Morecombe Bay and is now classed as a raised reservoir.

The 300mm diameter Ulverston to Barrow High Pressure Steel Gas Pipeline runs underneath the northern slope of the canal embankment / towpath. The pipeline runs along the canal embankment from an AGI near the western end at approximate Ordinance Survey National Grid Coordinates 329651E, 478435N and travels for approximately 750m east, before turning 90° south and crossing beneath the canal (330350E, 478116N). A site location plan is included in Appendix A and chainage along the section of interest can be seen within the drawing in Appendix B. The chainages along the embankment are measured from the railway bridge.

2.2 Ulverston Canal Embankment Ownership

The canal and its embankment / towpath were previously owned by GlaxoSmithKline (GSK) until 2009, when it was gifted to POS Landcare Ltd. (a subsidiary of NPL Properties). POS Landcare Ltd. are now the legal guardians of the canal and its embankment / towpath. The relevant contact at POS Landcare Ltd. and the farmer who owns the grazing field (i.e. Rame Farm) adjacent to the north slope of the embankment is detailed in Table 2-1.

Table 2-1 Contact detail

Details	POS Landcare Ltd	Resident Farmer
Name	Roger Warren	Mark Wood
Title	Managing Director	Farmer
Company	POS Landcare Ltd (Subsidiary of NPL properties)	Rame Farm
Address	Nash Road, Trafford Park, Manchester. M17 1SX	
Tel	0161872 7930	n/a
DD Tel	0161503 0748	n/a
Mob	07933 231605	07833231605
E-mail	roger.warren@pos-landcare.com	n/a
Website	www.pos-landcare.com	n/a

2.3 Pipeline Properties

The pipeline details have been taken from the associated IGE/TD/1 affirmation report /8/ and are listed in Table 2-2.

Table 2-2 Properties for the Ulverston to Barrow Gas Pipeline

Parameters	Ulverston to Barrow Gas Pipeline
Pipeline PSR ID	1091
Commissioning Date	1975
Outside Diameter	323.9 mm
Nominal Wall Thickness	9.52 mm
Material Grade	X46
Specified Minimum Yield Strength (SMYS)	317 N/mm^2
Maximum Operating Pressure (MOP)	17.2 bar
Hydro-test Pressure	103.5 bar
T/PM/P/18 /9/ applicable	Yes

3 SUMMARY OF GROUND INVESTIGATION REPORT (GIR)

Cadent Gas Limited commissioned DNV GL to undertake site investigations to determine the condition of the embankment in which the pipeline is located. The investigation scope included a desk study review, topographical survey, Ground Penetrating Radar (GPR) survey, and ground investigation using inspection pits and Cone Penetration Testing (CPT).

DNV GL presented the site investigations and their findings in a Geotechnical Investigation Report (GIR) prepared in general accordance with BS EN 1997-1:1994 (General Rules) [/10/] requirements for a Ground Investigation Report (GIR).

The following sub-sections summarise the GIR's conclusions and recommendations. The reader is advised to consult DNV GL's GIR [/6/] if they wish to obtain in-depth detail of the site investigations and their findings.

3.1 Conclusion of GIR

The pipeline was located at depths between 1.1 and 1.4m below ground level (bgl) in the shoulder of the north slope of the embankment. Ground investigation found that the embankment comprised granular Made Ground down to 1.2m bgl, overlying low strength cohesive Made Ground, which overlays natural ground of Sands and Gravels of the Marine Raised Deposits stratum. The ground investigation also inferred groundwater levels to be between 1.1 and 2m bgl and suggested that the embankment is being infiltrated by water (possibly from leakage of the Canal) in certain locations.

The embankment was identified as being in an environmentally sensitive area that is subject to flooding. The embankment also has a history leakage and has undergone numerous remedial works and level monitoring between 1996 and 2006. The GIR identified instability of the north slope and saturation of the soils as causes of previous ground settlement on the embankment. No further significant ground movement would appear to have occurred since these remedial works had been undertaken. However, the stability of the embankment and monitoring of changes should be assessed when considering any works on the pipeline to ensure safety of the works and possibility of settlement and effect on pipeline integrity.

3.2 Recommendations of GIR

In view of the findings of the investigation, DNV GL put forward the following recommendations:

- Cadent should inform the canal owner of the risk posed to the pipeline from failure of the canal embankment slope and their duty of care to ensure the safety of the canal users.
- Remedial works to ensure the long-term stability of the canal embankment should be undertaken. Such works should include:
    - Further survey works to obtain a more detailed profile of the embankment and cross-sectional information (which will require removal of vegetation) so that better visual observations and topographical survey of subsidence features can be made.
    - Instigate a vegetation management plan which would include regular trimming of the north slope's toe and clearance of areas of excessive vegetation particularly along the north slope. Removing substantial trees will reduce the risk of embankment damage from tree up-rooting, although it should be noted that these actions might cause rebound of a locally supressed water level.

- Undertake an assessment to determine the maximum allowable vehicle weight that should be allowed on the towpath. Heavy vehicles could result in further ground instability.
- Undertake a ground investigation that will provide geotechnical parameters that can be used to carry out a stability assessment of the embankment. This would also provide the required geotechnical parameters for remedial works design.

4 SUMMARY OF SOIL / PIPELINE INTERACTION ANALYSIS (SPIA)

This section outlines the SPIA phase of the project. The full details of the inputs, assumptions, SPIA and discussions can be found within DNV GL report 119H8FGN-7 [7].

Following a review of the ground conditions and the ground movements measured on site, the response and structural behaviour of the pipeline was modelled within the proprietary software 'Ple4Win' [11].

Once the ground movements were understood, the model was used to undertake a study to review how increasing the magnitudes of ground movement altered the responsive behaviour of the pipeline and the distribution of pipeline stresses.

4.1 Methodology

The Barrow to Ulverston Pipeline has been modelled as a predominantly straight section of pipeline. The pipeline exits the above ground installation, followed by a 90° horizontal bend and then runs parallel to the embankment for approximately 750m. There is another 90° horizontal bend, followed by an over-bend to drop the pipeline elevation and an under-bend to direct the pipeline beneath the canal. The pipeline was modelled utilising the properties listed within Table 2-2.

The ground level along the pipeline length has been assumed to be constant for modelling purposes and the pipe level (i.e. cover depth) has been taken from the original strip map Drg. No. 100/154 [12].

Based upon the findings of the GIR, the pipeline is buried within made up ground that consists of low strength clay. Cohesive soil type has therefore been modelled within Ple4Win.

Two settlement cases have been considered. The first (S1) utilised the drawings provided by Cadent and were based upon the ground level changes measured in 2007 / 2008 [13], and the second settlement profile (S2) is based upon a topographical survey and a ground penetrating radar (GPR) survey (to determine the depth of cover to the pipe) undertaken as part of the current project. Even though similar, to the previous survey, settlement profile S2 is considered to be more accurate as ground and pipeline cover depths have been measured at more regular intervals (approx. every 10m). Both profiles have therefore been considered within the assessment.

Performance acceptance limits for the pipeline have been based upon the requirements for high pressure steel pipelines detailed within specification T/SP/GM/1 [14]. The assessment considers the acceptable limit for von Mises equivalent stress, which is 90% of the SMYS.

Additional performance acceptance criteria are applicable to this pipeline, as determined within the 2008 report by DNV GL [1]. These criteria limit the allowable longitudinal stresses within the pipeline, due to the presence of stress corrosion cracking and have been based upon a fracture mechanics assessment.

4.2 Results

The results of the analyses suggest that the pipeline is currently operating above the previously established axial stress limits in a number of locations. However, it should also be noted that 5 No. epoxy shells were previously installed on the pipeline during the previous weld inspection and strain gauge installation works in 2008. These epoxy shells will partially mitigate the stress issues related to the welds at these locations. However, this will not counter any stress increases at the welds where there are no shells installed; this is a possibility due to the potential number of peak stress locations.

4.3 Limitations / Assumptions

Due to limitations in the historical survey data and access constraints beneath the canal, assumptions had to be made of the displacement profile at the section of pipeline beneath the canal and the adjacent bends; it has been assumed that the bed of the canal is stable. Settlements of the pipeline have been applied in the "Z" direction (vertical) only, as no information is available on lateral pipeline movement.

When the model was created, the geometry of the pipeline at the canal crossing was not available and had been based upon engineering judgement.

This assessment has not accounted for any surface loading on the embankment. As noted during site visits, the access route is being utilised by vehicles of up to the size of a modern tractor, which can be in the region of 12 tonne mass.

4.4 Discussion

As part of the proposed diversion routing options (see drawings in Appendix C), a number of tie-in locations were proposed. Route options 2 and 3 do not utilise the section of existing pipeline within the embankment.

Route 1 proposes to utilise the existing canal crossing and divert the section of pipeline from the crossing to the AGI. One of the key hazards to consider when utilising the existing canal crossing is the condition of the existing pipeline bends, installed as part of the crossing construction. Due to limited historical survey data at this location, the settlement displacement profile and associated pipeline displacements could not be accurately determined when undertaking the SPIA.

Following subsequent provision and review of the original canal crossing drawing [/15/], it can be seen that the pipeline was constructed with a concrete surround within the canal bed and was also embedded into a sheet pile wall that was constructed along the alignment of the canal bank. It is envisaged that the purpose of the sheet pile wall was to provide a temporary works function by reducing water seepage and providing stabilisation of the canal bank during excavation and pipeline construction.

The presence of the concrete surround and embedment within the sheet piles would result in an end load restraint on the pipeline at this location, as it is unlikely that the sheet piles will have experienced the same levels of settlement as the embankment. The concrete pipeline surround within the section under the canal (which runs from the sheet pile wall to the opposite embankment) would be considered relatively stable and would also result in a stiffer pipeline cross section that would resist any bending forces.

4.5 Recommendation from SPIA

When considering the results of the SPIA, any settlement that occurs within the embankment itself along the length of the pipeline could induce stress concentrations at the location of the bends. As the condition of the bends is unknown, this would need to be determined to ensure that utilising the existing canal crossing would not compromise the safe operation of the pipeline. This would include exposing the bends and a short length of the adjacent linear section of pipeline in the embankment and undertaking residual stress measurement (RSM) on the straight / unbent section of pipe.

5 ENGINEERING OPTIONS

When considering the current stress condition of the pipeline, a number of engineering solutions have been considered and the following are discussed within this section:

- Do Nothing – pipeline and embankment in its current state and continue to monitor.
- Pipeline remediation – inspect all welds and fit epoxy repair sleeves where required.
- Pipeline and embankment remediation – review the stability of the embankment, remediate where necessary and undertake selective inspection and epoxy repair.
- Pipeline diversion outside of the embankment.

5.1 Do Nothing

Ongoing monitoring of the pipeline with no remediation is not an option that should be considered in the long term. Based on the previous weld inspections undertaken in 2008, 50% of the welds that were inspected had evidence of stress corrosion cracking (SCC). It cannot be directly inferred that this proportion would be replicated along the rest of the pipeline and could me more or less than 50%.

Although it is noted that there have not been any additional failures on this pipeline since the previous repairs, the potential for ongoing ground movements would subject the pipeline and its welds to stresses not previously encountered.

The predicted longitudinal stresses and the latest strain gauge readings taken in March 2018 [/16/] suggest that the pipeline is continues to exceed the previously established limits for longitudinal stress, which will increase with further ground movements and thus increase the potential risk of loss of containment.

5.1.1 Enabling Works Required

Minimal enabling works would be required. An update of the monitoring equipment to allow real time monitoring would be recommended as a minimum.

5.1.2 Residual Hazards

The following residual hazards would remain for this option:

- The pipeline would remain within the existing easement in the embankment, which may result in access issues in the future.
- The condition of any welds subjected to SCC is unknown and therefore their capacity to accommodate any increase in stress due to settlement cannot be relied upon.
- The pipeline will still be subjected to regular surface loading from vehicles (assessment outside the current scope of work).
- There is a lack of knowledge relating to the condition of the pipeline bends at the canal crossing, and these would need to be investigated. There is the possibility that the stresses at this location would become unacceptable due to ongoing movements, if not already.
- The condition of the pipeline underneath the canal is unknown.

5.1.3 Cost / Benefit

This option would have the lowest capital cost as there are minimal works to be undertaken. However, there would be ongoing monitoring costs and there is also the risk that compensation or remediation costs would become apparent should another leak be detected on the pipeline.

This option would have a high number of residual hazards and associated risk to manage.

5.2 Existing Pipeline Remediation

Remediation of the pipeline through the use of inspection and epoxy shelling, whether undertaken as one, or multiple work phases would increase the resilience of the pipeline. The limitations due to SCC around the welds would be mitigated, such that the membrane stress would become the limiting factor. This would allow the straight section of pipeline within the embankment to accommodate higher levels of settlement in the future.

5.2.1 Enabling Works Required

All welds would need to be inspected in order to ensure the resilience of the pipeline. Depending on the outcome of those inspections, a number of welds would require epoxy shells. As mentioned within Section 5.1, 50% of the welds that were inspected during the 2008 works had evidence of stress corrosion cracking (SCC) and required epoxy shells to be installed. This ratio may not be strictly applicable to the rest of the pipeline, as there could be more or less than 50% of the total welds in this section requiring epoxy shells.

The stress condition of the welds at the bend by the canal crossing will need to be determined to ensure that utilising the existing canal crossing would not compromise the safe operation of the pipeline. This would include inspection as above and undertaking residual stress measurement (RSM) on the adjacent straight / unbent section of pipe.

5.2.2 Limitations

This approach would be subjected to agreement with the embankment owner as well as working with local stakeholders due to access requirements on the road.

There are also a large number of welds that would require inspection and potentially repair; when considering the chainage between the railway bridge and the canal crossing, there would be *circa* 70 No. welds (minus those already done in 2008). This may result in a large lead time for epoxy shells and sub-contractors to undertake the inspections and installation. The feasibility of this option would also be dependent on the outcome of these investigations at the canal bends.

5.2.3 Residual Hazards

The following residual hazards would remain for this option:

- The pipeline would remain within the easement in the embankment, which may result in access issues in the future.
- The pipeline will still be subjected to regular surface loading from vehicles.
- A large number of excavations along the embankment to facilitate the works would raise temporary works hazards and could lead to additional instability of the embankment in the future.
- As the ongoing stability of the embankment could not be guaranteed, the unknown condition of the pipeline bends at the canal crossing would need to be investigated. Any issues at this location would be harder to mitigate.
- The condition of the pipeline underneath the canal is unknown.

5.2.4 Cost / Benefit

This option would have a higher capital costs in order to cover the excavations, inspection, manufacture and installation of the epoxy shells; although the cost of remediating all welds is less than the cost of diversion over this section length. Additional costs would be required to investigate and establish the condition of the bends at the canal crossing. This option would retain some level of operational risk as the pipeline is still within the embankment and any stresses at the canal bends would be retained.

Ongoing ground movement monitoring would be required to capture future unexpected ground movement events.

5.3 Embankment Remediation

A review of the stability of the embankment could be undertaken with remediation necessary to stabilise and minimise / prevent potential future settlement issues. This would control the increase in bending stresses in the pipeline. Ongoing monitoring of the embankment would be recommended in order to capture any unforeseen movements or events.

This option is of course dependent on any future mechanism of ground movement; such as slope instability, or washout of materials caused by canal leaks, and whether it can be controlled. There will remain a risk from third party interaction with the embankment, such as ongoing repair works to the road surface and road surface loading from vehicles. The condition of lining inside the bank of the canal is also important, in order to prevent any leaks through the embankment (as has happened previously), which could cause localised ground softening and slip movements.

5.3.1 Enabling Works Required

Agreement would need to be established with the embankment owner as well as with any governing bodies due to land sensitivity issues that may result in perimetry being required.

Cutting back of vegetation on the embankment to allow for access, which will include removal of mature trees such that further survey works can be undertaken to obtain a more detailed profile of the embankment and cross-sectional information.

Undertake detailed ground investigations to provide geotechnical parameters to be used to carry out a stability and settlement risk assessment of the embankment, as well as to feed into the design information for remedial works.

Undertake an assessment to determine the maximum allowable vehicle weight that should be allowed on the towpath during the works as trafficking by heavy vehicles may result in further ground movement.

The condition of the welds at the bend by the canal crossing will need to be determined to ensure that utilising the existing canal crossing would not compromise the safe operation of the pipeline. This would include inspection and undertaking residual stress measurement (RSM).

5.3.2 Limitations

This approach would be subjected to agreement with the embankment owner as well as working with local stakeholders due to access requirements on the road. There may be contractual issues regarding ownership of responsibility / duty of care when it comes to undertaking the physical works on site.

The feasibility of this option would also be dependent on the outcome of the investigations at the canal bends.

5.3.3 Residual Hazards

The following residual hazards would remain for this option:

- The pipeline would remain within the easement in the embankment, which may result in access issues in the future.
- The condition of any welds subjected to SCC is unknown (unless repaired) and the pipeline will still be subjected to regular surface loading from vehicles.

- There is an unknown risk around the condition of the pipeline bends at the canal crossing, and these would need to be investigated. There is the possibility that the stresses at this location would become unacceptable due to ongoing movements, if not already.
- The condition of the pipeline underneath the canal is unknown.

5.3.4 Cost / Benefit

This option requires a reasonable lead time for works to enable a slope stability analysis and before any necessary remediation works can be undertaken, in order to commence the enabling works outlined within Section 5.3.1.

The overall costs for embankment remediation would be low in comparison to a pipeline diversion. The details of the remediation and final cost would be dependent on the slope stability analyses.

Remediation of the embankment would not prevent any issues caused by third party interaction.

5.4 Pipeline Diversion

As part of a previous study commissioned by Cadent (then National Grid) and undertaken by Saith Limited, three diversion routing options were proposed. The purpose of the diversion routes is to bypass the section of existing pipeline within the northern embankment. This was outlined within the Cadent "Health and Safety File" /17/.

The general arrangement drawings for the proposed routes can be seen in Appendix C.

5.4.1 Routes

5.4.1.1 Diversion Route 1

Diversion Route 1 is shown on Drawing 0949-ULVA-ME-L-001.

This route utilises the existing canal crossing and the eastern tie in is just beyond the existing sheet pile cap by the crossing bends (see Appendix D). The pipeline is then diverted down the embankment and into the adjacent field on the northern side of the canal. The western tie in is at the AGI.

5.4.1.2 Diversion Route 2

Diversion Route 2 is shown on Drawing 0949-ULVA-ME-L-002.

This would be a completely new route that includes a new canal crossing adjacent to the AGI, followed by routing the new pipeline beneath one of the main roads towards the western boundary of the GlaxoSmithKline (GSK) complex.

Consideration must be made to the section of pipeline adjacent to the southern bank of the canal crossing, as this will need to be capped so that the southern section of pipeline can remain live in order to maintain the supply to GSK, whilst abandoning the crossing. This would possibly involve an additional set of stoppling activities between the GSK connection and the canal.

5.4.1.3 Diversion Route 3

Diversion Route 3 is shown on Drawing 0949-ULVA-ME-L-003.

This route follows the similar path as Route 1; however, a new canal crossing would be constructed and the eastern tie in would be near to the GSK offtake. This diversion removes the pipeline completely from the north embankment and also eliminates the needs for any street works.

5.4.2 Enabling Works Required

5.4.2.1 Route 1

As identified within the SPIA in Section 4.5, the pipeline at the existing canal crossing has unknown stresses within the bends. The bends would need to be investigated and RSM undertaken at this location. Due to the proposed stoppling and bypass activities in this area, the area of investigation (and potentially RSM) would need to be extended in order to cover the area of pipeline to be exposed as part of the works. This is due to the potential for bending stresses within the straight section of pipeline due to the embankment settlements.

Additional weld inspections would need to be undertaken as part of the stoppling activities as per T/PM/P/18.

The weight of proposed stoppling equipment as well as the excavations as part of the stoppling and weld inspections would require bank stabilisation works to be undertaken prior to commencing the main works, as outlined within the civils drawing in Appendix D. Access to the working area may be also be limited due to the weight of stoppling equipment and materials and the effect on the rest of the embankment, which would need to be confirmed.

Easements within the field and underneath the railway boundary would need to be agreed.

The drain underneath the railway bridge may need diverting during works due to limited space.

5.4.2.2 Route 2

Route 2 would require a more in-depth stakeholder engagement plan, due to the potential access and environmental concerns that would arise. Liaison with local highways and acquisition of permits under NRSWA to undertake the works would be required.

It should be noted that there have been recent site developments on the south side of the canal embankment at the proposed location of the crossing launch / reception pits. Due to these developments, additional landowner engagement would be required and would likely result in an additional feasibility study to be undertaken in order to find a new crossing location.

Additional investigations will be required to determine the ground conditions at the proposed locations of the "no dig" crossing, to inform the selection of the preferred method of trenchless construction.

5.4.2.3 Route 3

For Route 3 the launch and reception pit locations for the canal crossing will need to be finalised.

The location of the GSK offtake would need to be confirmed on the south side of the canal in order to ensure that the new tie-in location does not conflict with it, and that supply to GSK can be maintained.

Easements within the field and underneath the railway boundary would need to be agreed.

The drain underneath the railway bridge may need diverting during works due to limited space.

Additional investigations will be required to determine the ground conditions at the proposed locations of the "no dig" crossing, to advise on the preferred method of construction.

Thorough surveys will be required to determine the dimensions of the canal (particularly depth and bed construction / lining) as part of the "no dig" profile.

5.4.3 Limitations

5.4.3.1 Route 1

This approach would be subjected to agreement with the field and embankment owners, as well as working with local stakeholders due to access requirements on the road.

Depending on the proposed method of working, access for equipment to undertake the stoppling activities may not be possible due to weight restrictions on the embankment, as well as the surface loading limitations of the pipeline, both of which would need to be confirmed.

The feasibility of this option would also be dependent on the outcome of the investigations at the canal bends.

5.4.3.2 Route 2

As mentioned within the enabling works, the access on the south side of the canal for the canal crossing is limited and the original location for the launch / reception pit is potentially no longer viable. Therefore, an alternative crossing location will need to be found. This will prove challenging due to the level of development on the south canal bank.

Construction of the pipeline within the road may also be difficult due to the access requirements of local population and businesses.

Testing of the newly completed section of pipeline needs to be considered. As per Section 8.2 of the Mechanical Calculations as part of the Cadent feasibility study [/18/], an exclusion zone of 100m is required during hydrotesting. Due to the proximity of normally occupied buildings, this may not be viable and an alternative method of testing may need to be considered.

Supply to the GSK compound will need to be maintained. The offtake for the site is situated near to the south side of the canal. Therefore, an additional stoppling exercise will need to be undertaken in order to maintain the supply.

5.4.3.3 Route 3

The positions of the launch and reception pit locations for the canal crossing will need to be finalised. Due to the possibility of flooding in the field to the north, these works would have to occur within the summer months.

5.4.4 Residual Hazards

5.4.4.1 Route 1

The following residual hazards should be considered for Route 1:

- The pipeline would remain within the easement in the embankment, which may result in access issues in the future.
- The pipeline will still be subjected to regular surface loading from vehicles when in the embankment.
- The condition of the pipeline underneath the canal is unknown.
- P/18 and SCC considerations during stoppling.

5.4.4.2 Route 2

The following residual hazards should be considered for Route 2:

- The new pipeline route would be underneath a main road, and as such will have a higher risk from third party interaction.
- Higher risk profile due to proximity to normally occupied buildings.
- P/18 and SCC considerations during stoppling.

5.4.4.3 Route 3

The following residual hazards should be considered for Route 3:

- Open cut excavation within the field will need to be offset from the embankment and associated back drain to prevent the excavation from having a detrimental effect on the embankment stability.
- High water table may be present, requiring appropriate temporary works measures.
- P/18 and SCC considerations during stoppling.

5.4.5 Cost / Benefit

5.4.5.1 Route 1

Of the three route options, Route 1 potentially has the lowest capital costs as no new canal crossings will need to be installed as part of the diversion. There may be additional costs relating to excavation, inspection of the section by the canal crossing, manufacture and installation of the epoxy shells (if required). This option would retain some level of operational risk as the pipeline is still within part of the embankment and any stresses at the canal bends would be retained.

5.4.5.2 Route 2

Route 2 is most likely to have the highest capital costs of any of the engineering options, due to the requirement of a new canal crossing and the diversion routing beneath a key road. In addition to the construction costs, there is the risk that additional compensation costs may be incurred due to the above works. Future access to the pipeline, although undertaken under NRSWA, would cause interference and may be a factor with stakeholders.

This route would require an additional stoppling exercise that would not be required within Route 1 or 3, due to the GSK feed south of the canal. The stoppling exercise would be required to decommission the canal crossing and section of pipeline within the embankment, whilst keeping the GSK feed operational.

This route does however, remove the requirements of the embankment and the existing canal crossing and as such remove this hazard. This is of course offset by the increased risk from third party interactions within the road under which the pipeline would be routed.

5.4.5.3 Route 3

The costs for Route 3 are anticipated to be more than Route 1 – due to additional canal crossing construction, but less than Route 2 – as the diversion distance is shorter as well as any secondary costs. However, Route 3 would not require the use of any section of the existing embankment or canal crossing and as such any unknowns associated with SCC in these areas would be mitigated.

This route also has the advantage that it would not be constructed within a road and access would be easier to manage as maintenance would not be subject to NRSWA and can be undertaken within the field (and not requiring works within the embankment).

5.5 Optioneering Matrix

A high-level optioneering matrix has been developed for the above engineering options, taking into consideration the outcomes from the current GIR and SPIA reports. This matrix has been developed using assumptions based upon engineering judgement and is considered a qualitative assessment only.

Within the matrix, a number of factors have been considered to which their importance is weighted. The weighting is from 1 - being considered least important, to 5 – being considered important / deciding factor. The factors considered for each option are:

- Technical - how well does the option resolve the issue of existing and future stress in the pipe;
- Constructability - how easy or simple is the option to build (including considerations relating to legal / easements);
- Maintenance - how much maintenance or ongoing monitoring / remedial works will be required following implementation of the option;
- Health and Safety - what construction hazards will be induced by the design;
- Sustainability - use of materials / efficiency of design;
- Cost – considers the perceived (qualitative) construction and material costs;
- Residual Risk - what hazards cannot be eliminated by the design and what hazards are induced by implementing that option.

For each option, a ranking is assumed against each of the factors, the ranking following the same format as above: 1 – being considered least applicable / low value, to 5 – being considered most applicable / highest benefit.

For each of the options, the factor weighting is multiplied by the assumed ranking to give an overall value. The sum of the overall values for each option are then compared in order to provide an overall order ranking for each option. This is shown within the table below.

Table 5-1 Qualitative Optioneering Decision Matrix

		Do Nothing		**Pipe Remediation**		**Embankment Remediation**		**Route 1**		**Route 2**		**Route 3**	
Factor	**Weight**	R	W	R	W	R	W	R	W	R	W	R	W
Technical	5	1	5	3	15	3	15	4	20	5	25	5	25
Constructability	3	5	15	3	9	3	9	3	9	2	6	3	9
Maintenance	5	1	5	3	15	4	20	4	20	4	20	4	20
HSW	5	4	20	3	15	3	15	2	10	1	5	2	10
Sustainability	2	4	8	3	6	4	8	3	6	2	4	2	4
Cost	3	4	12	4	12	4	12	3	9	1	3	2	6
Residual	5	1	5	3	15	3	15	3	15	3	15	5	25
	Overall Value		70		87		94		89		78		99
	Order Ranking		**6**		**4**		**2**		**3**		**5**		**1**

R = Rank

W = Weighting

5.5.1 Preferred Option

Based upon the optioneering matrix and the discussions within the engineering options, undertaking a diversion is still considered the most appropriate method for reducing operational risk to the pipeline (as per the previous assessment undertaken in 2008 [/1/]).

The matrix suggests that the embankment option is a close second. This is partly due to the perceived costs associated with the works required (such as repair of affected welds and the civils works to stabilise the bank), compared to those of Route 3 (stoppling, "no dig" canal crossing installation, open cut costs).

However, the residual risks of the embankment option are considered higher than for Route 3 as the pipeline will remain in the current stress state, which also relies on the condition of the bends at the canal crossing and the condition of the pipework underneath the canal. A new diversion would substitute this section and therefore remove the risk associated with these existing stresses.

5.5.2 Optimisation

The decision matrix can be updated should updated projected costs be available for the options above. However, it is considered that the ongoing resilience of the pipeline is the overriding factor.

6 IMMEDIATE ACTIONS TO MANAGE RESIDUAL RISK

Considering the limitations outlined within the options in Section 5 and the current hazards associated with the existing pipeline, a number of immediate (<12 months) actions are recommended in order to facilitate future decision making and to further understand the current pipeline condition. These are summarised within this section.

6.1 Surveying and Ground Movement Monitoring

In order to manage the potential ongoing risk of the embankment and pipeline, monitoring of the ground and pipeline movement should continue. Initially, Cadent should instigate a quarterly monitoring regime utilising the benchmarking and reference points incorporated into the recent survey. This would make it easier to evaluate the rate and magnitude of any potential settlement over a 12-month period. This would confirm any seasonal changes as well as capture any external factors such as road repairs, should they occur.

Following the initial 12 months, annual surveys can be undertaken to capture any unexpected events, up until any proposed pipeline remediation works are undertaken. This can include inspection of the canal wall, towpath, embankment and back drains by a geotechnical specialist to identify any new potential stability issues.

As part of the movement monitoring, in addition to the ground level above the pipeline, the pipeline depths should be measured. This will capture any corresponding pipeline displacements.

Additional monitoring markers should be placed on the cast concrete pile cap at the location of the canal crossing. This should be stable and therefore the levels should be the same for each survey. A schedule is provided in Appendix E.

6.2 Strain Gauge Monitoring

The vibrating wire strain gauges (VWSG) should continue to be monitored and should be undertaken at the same time at the ground movement monitoring. After the initial 12 months (as per the movement monitoring), the frequency of readings should continue to be quarterly, providing the VWSG data does not indicate any detrimental trends.

6.3 Investigation of Canal Bends

When considering the geometry of the pipeline at the canal crossing, the displacement profile of the pipeline due to settlement of the embankment could induce stress concentrations at the location of the bends.

As mentioned previously, the condition of the bends is unknown and would need to be determined to ensure that their current condition is not at risk. In addition, the condition of the bends or pipework adjacent to the bends would inform as to whether the existing canal crossing can be utilised whilst not compromising the safe operation of the pipeline.

In order to determine the condition of the bends, residual stress measurements (RSM) need to be undertaken adjacent to the bends at the canal crossing. RSM is to be undertaken in accordance with T/SP/GM/8 [/19/]. The crown of the pipeline will need to be exposed to identify the bend location, so that the RSM can be positioned.

It is proposed that the RSM be undertaken at 2 No. positions along the pipeline, with each position having 3 No. RSM taken at 0° (crown of the pipe), 120° and 240° positions around the pipe circumference. This will allow for calculation of the bending, axial and total stress state of the pipeline.

The first position of the RSM should be located approximately 0.5m from the end of the side bend, in the direction of the embankment in a westward direction, to ensure avoiding any girth welds that may be present (the presence of a girth weld depending on whether the bend is a forged bend or a cold-formed bend). The second position of the RSM should be 2m from the bend, again noting to avoid any girth weld that may be present.

Whilst undertaking RSM, as the pipeline is exposed it is recommended that non-destructive examination (NDE) be undertaken on the girth welds to confirm their condition and to identify whether stress corrosion cracking is present. It is recommended that the girth welds either side of the side bend are also inspected.

7 CONCLUSIONS

Based upon the information and assumptions stated within this report, the following conclusions can be drawn:

1. The pipeline is subjected to longitudinal / axial stress due to the current settlement profile of the embankment. Due to the presence of historical stress corrosion cracking (SCC) in the pipeline caused by Towns Gas, these stresses exceed previously defined acceptable limits. These limits were determined by a fracture mechanics assessment on the SCC defects, outlined within the 2008 report by DNV GL [/1/].
2. Ongoing stability of the embankment cannot currently be assumed in the long term, and as such a form of remediation and / or monitoring / inspections should be undertaken.
3. Additional considerations and limitations regarding existing pipe stresses around the canal crossing and the condition of the pipeline underneath the canal must be accounted for within any future works.
4. Do nothing / continuation of monitoring only is not an option that should be considered long term.
5. A range of engineering options can be applied to mitigate the risk to the pipeline, which include in-situ remediation of the pipeline or embankment, or construction of a pipeline diversion.
6. Based upon a qualitative engineering options matrix and considering residual hazards for each engineering option, Diversion Route Option 3 would be the preferred approach to ensuring the long-term operability of the pipeline.

8 RECOMMENDATIONS

Based upon the information and discussions within this report, the following recommendations are provided:

1. In order to support any future diversion, the bends within the embankment at the canal crossing should be investigated to ensure they are not subject to / withstanding excessive stresses as per Section 6.3.
2. Ground movement monitoring and strain gauge measurements should continue until proposed remediation works are undertaken.
3. Additional ground investigations will be required to inform on preferred methods of construction for any new canal crossings.
4. Based upon the long-term operability of the pipeline and the residual hazards associated with each diversion route, Route 3 is recommended as the preferred routing option.

9 REFERENCES

/1/ Report No. 8189, "Investigation of the settlement of Ulverston Canal embankment on the integrity of the 300mm Barrow to Whasset pipeline." Advantica, 10th Nov 2008.

/2/ Technical Note No. 11507, "The 300mm Barrow to Whasset pipeline. Summary of analysis and results of Ulverston canal strain gauges." GL Noble Denton, 18th July 2011.

/3/ Technical Report 111AD0QV-1, "Ulverston-Barrow Pipeline, Ulverston Canal Summary of Strain Gauge Monitoring", DNV GL, 16/12/2016.

/4/ Document No. 1130U1T9-1, "Ulverston to Barrow HP Pipeline. Strain Measurement Summary." Rev A., DNV GL, 1st Sept 2017.

/5/ Document No. 118HYXV2-7, "Ulverston to Barrow HP Pipeline. Strain Measurement Summary." Rev A., DNV GL, 30th March 2018.

/6/ Document No. 119H8FGN-6, "Ulverston Canal, Geotechnical Investigation Report." Rev B., DNV GL, December 2018.

/7/ Document No. 119H8FGN-7, "Ulverston Canal, Soil / Pipeline Interaction Analysis." Rev B., DNV GL, December 2018.

/8/ Report No. 16538, "IGE/TD/1 Report, Ulverston – Barrow Pipeline (1091) including: Glaxo Supply (1084)". Rev 1., DNV GL, 31st December 2015.

/9/ T/PM/P/18, "Management Procedure for: Working on pipelines Containing Defective Girth Welds or Girth Welds of Unknown Quality." National Grid, April 2013.

/10/ BS EN 1997-1:2004, "Eurocode 7: Geotechnical design. Part 1: General rules." British Standards Institute (BSI).

/11/ Ple4Win v4.5.0, ©2018 Expert Design Systems, Geestbrugweg 44, 2281 CM Rijswijk, The Netherlands.

/12/ Drawing No. 100/154, "12 ¾ O.D Steel Pipeline Barrow / Whasset Record Map." British Gas Corporation North West Region, 30th March 1973, Amended 1993.

/13/ Drawing No. 53074, "Longitudinal Section Along Pipeline Adjacent to Ulverston Canal Comparing Existing with Original Levels." National Grid, 14th January 2008.

/14/ T/SP/GM/1, "Specification for: The Protection of Pipelines from Ground Movement and External Loading. External Loading on Steel Pipelines and Buried Piping at Installations." National Grid, June 2014.

/15/ Drawing No. 100/2C, "12 ¾ O.D Pipeline, Proposed Crossing of (Disused) Canal @ Ulverston." British Gas Corporation North West Region, 19th March 1973.

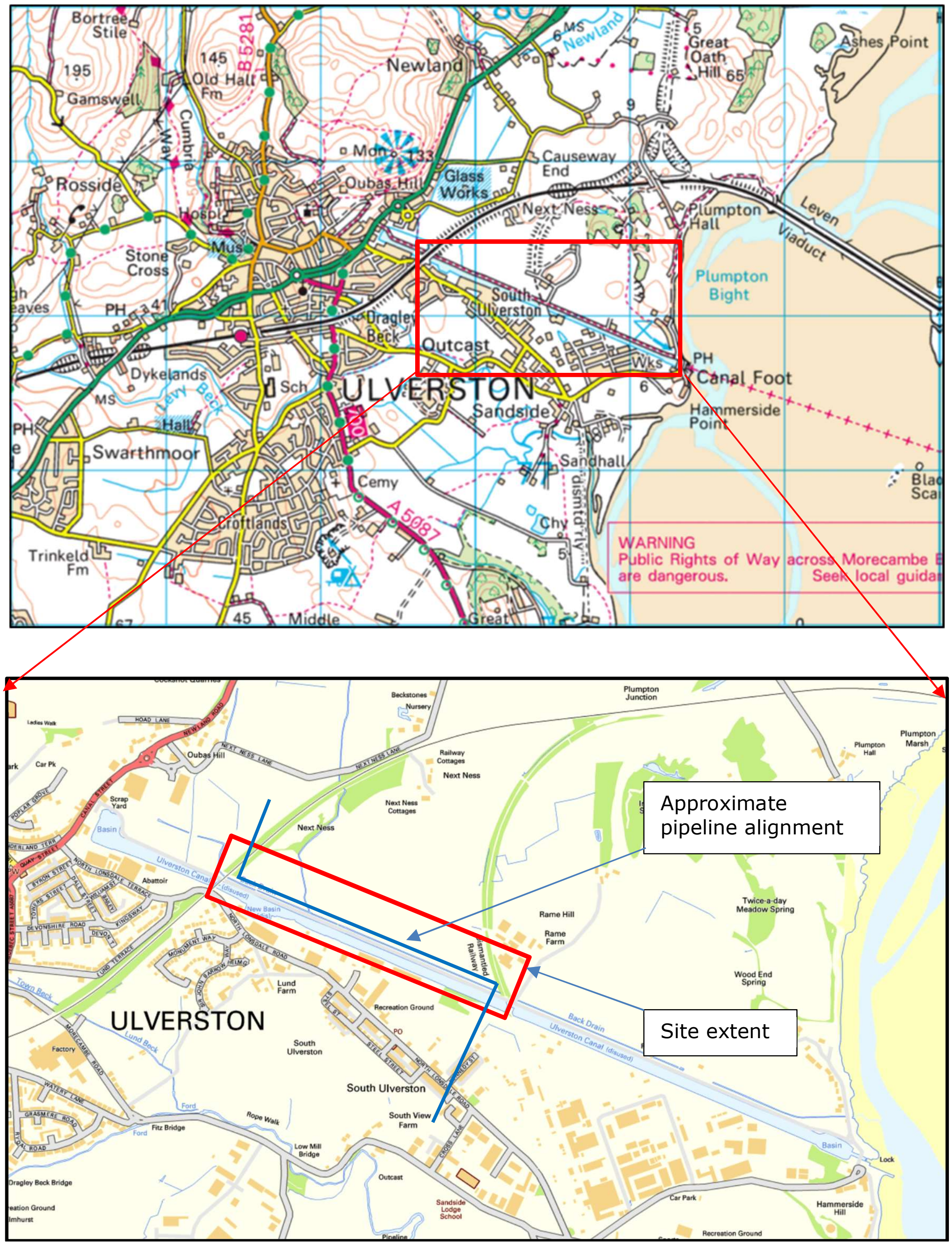
/16/ Document No. 118HYXV2-7, "Ulverston to Barrow HP Pipeline. Strain Measurement Summary." Rev A., DNV GL, 30th March 2018.

/17/ Document Ref. 0949/ULVE/H001, "Ulverston to Barrow Pipeline Diversion, IGEM/TD/1 Pipeline Assessment, Project No. 0949." Rev 0., Cadent (then National Grid).

/18/ Document Ref. 0949-ULVE-ME-CLC-001, "Feasibility Study – Mechanical Calculations, Ulverston to Barrow Pipeline Diversion (PSR ID 1091)." Rev 0., Saith Limited, 2nd September 2016.

/19/ T/SP/GM/8, "Specification for: Monitoring and Measurement of the Effects of External Loads on Pipelines." National Grid, October 2005.

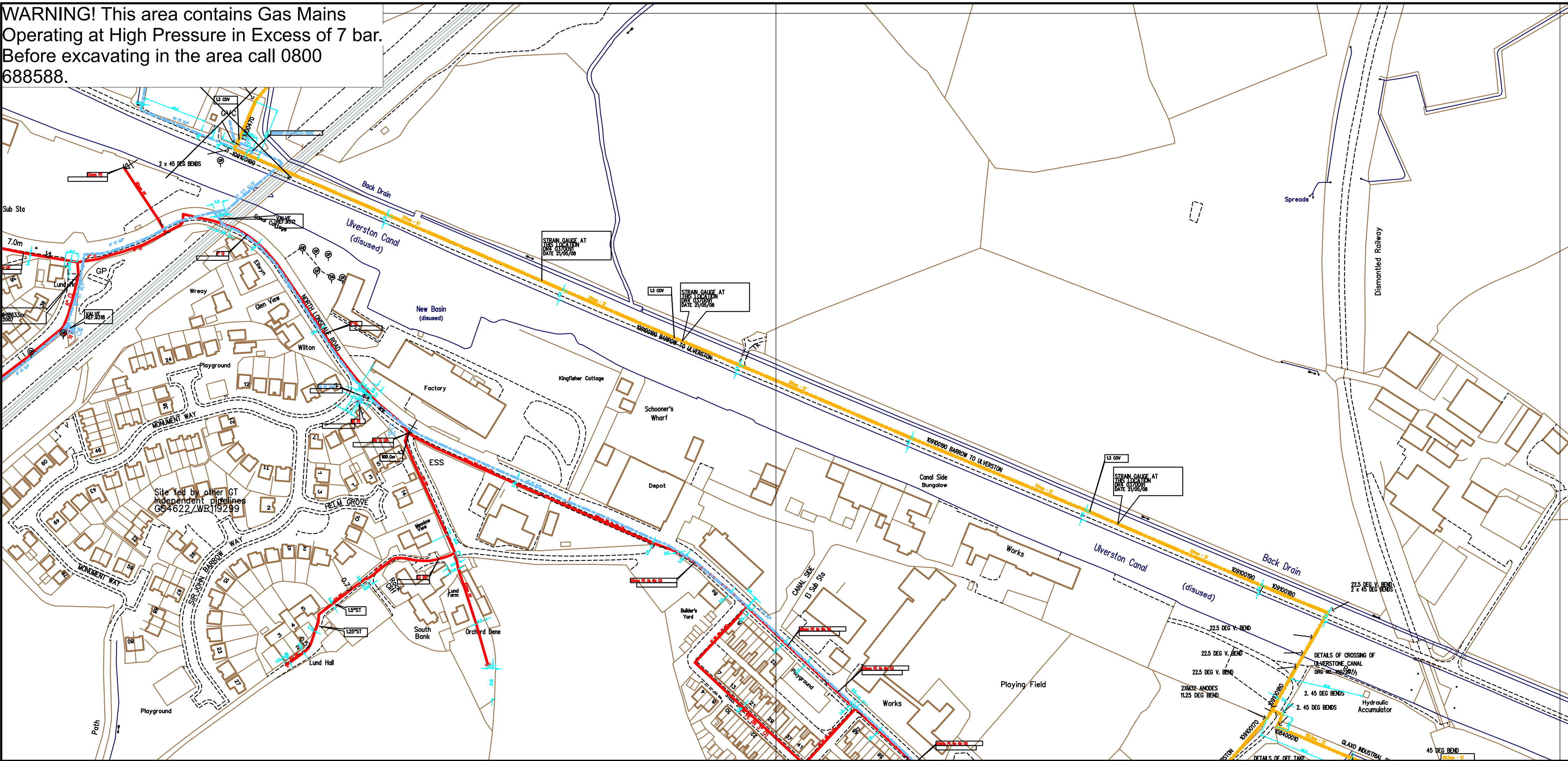
APPENDIX A
Site Location and Asset Maps



Background Mapping information has been reproduced from the Ordnance Survey map by permission of Ordnance Survey on behalf of The Controller of Her Majesty's Stationery Office. © Crown Copyright Ordnance Survey. National Grid Electricity - 100024241. National Grid Gas -100024886

Figure A 1: Site Location Plan

WARNING! This area contains Gas Mains Operating at High Pressure in Excess of 7 bar. Before excavating in the area call 0800 688588.



SCALE: Not to scale
USER ID: ADAFAR
DATE: 05/11/2018
EXTRACT DATE: 13/06/2018
MAP REF: SD3078
CENTRE: 330006, 478265

Mains type	
LP MAINS	
MP MAINS	
IP MAINS	
LHP MAINS	

Some examples of Plant Items:

Valve | Depth of Cover | Syphon | Diameter Change | Material Change | Out of Standard Service

This plan shows those pipes owned by Cadent Gas Ltd in their role as a Licensed Gas Transporter (GT). Gas pipes owned by other GTs, or otherwise privately owned, may be present in this area. Information with regard to such pipes should be obtained from the relevant owners. The information shown on this plan is given without warranty, the accuracy thereof cannot be guaranteed. Service pipes, valves, syphons, stub connections, etc. are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Cadent Gas Ltd or their agents, servants or contractors for any error or omission. Safe digging practices, in accordance with HS(G)47, must be used to verify and establish the actual position of mains, pipes, services and other apparatus on site before any mechanical plant is used. It is your responsibility to ensure that this information is provided to all persons (either direct labour or contractors) working for you on or near gas apparatus. The information included on this plan should not be referred to beyond a period of 28 days from the date of issue. Further information on all DR4s can be determined by calling the DR4 hotline on 01455 892426 (9am-5pm) A DR4 is where a potential error has been identified within the asset record and a process is currently underway to investigate and resolve the error as appropriate.

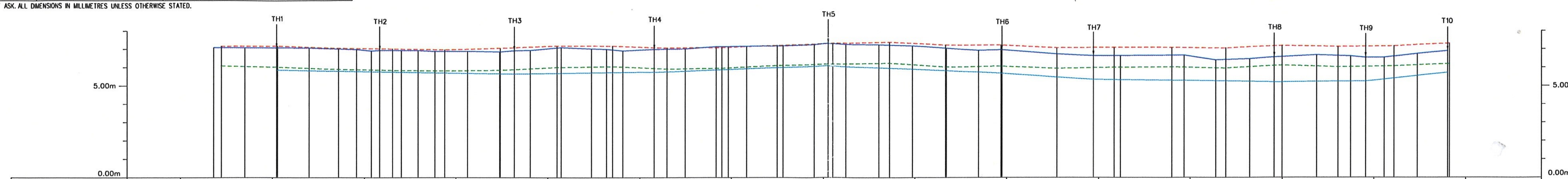
MAPS Viewer Version 5.8.0.1

Local Machine

APPENDIX B
Drawing 53074: 2008 Chainage and Updated Pipeline Levels

Drg No: | Site: | Title:

DO NOT SCALE. IF IN DOUBT ASK. ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED.



CHAINAGE FROM BRIDGE (METRES): 0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700

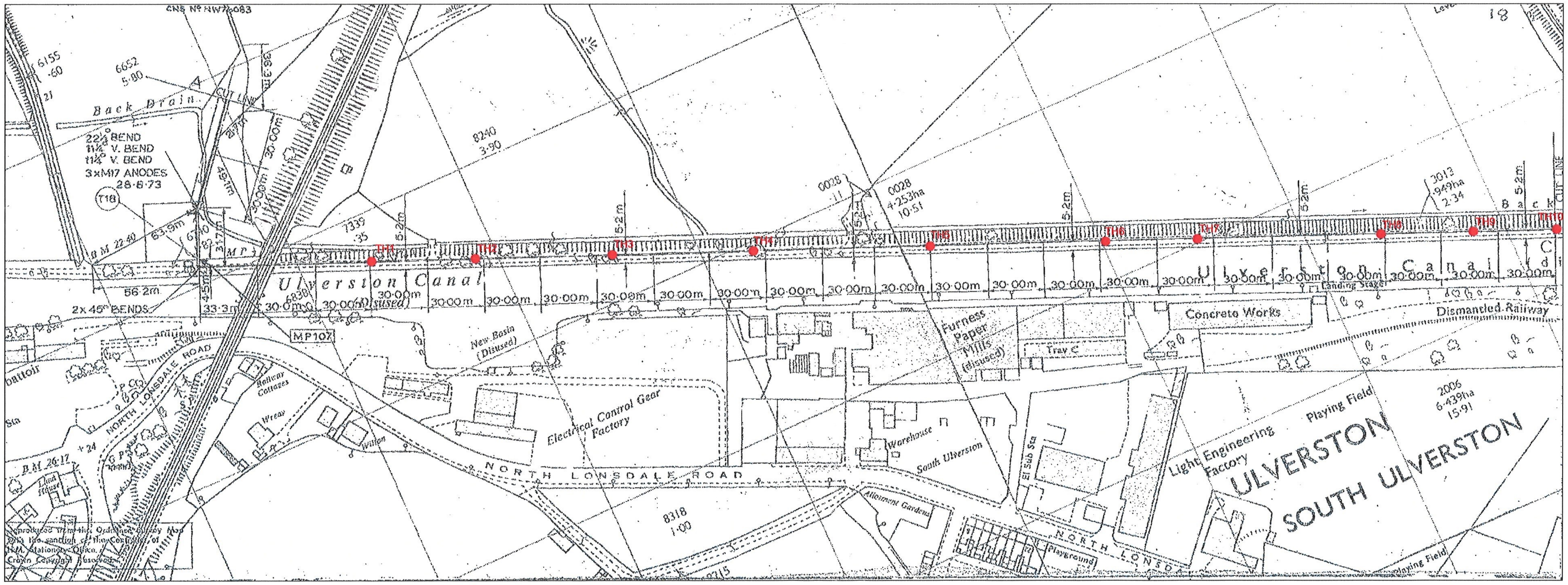
Trial hole	GROUND LEVEL DIFFERENCE (METRES)	PIPE LEVEL DIFFERENCE (METRES)	CURRENT PIPE LEVEL (TOP) (METRES A.O.D.)
TH1	-0.11	-0.16	5.87
TH2	-0.10	-0.10	5.75
TH3	-0.17	-0.24	5.63
TH4	-0.10	-0.20	5.74
TH5	-0.01	-0.10	6.09
TH6	-0.27	-0.38	5.69
TH7	-0.46	-0.65	5.35
TH8	-0.62	-0.89	5.21
TH9	-0.62	-0.80	5.25
T10	-0.42	-0.47	5.71

ORIGINAL GROUND LEVEL (METRES A.O.D.)	ORIGINAL PIPE LEVEL (TOP) (METRES A.O.D)
7.18	6.09
7.20	6.03
7.07	5.90
7.02	5.83
6.98	5.81
7.06	5.84
7.18	5.99
7.17	6.03
7.09	5.92
7.10	5.96
7.22	6.10
7.34	[illegible]
7.40	6.23
7.24	6.02
7.24	6.07
7.11	5.97
7.13	6.01
7.12	6.03
7.07	5.95
7.22	6.13
7.16	6.03
7.20	6.08
7.33	6.19

CURRENT GROUND LEVEL (METRES A.O.D.)
7.11
7.09
7.09
7.08
6.99
6.90
6.93
6.93
6.93
6.88
6.89
6.85
6.92
6.94
7.08
7.01
6.98
6.90
7.01
7.02
7.13
7.14
7.16
7.19
7.26
7.32
7.28
7.25
7.18
7.06
6.95
6.97
6.76
6.66
6.66
6.68
6.41
6.46
6.58
6.69
6.63
6.56
6.56
6.75
6.91

LONGITUDINAL SECTION ALONG PIPELINE FROM BRIDGE TO TH 10

HORIZONTAL SCALE 1:1250, VERTICAL SCALE1:125



EXTRACT FROM STRIP MAP NO 100/154

FOR INFORMATION ONLY

UNCONTROLLED WHEN PRINTED

NOTES:

1. ALL LEVELS RELATIVE TO OSBM (VALUE) 6.82M LOCATED APPROX. 40M WEST OF ULVERSTON AGI.

Rev	Rev Ref	Date	Drn by	Chk by	Apr by
Description					

nationalgrid

NATIONAL GRID PLC
UK DISTRIBUTION - NETWORK STRATEGY
BLOCK 4 - AREA 8
BRICK KILN STREET
HINCKLEY
LEICESTER
LE10 ONE
TEL: (01455) 251111

A1

Drawn By	J.R.H.	14/1/08
CAD Check by		
ENG Check By		
Approved By		
Scale (@ A1)	1:1250	

Site: BARROW-WHASSET 12" HP GAS PIPELINE

Title: LONGDITUDINAL SECTION ALONG PIPELINE ADJACENT TO ULVERSTON CANAL COMPARING EXISTING WITH ORIGINAL LEVELS

Drg No: 53074

APPENDIX C
Conceptual Diversion Route Options

DO NOT SCALE. IF IN DOUBT ASK.

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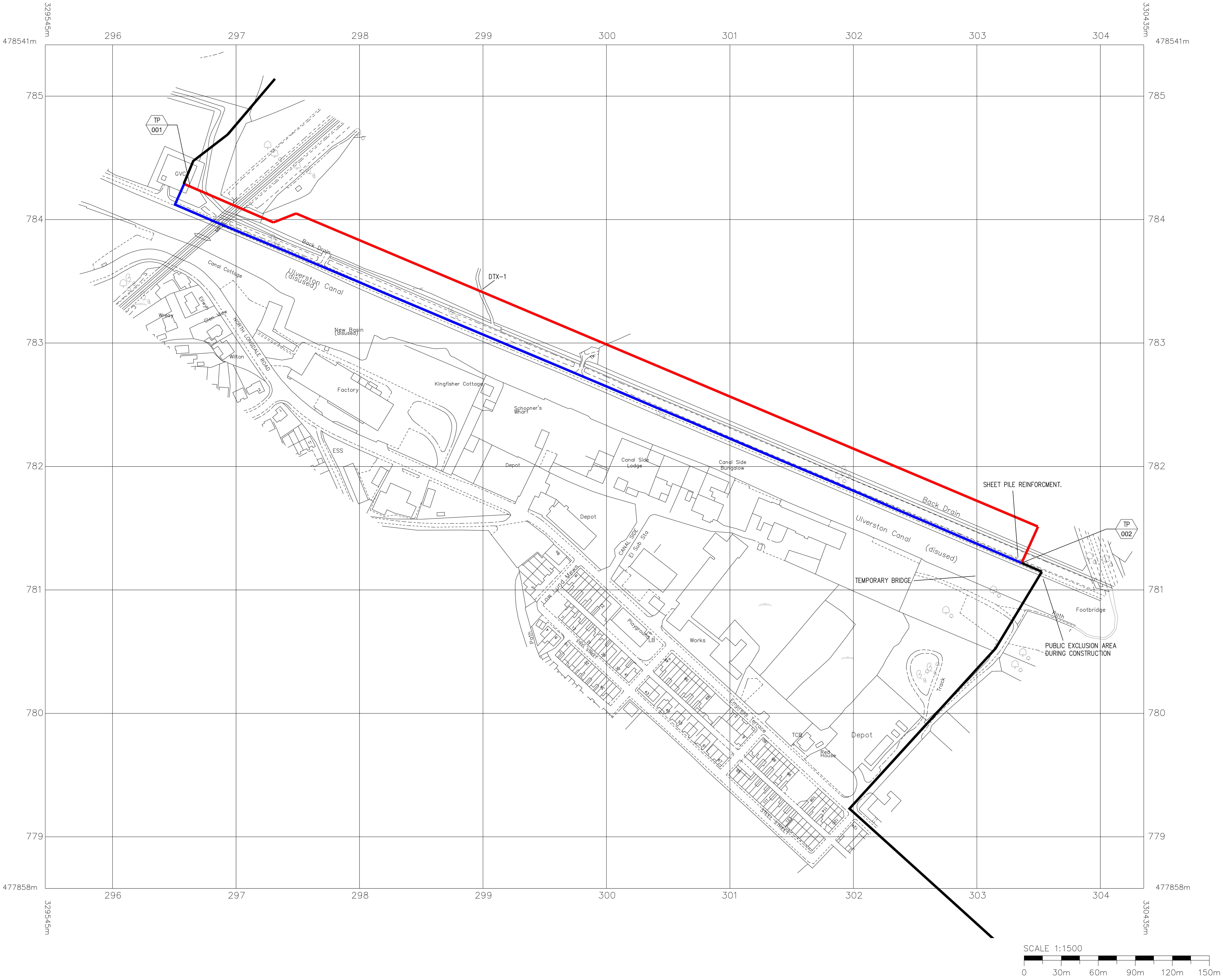


KEY.

EXISTING PIPELINE

PROPOSED NEW ROUTE

REV	DESCRIPTION	DRN	CHK	APP	DATE
1	ISSUED FOR CDS	NJ	MR	TB	14.10.16

CLIENT

National Grid
Warwick Technology Park
Gallows Hill
Warwick
CV34 6DA

A1

nationalgrid

SAITH LIMITED

Tel: 01425 480286 www.saithlimited.com

PROJECT

ULVERSTON DIVERSION

TITLE

ULVERSTON DIVERSION
GENERAL ARRANGEMENT (OPTION 1)

ISSUE

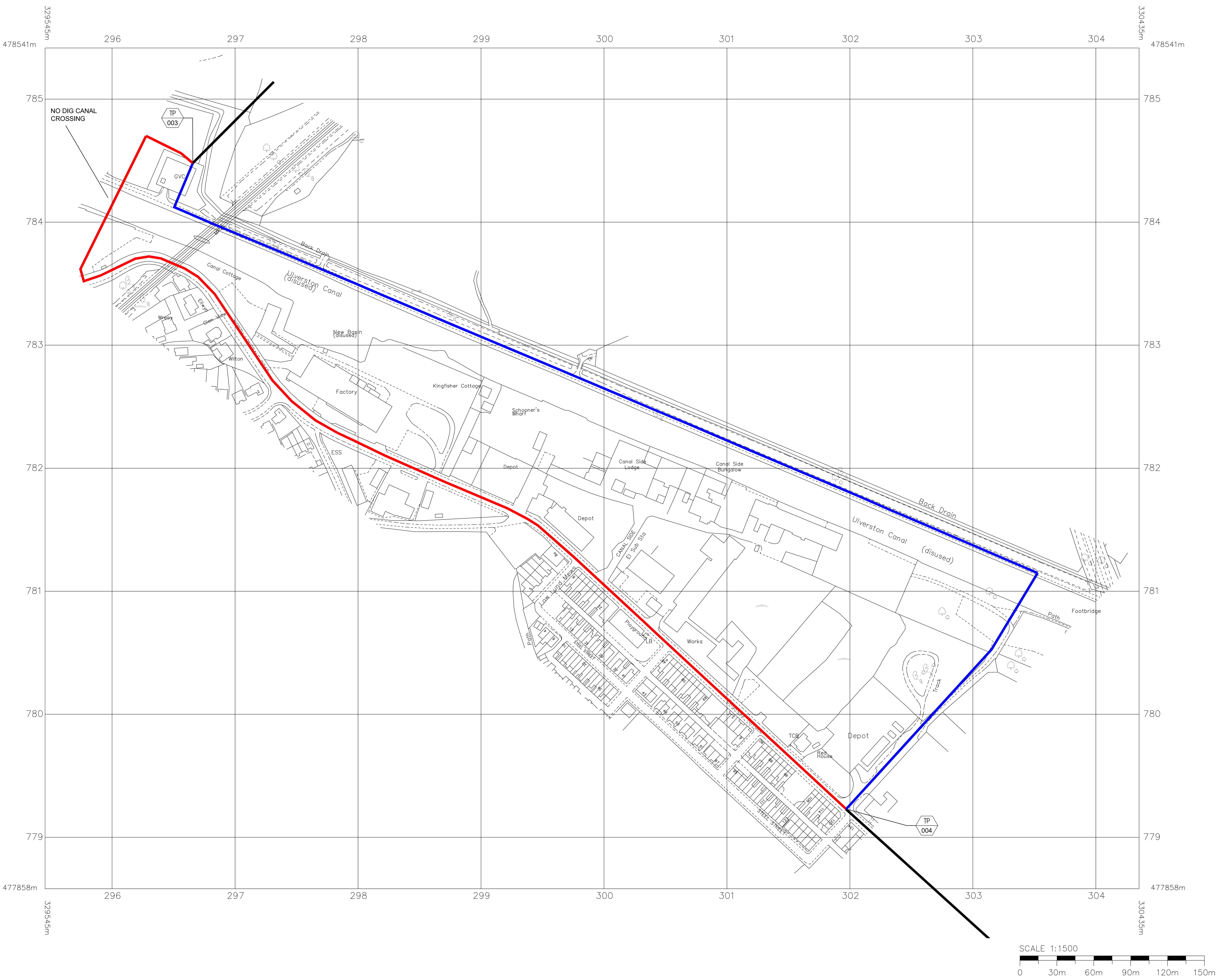
CDS ISSUE

DRAWN	CHECKED	APPROVED
NJ	MR	MR
SCALE	ORIG SIZE	DATE
1:1500	A1	30.09.16

EXTERNAL DRAWING NO.

INTERNAL DRAWING NO.	REVISION
0949-ULVE-ME-L-001	1

DO NOT SCALE. IF IN DOUBT ASK.



KEY.

EXISTING PIPELINE

PROPOSED NEW ROUTE

REV	DESCRIPTION	DRN	CHK	APP	DATE
1	ISSUED FOR CDS	NJ	MR	TB	14.10.16

CLIENT

National Grid
Warwick Technology Park
Gallows Hill
Warwick
CV34 6DA

nationalgrid

SAITH LIMITED

Tel: 01425 480286 www.saithlimited.com

PROJECT

ULVERSTON DIVERSION

TITLE

ULVERSTON DIVERSION
GENERAL ARRANGEMENT (OPTION 2)

ISSUE

CDS ISSUE

DRAWN	CHECKED	APPROVED
NJ	MR	MR

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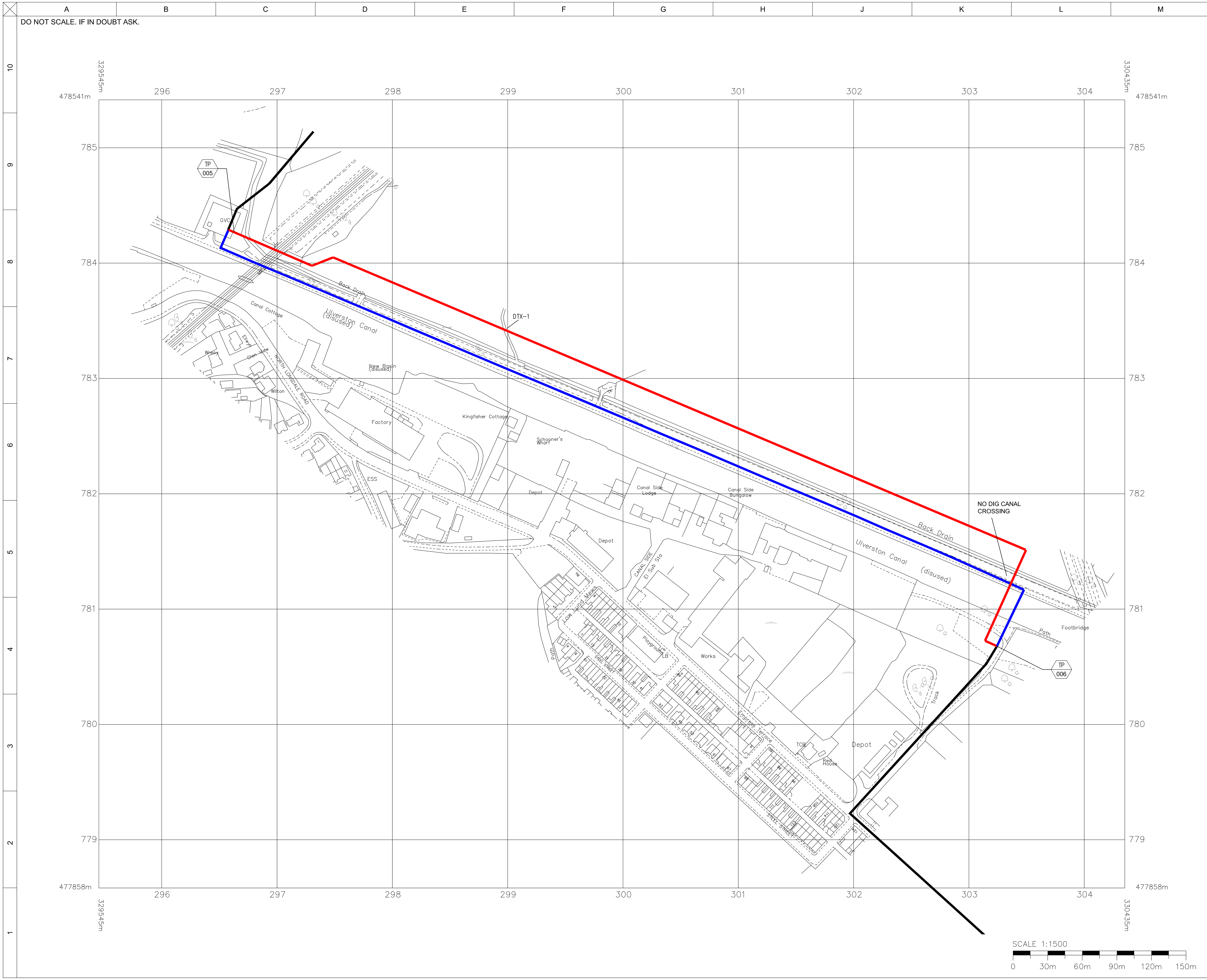
INTERNAL DRAWING NO.	REVISION
0949-ULVE-ME-L-002	1

DO NOT SCALE. IF IN DOUBT ASK.



KEY.

- EXISTING PIPELINE (blue)
- PROPOSED NEW ROUTE (red)

REV	DESCRIPTION	DRN	CHK	APP	DATE
1	ISSUED FOR CDS	NJ	MR	TB	14.10.16

CLIENT

National Grid
Warwick Technology Park
Gallows Hill
Warwick
CV34 6DA

A1 nationalgrid

SAITH LIMITED
Tel: 01425 480286 www.saithlimited.com

PROJECT
ULVERSTON DIVERSION

TITLE
ULVERSTON DIVERSION
GENERAL ARRANGEMENT (OPTION 3)

ISSUE
CDS ISSUE

DRAWN	CHECKED	APPROVED
NJ	MR	MR

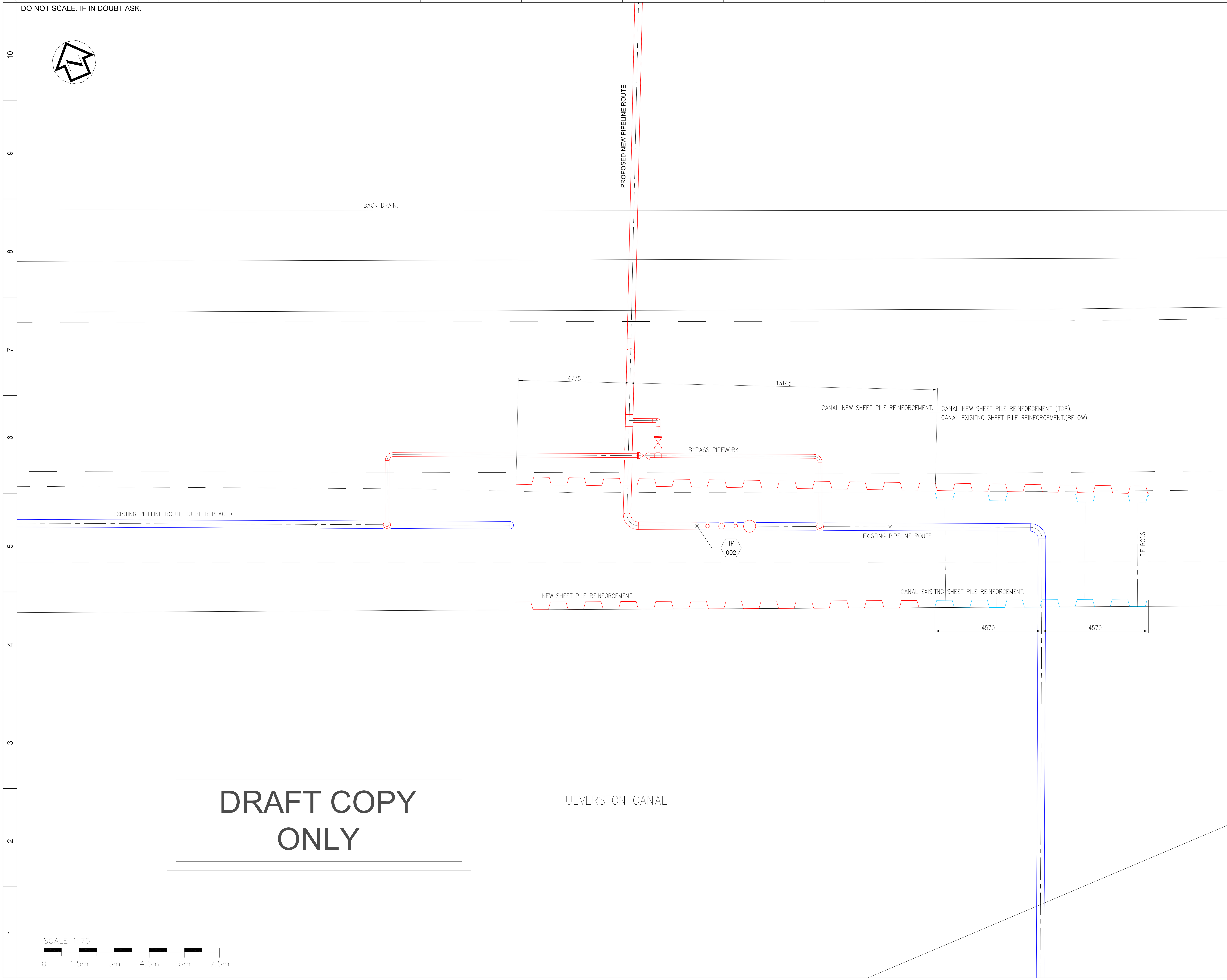
SCALE	ORIG SIZE	DATE
1:1500	A1	30.09.16

EXTERNAL DRAWING NO.

INTERNAL DRAWING NO.	REVISION
0949-ULVE-ME-L-003	1

APPENDIX D
Diversion Route 1 Civil Works Drawing

DO NOT SCALE. IF IN DOUBT ASK.



DRAFT COPY ONLY

KEY

EXISTING PIPELINE

PROPOSED NEW ROUTE

REV	DESCRIPTION	DRN	CHK	APP	DATE

CLIENT

National Grid
Warwick Technology Park
Gallows Hill
Warwick
CV34 6DA

A1 nationalgrid

SAITH LIMITED

Tel: 01425 480286 www.saithlimited.com

PROJECT: ULVERSTON DIVERSION

TITLE: ULVERSTON DIVERSION SHEET PILE EXTENSION (OPTION 1)

ISSUE: FIRST ISSUE

DRAWN	CHECKED	APPROVED
NJ		

SCALE	ORIG SIZE	DATE
1:75	A1	

EXTERNAL DRAWING NO.

INTERNAL DRAWING NO.	REVISION
0949-ULVE-CI-L-001	0

APPENDIX E
Embankment Movement Monitoring Schedule

Scope

To manage the potential ongoing risk to the pipeline due to embankment movement, by monitoring of the ground and pipeline movement.

Initial survey frequency is to be quarterly for the first 12 months and then annually until remediation or diversion of the pipeline is undertaken.

The survey should be accompanied annually by an experienced civil/geotechnical engineer to assess accessible parts of the embankment, canal wall and back drain for signs of instability.

Survey Extents

The survey is to focus on the linear section of pipeline within the embankment running from the railway bridge to the west, to the canal crossing to the east.

The starting chainage of each survey is to be on the eastern face of the bridge, at approx. coordinate 329691E, 478396N. The finish chainage of each survey is to be at the canal crossing (indicated by a concrete pile cap just above water level on the bank) – the approx. chainage at the location of the bends for the crossing is 715m. The approx. coordinate of the centre point of the pile cap is 330349E, 478112N.

Survey Benchmarks

Previous surveys have been benchmarked to GPS, or tied into the nearest OS benchmark at:

Square	Easting	Northing	Mark type	Description	Height	Order	Datum	Verified year	Levelling year	Metres above ground
SD	3131	7764	CUT MARK	BAY HORSE INN NW FACE W ANG	7.665	3	'N'	1968	-	0.600

The concrete pile cap at the canal crossing should not move due to the inherent structure. Therefore, this can be utilised as a marker and crosschecked against the benchmark. Please refer to Greenhatch survey drawing 20729_T_REV0 for recent levels on the pile cap.

Survey Movement Monitoring

From the starting point at 329691E, 478396N, the pipeline is to be traced and both ground and pipeline levels taken every 10m. The method of trace used for drawing 20729_T_REV0 was Ground Penetrating Radar (GPR) and it is recommended that the same method is utilised so that subsequent surveys are comparable. It is recommended that a CAT is used to record secondary readings at each 10m chainage, such that the results of the GPR can be corroborated.

Limitations

The use of marker pins on the road or verge to monitor changes in ground level may be affected by road repairs, plus the passage of vehicles on the towpath and occasionally on the verge, which may affect their accuracy and repeatability of measurements.

About DNV GL

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